Technology Adoption in Food Supply Chain Management in Developing Countries: A Review

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Abstract: ***Food loss and waste are one of the primary reasons for global food insecurity. Food losses occur at all stages of the food supply chain, including agricultural produce, harvesting, transport, storage, and processing. Food loss and waste are exacerbated by a lack of adequate and effective food supply chain management (FSCM). An effective food supply chain (FSC) involves designing and operating processing and distribution centres, managing the cold chain, and implementing reverse logistics. It also includes functions such as allocating warehouse storage capacity, vehicle routing and material flow optimisation, delivery scheduling, and inventory management. The adoption of new information technology, such as big data and the Internet of Things, can improve FSC performance and have a significant impact on reducing food waste and loss. An effective system for sharing information can enhance FCC performance, and intelligence in automated retail ordering can prevent food spoilage. Meanwhile, machine learning and blockchain can improve FSC traceability. However, several obstacles hinder the use of technology in the FSC, particularly in developing countries. These are classified as technical, financial, social, operational, educational, and governmental. This paper provides an in-depth review of the existing literature on the FSC, technology applications in improving FSCM, key challenges associated with technology adoption, and interventions that may help overcome these challenges. It contributes to the existing literature on FSCM, particularly about technology adoption in the FSC by developing countries. It serves as a valuable resource for students, researchers, and professionals in the food supply chain.***

Keywords: Food Supply Chain Management, Technology, IoT, Developing Countries, Challenges

I. INTRODUCTION

Food loss and waste are a major contributor to global food security (Krishnan et al., 2020 [1]). Food losses occur throughout agricultural production, harvesting, transport, storage, and processing (Gustavsson, Cederberg, Sonesson, Otterdijk, & Meybeck, 2011 [2]), whereas food waste happens during distribution, retail, and consumption. According to a recent study, 14% of global food production is lost before it reaches retailers (FAO, 2020 [3]).

The design of processing and distribution centres, management of the cold chain, and design of a reverse logistics network are all part of the food supply chain (FSC). It also includes functions like allocating warehouse storage capacity, vehicle routing and material flow issues, delivery scheduling, and inventory management issues (Li, Wang, Chan, & Manzini, 2011 [4]). A lack of adequate and effective FSCM exacerbates food loss and waste. Such losses have been discovered to be primarily caused by elements in the food supply chain (FSC), such as a lack of transportation and distribution systems, insufficient processing and packaging, and insufficient storage facilities and techniques (Chauhan, Debnath, & Singh, 2018 [5]).

By enhancing FSC performance, information technology can significantly contribute to reducing food waste and loss. According to Kaipia, Dukovska-Popovska, & Loikkanen (2013)[6] an effective information exchange system and on-time deliveries can increase FCC performance, while van Donselaar et al. (2006)[7] illustrated how supermarkets can reduce food perishability by enhancing the intelligence of automated shop ordering systems.

However, several obstacles hinder the use of technology in the FSC, particularly in developing countries. These are classified as technical, financial, social, operational, educational, and governmental.

There is a lot of existing research on FSCM from the perspectives of collaboration, supply chain integration, communication, and the role of data availability in food waste management (Rosenlund, Nyblom, Ekholm, & Sörme, 2020 [8]). Recent studies focus on the question of how the FSC should use technology, specifically IoT, machine learning, and blockchain, to improve FSC traceability and visibility (Zhong et al., 2017 [9]). However, there is still a lack of coordination in terms of progress in technology application, as well as challenges and solutions to these challenges. As a result, the purpose of this paper is to review the various technological innovations that can be implemented in the FSC, as well as the implementation challenges and interventions to help overcome these challenges. The study specifically addresses the following research questions:

RQ1: What effect does effective FSCM have on reducing food loss and waste?

RQ2: How can technology help to improve FSCM?

RQ3: What are the challenges for developing countries in implementing technology in FSCM?

RQ4: How can these obstacles be overcome?

The following outlines the paper's structure. The following section provides an in-depth review of the literature on FSCM, its impact on reducing food loss and waste, and the use of technology to build an effective FSCM.

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Following that, some challenges in implementing technology for FSCM in developing countries are discussed, along with interventions that can help overcome these challenges. Finally, the discussion section discusses the study's practical implications, limitations, and future research opportunities.

II. FOOD WASTE AND LOSS

Food loss and waste (FLW) is a major contributor to global food security (Krishnan et al., 2020 [1]). Food losses occur throughout agricultural production, harvesting, transport, storage, and processing (Gustavsson et al., 2011 [2]), whereas food waste happens during distribution, retail, and consumption. According to a recent study, 14% of the worldwide food supply is lost before reaching stores (FAO, 2020 [3]).

Gustavsson et al. (2011)[2] classified FW into five generation sources based on each stage of the food supply chain: agricultural production, postharvest handling and storage, processing, distribution, and consumption. Stangherlin and de Barcellos (2018)[10] define food waste as "food of good quality and fit for human consumption that does not get consumed because it is discarded either before or after it spoils".

FLW exacerbates the already pressing global food security issue. In 2019, approximately 690 million people (8.9% of the worldwide population) lacked access to food, according to the latest figures. Two billion individuals were affected by severe and medium food insecurity (FAO, 2020 [3]). With the development of the COVID-19 pandemic, there is an increased danger of food insecurity in a number of places, notably in emerging and least-developed nations (Torero, 2020 [11]).

It is anticipated that the global population will approach 8.5 billion by 2030 and 9.5 billion by 2050. (UNDESA, 2015 [12]). Even though the world's population is 7.7 billion, upwards of 820 million people go to bed hungry every night (FAO, 2019 [13]). Consequently, it appears impossible to supply future food demand, increasing pressure on food SCM (Shashi et al, 2021 [14]). Remarkably, 30% of all worldwide food production is lost or squandered annually. This translates to 1,300,000,000 tonnes of food (FAO, 2019 [13]), $1 trillion in economic costs, $700 billion in environmental costs, and $900 billion in social costs (FAO, 2019 [13]).

Additionally, this substantial amount of food waste significantly contributes to global greenhouse gas emissions and reduces the productive capacity of food systems. The carbon impact of food waste is roughly 3.3 billion tonnes of carbon dioxide (FAO, 2019 [13]). Limiting this waste would enable us to feed roughly four times as many needy people annually with the food that is wasted globally (We Eat Responsibly, 2019 [15]).

As a result, it is critical to address the FLW issue.

III. FOOD SUPPLY CHAIN

Specifically, the food supply chain (FSC) is defined as "the design and operation of efficient and effective production and logistics networks, as well as the intra- and inter-organizational management of supply, transformation, and delivery processes" (Brandenburg and Rebs, 2015 [16]).

The agriculture supply chain (ASC) concept has been around for 1,000 years, but it only gained popularity after Keith Oliver developed SCM. Tsolakis et al. (2014) [17] defined ASC as a set of activities in a "farm-to-fork sequence that includes farming (i.e. land cultivation and crop production), processing/production, testing, packaging, warehousing, transportation, distribution, and marketing".

Transportation and all related logistical processes for delivering food to consumers are an essential step in the journey of food products from farm to fork. Improving the efficiency of these processes begins with the design of the food supply chain (FSC) network, which considers the design of processing and distribution centres, cold chain management, and the development of a reverse logistics network. Other tactical issues associated with FSC network design include warehouse storage capacity allocation, vehicle routing and material flow issues, delivery scheduling, and inventory management issues (Li, Wang, Chan, & Manzini, 2011 [4]).

A food supply chain (FSC) is particularly complicated because it integrates diverse economic sectors (agricultural, food processing, and distribution) in a market driven by quickly changing consumer demands.

The food chain is a temperature-based supply chain that is complicated and dynamic; perishable products (fruits and vegetables) must be kept at the required temperature for quality. Food cold chain management (FCCM) is a set of SC practices that aims to keep perishable goods in a safe environment while avoiding microbial spoilage.

In recent years, the focus of SCM has evolved from economic growth to an integrated social and environmental approach (Khan et al., 2020 [18]).

FSCM has recently shifted from separate transactions to more collaborative interactions between producers, processors, manufacturers, retailers, and customers. The magnitude of the food industry's recent challenges, such as global food insecurity on the one hand and food waste on the other, all emphasise the importance of FSCM (Govindan, Jafarian, Khodaverdi, & Devika, 2014 [19]).

Food traceability is a crucial aspect of SFSCM, enabling the improvement of food safety and enhancing consumer confidence. Food traceability refers to the capability to trace and track a food, feed, food-producing animal, or substance meant to be, or anticipated to be, included in a food or feed throughout all phases of production, processing, and distribution. Incorporating food traceability technologies will provide more opportunities and information to improve food quality, reduce food waste, and improve food system sustainability and monitoring systems, all of which will help to advance the development of SFSCM.

Research shows that between 30 and 35 percent of all food produced is wasted in India and worldwide because of a lack of adequate infrastructure and food processing activities (Parwez, 2014 [20]).

The FCC is a rapidly growing research field because it prevents food waste, which has numerous negative consequences.

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Food waste has social, environmental, and economic consequences.

A lack of appropriate food supply chain management is one of the leading causes of excessive food price inflation in emerging nations such as India. A lack of stable cold storage and inadequate cold chain management lead to high rates of food waste and a decline in food quality.

Researchers have been motivated to address the issue of food storage and preservation due to technological advances. This significant technological advancement has accelerated and simplified the food supply chain, indicating a future increase in the food supply chain's reliance on technology. According to Chauhan et al. (2018)[5], food waste is also a waste of national resources, including seeds, fertile land, water, energy, and other resources employed in its production. In developing nations such as India, food security is attained through the administration of the food supply chain (Negi & Anand, 2014 [21]).

Because it encompasses crucial food parameters such as quality, safety, and freshness, the food supply chain is much more complex and challenging to manage than other supply chains (Zhong et al., 2017 [9]). The food supply chain involves the management difficulty of perishable items and a large number of associated entities (Ben-Daya et al., 2019 [22]). Bourlakis and Matopoulos (2010) [23] maintain that FSC requires collaboration among its stakeholders, which include various entities such as producers, processors, manufacturers, and retailers. The crucial and innate properties of food present specific requirements, such as safety, quality, and spoilage, that add to the challenges of food safety and quality management (FSCM). Food perishability, safety, seasonality, shelf time, freshness, storage, and environmental conditions are unique to the FSC (Affia, Yani, & Aamer, 2019 [24]). The necessity of maintaining the basic food characteristics in a limited amount of time efficiently and effectively is what makes FSCM more complex and challenging than non-FSC (La Scalia et al., 2016 [25]).

IV. FSCM FOR WASTE REDUCTION

The FSC's most crucial function is to maintain high food quality, encompassing other essential properties such as safety and freshness. Several studies have shown that FSCM has a significant impact on food quality (Aung and Cang, 2014 [26]). Perishable items require a temperature-controlled atmosphere throughout the whole supply chain (SC), from manufacture to consumer interaction. Cold chain management (CCM) is essential in FSCM (Shashi, Centobelli, Cerchione, & Ertz, 2021 [14]) for modern global perishable product industries. CCM is a post-production cold chain (CC) for perishable and temperature-sensitive goods that is designed to maintain these goods in a conditioned environment (i.e., within optimal temperature and humidity range) to ensure product safety, preservation of value, and maximisation of commercial potential. Thus, refrigerated transportation and storage are two critical aspects in preventing product quality degradation (James and James, 2010 [27]). FCC is a rapidly growing research field within the overarching research area of CC management (Göransson et al., 2018 [28]) because it prevents food waste, which has numerous negative consequences. Food waste has social, environmental, and economic impacts.

While strategies to increase agricultural production can help solve the food security problem, the statistics on FLW suggest that reducing it through effective FSCM is a more efficient solution. The overall situation of food waste in poor countries can be described as legislatively mismanaged. Furthermore, most countries have not received adequate attention from stakeholders, who must be integrated and guided to resolve FLW challenges (Liu, 2013 [29]). India has extensive terrain and long distances between communities, and its fresh produce business is unorganized and understaffed (Joshi, Banwet, & Shankar, 2009 [30]). A well-developed supply chain with specialist knowledge helps reduce the role of intermediaries, which in turn aids in waste reduction during transportation and when selling in the APMC market. Because of a lack of warehouses, cold storage facilities, and sophisticated transportation systems, one-third of fruits and vegetables are wasted as a result of storage and transportation losses.

Coordination of production and distribution activities, as well as timely information sharing, helps decrease forecasting inaccuracies and supply chain unpredictability (price, supply, and demand uncertainty), thereby considerably reducing FLW at every level.

Several studies have found that FLW is primarily driven by FSC elements such as a lack of transportation and distribution systems, insufficient processing and packaging, and inadequate storage facilities and techniques (Chauhan et al.,2018 [5]). Because of data inconsistency and unavailability, the FSC is concerned about a lack of traceability, visibility, and transparency. One of the five significant challenges for reducing FLW is the availability of data for measuring and monitoring FLW. As a result, utilising and sharing data is critical for improving FSCM (Kaipia et al., 2013 [6]).

FSCM has become more complex in recent years, with more data-driven decisions (Aamer, 2018 [31]). Transparency and information, according to Astill et al. (2019) [32], are critical building blocks in the modern FSCM. As a result, stronger and more resilient FSCM tools and techniques are required (Aamer, 2018 [31]). The importance of information sharing and visibility in the FSC can be achieved through the use of data-driven technologies.

V. HOW TECHNOLOGY CAN ASSIST

Recent technological advancements have the potential to be powerful enablers of FSCM improvement. This is due to several key areas where technology can assist.

According to Kaipia et al. (2013)[6], an effective system for sharing information and on-time delivery can boost FCC performance. Similarly, van Donselaar et al. (2006)[7] reached a conclusion regarding how to improve the intelligence of automated shop ordering systems in supermarkets to prevent food spoilage.

Prior research has demonstrated that sound information sharing systems are an efficient method for managing food waste (Kaipia et al., 2013 [6]). Similarly, recent research has demonstrated that digital networks serving as "circularity brokers" facilitate the matching of tasks to decrease food waste (Ciulli et al., 2019, p. 1 [33]).

Using data-driven decision technology for FSCM, such as Cloud Computing, Big Data Analytics, and IoT, can result in enhancements that render the food supply chain more resilient and sustainable (Zhong et al., 2017 [9]).

A. The Internet of Things (IoT)

IoT can enhance FSCM by reshaping and upgrading it to become smarter and add more value.

IoT in supply chain management has been defined as a collection of digitally connected physical items that enable the detection and tracking of supply chain interactivity, agility, visibility, and information sharing, facilitating the planning, control, and coordination of supply chain processes. IoT technology has the potential to be used in automated food processing, such as automated food waste weighing using the IoT network system and analytical functions such as shelf-life prediction using sensor data (Abdel-Basset et al., 2018 [34]).

Food waste assessment can be made more efficient by integrating intelligent containers that analyse the freshness, quality condition, visual appearance, and biodegradable characteristics of food waste using Internet of Things (IoT) sensors. In this case, inspection and assessment of food waste will be achieved more accurately with less cost and at a faster pace (Fadhel, 2021 [35]).

Benefits of an IoT-enabled supply chain include cost reduction, real-time information sharing, transparency, efficiency, traceability, and sustainability (Affia, Yani, and Aamer, 2019 [24]).

B. Radio Frequency Identification (RFID)

In conceptual, theoretical, and practical research, RFID has been demonstrated to be a crucial technology in FSCM. Traceability is the primary advantage of RFID for enhancing FSCM, followed by temperature fluctuations control (Qi et al., 2014 [36]).

RFID can be deployed for tracking food and providing instant information that supports a more sustainable decision-making process (Fadhel, 2021 [35]),

RFID uses radio waves to track items wirelessly. It utilises tags or transponders (data carriers), readers (receivers), and computer systems (encompassing software, hardware, networking, and databases). The significant benefits of RFID technology in the food industry include increased speed and efficiency in stock rotation, as well as improved tracking of products throughout the supply chain, resulting in enhanced on-shelf availability at the retail level and improved forecasting. RFID technology also provides security and safety benefits for food companies through tracking the origin of supplies. This intelligent packaging technology is also being extended to refrigeration and freezing. Appliances can communicate with the packages and identify information related to the storage of the packaged products (Patil et al., 2017 [37])

Aiello et al. (2012)[38] revealed that RFID could offer solutions to critical problems that arise in each of the FSCM functions, which are differentiated by a deterministic temperature and a stochastic interval.

C. Other Technologies

Combinations of technology, such as ERP and barcode readers, can facilitate the development of procedures like "ready-to-dispose." With these procedures, dealers can recognise and sell the earliest-made unit. Such strategies are essential for supply chains with very perishable goods (Chauhan, 2020 [39]).

In addition, electronic platforms can assist in identifying high-waste areas and enhancing demand forecasting by linking food makers with retailers or restaurants (Chauhan, 2020 [39]).

VI. DIFFICULTIES IN IMPLEMENTING CUTTING-EDGE TECHNIQUES IN DEVELOPING COUNTRIES

The difference between developing and developed countries is determined by Gross National Income (GNI). The International Statistical Institute classifies countries as developing if their GDP is less than US$11,905 (as of 2014). GNP is not only one of the main factors relating to a country's FW generation rate, but it also causes specific barriers in the adoption of technology for curbing FLW through changes in the FSC (Thi, Kumar and Lin, 2015 [40]).

Child hunger persists in LDCs despite a worldwide food surplus and enhanced global trade and food assistance; recent increases in food supply have only moderately alleviated it.

Some of the significant barriers to widespread adoption of IoT technology in the FSCM, particularly in developing countries, are technical, financial, social, operational, educational, and governmental.

D. Technical difficulties

Some of the technical challenges include hardware issues, network structure issues, the possibility of interoperability and integration, managing big data, and ensuring Internet availability. A substantial amount of specialised hardware, a complex and interlaced network, and proprietary protocols are needed to set up an IoT-based FSCM (Xu et al., 2020 [41]). Some hardware issues are specific to the FSCM because it's challenging to insert some IoT components like microprocessors, sensors, and antennas in food products to ensure food safety and quality (Verdouw et al., 2019 [42]). Designing and managing a robust IoT hardware infrastructure that supports FSC procedures and activities remains a significant challenge in FSCM, given the delicate and unique nature of food products.

Because of the complexity of FSCM and its network structures, network structure is another technical key challenge. Companies that want to utilise IoT face a significant challenge in maintaining the FSC's complex networked structures efficiently. The complex nature of food supply chain management and its network structures enhances the complexity of internet applications. This could explain why there

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have only been a few large-scale internet applications in food supply chain management implemented (Hong et al., 2011 [43]).

Interoperability and integration with current information technology are complex, as IoT technology cannot always be fully compatible with the FSCM. Complete integration with disparate technologies and data services across multiple supply chains is required (Haddud et al., 2017 [44]). The most apparent problem in this area is making sure that all the sensors, devices, and system parts in the FSC network can work together well enough to do what is intended (Ben-Daya et al., 2019 [45]). The collected data would be less significant and valuable if there were no interoperability across the entire FSC (Astill et al., 2019 [32]).

IoT applications create vast amounts of data that need to be stored and processed. This makes it hard to manage and analyse big data (Lee and Lee, 2015 [46]). Big data management and analytics are complex because applications create a lot of data that needs to be stored and looked at (Lee and Lee, 2015 [46]).

The vast amount of data generated by multiple connected sources becomes problematic when it is not managed correctly (Alonso et al., 2020 [47]). Even with IoT, obtaining, storing, accessing, and using data from the field is significantly more difficult in the food industry because it labour labour-intensive and human-generated (Astill et al., 2019 [32]).

Internet availability and reliability are considerable difficulties in the FSCM, especially since most rural areas don't have the proper infrastructure and have poor Internet connectivity and reliability (Astill et al., 2019 [32]). This makes it hard to put sensors on food packaging (Mustafa and Andreescu, 2018 [48]).

E. Financial difficulties

High capital investment is still one of the most essential reasons why FSCM doesn't use and adopt IoT technology (Aryal et al., 2018 [49]). The IoT adoption options are not particularly attractive for small-scale food companies, due to the high cost of capital investments. Aside from the acquisition, the incentives for setting up the necessary infrastructure and architecture that traverses organisational boundaries along the entire supply chain are seen as problematic. Even when IoT technology is used in a small way, such as when biosensors are incorporated into food packaging, the expenses are pretty high.

Because of the numerous uncertainties, such as weather conditions, health conditions, food qualities, perishability of food products, harvest and production yield, and demand fluctuation, operations and maintenance cost challenges are numerous (Verdouw et al., 2019 [42]). Monthly service fees, frequent tag renewal, regular risk costs for implementation that can increase overall operating costs, and additional monitoring costs to meet time-temperature criteria and delivery under varying conditions are included in the operation and maintenance expenses (Ndraha et al., 2018 [50]).

F. Social difficulties

Cooperation among supply chain players such as producers, farmers, retailers, collectors, and customers is a significant challenge in facilitating harmonised and synchronised information sharing for stakeholders who do not share the same ownership. Also, a considerable obstacle is optimising available resources to manage the demand for a particular food treatment along the supply chain (Ndraha et al., 2018 [50]).

G. Operational difficulties

Because of the complexity of the FSC-generated data, new technologies, and the difficulty of its supply chain networks, it is very hard to manage the supply chain and IoT networks (Aryal et al., 2018 [49]). Data security and trust among supply chain participants is another operational key challenge for FSCM IoT adoption (Abdel-Basset et al., 2018 [34]).

H. Educational difficulties

Because IoT technology is still in its early stages of development, knowledge about its applications is limited. Different stakeholder perceptions of IoT may lead to the prevention or failure of IoT adoption. Multiple food products, especially in FSCM, will require different stakeholders to fully understand IoT technology to use it most effectively all along the supply chain (Astill et al., 2019 [32]). IoT is a relatively new field, so it comes with a lot of risk when it comes to IoT elements or related things like economic, social, and legal issues (Brad and Murar, 2014 [51]).

IoT technologies are still challenging to utilise in FSCM due to considerable uncertainty surrounding them. Given that IoT is a relatively new technology, technical skills in IoT are a significant challenge. As a result, IoT adoption in the FSCM would be heavily reliant on the technical knowledge of its users. One of the critical barriers to successful IoT implementation in agricultural FSCM is a lack of skilled personnel expertise to operate the technology.

Another factor influencing this phenomenon is a company's lack of financial resources and skills to invest in technical expertise (Verdouw et al., 2019 [42]).

I. Governmental difficulties

To manage FSC integrity, social impact, environmental issues, economic risk, and sustainability, regulatory authorities must develop government rules and policies for IoT. (Ndraha et al., 2018 [50]). Poor IoT regulation could lead to low standards for food safety and traceability, which could lead to uncontrolled chemical use, pollution, and not enough capacity to track food, especially in developing countries (Aung and Chang, 2014 [26]). Because of this, the right laws regulating the use of IoT in FSCM may affect how people choose to buy food (Bouzembrak et al., 2019 [52]).

Thus, the adoption of technology for FSCM is influenced by considerations such as potential benefit, accessibility of hardware and infrastructure, cost of implementation, security and privacy issues, readiness to adopt, degree of data complexity, peer and government assistance, access to technical knowledge - based resources, and compatibility with current FSCM should be taken into account (Affia, Yani, and Aamer, 2019 [24]).

VII. OVERCOMING IMPLEMENTATION DIFFICULTIES

A. Training

In the Indian context, despite the FSSAI's mandate for codex-based standards, not all participants in the fruit and vegetable supply chain possess a comprehensive understanding of quality control guidelines and procedures. Some training for stakeholders may help address this challenge.

Through the integration between government and NGOs, the farmers and middlemen could receive training on the GAP of postharvest technologies, for example, shading the agricultural products during trans- port to and from the marketplace, grading, usage of cold storage, and improvised solar-drying techniques (Ali et al., 2021 [53]).

Increasing the awareness and education regarding proper food preparation, food storage, date labelling, and the redistribution of excess food can reduce the impact of the wasted food (Fadhel, 2021 [35]).

B. Policy Framework

It is essential to integrate agriculture, health, and environmental policies, implying that policy integration is a political process in itself. Multilevel governance is key in the consolidation of new policy frameworks through bottom-up approaches and broad participation of relevant stakeholders (Galli et al., 2020 [54])

Policymakers in the agriculture, energy, education, and food sectors must collaborate to promote the use of cold chain technology, enhance logistics, maintenance, services, infrastructure, education, and management skills, and develop sustainable markets for the design, use, and funding of cold chains to reduce perishable food losses (Kitinoja, 2013 [55]).

Well-established guidelines can influence supply chain outcomes. Imposing certification requirements and regulations that address quality and safety concerns will help reduce food wastage.

Farmers, storage facilities, food processing companies, retailers, and logistics service providers will all benefit from a policy-backed push to build more cold storage facilities.

The Indian government's proposal to encourage 100% FDI in the food-processing sector with a five-year tax break will help enhance the efficiency of the FSC as in addition to finance, global firms will contribute modern food processing equipment, new information technology for tracking products in storage and transportation, and management expertise (MOFPI, 2014 [56]).

C. Infrastructure Development

Post-harvest loss can be cut down by putting money toward storage and logistics technologies and making it easier for farmers to get their goods to markets (World Food Programme, 2015 [57]).

Policymakers can provide incentives to encourage investment in cold chain transportation and storage infrastructures through private-public partnerships. NGOs could help small stakeholders access and benefit from these services by providing them at a low cost in the beginning (Moraes, Costa, Pereira, & Silva, 2021 [58]). Small farmers and intermediaries cannot adopt the improved refrigerated cold chain because it is costly, especially without access to microfinance. The role of the public-private partnerships is to fill this gap by investing in the cold chain transportation and storage for the perishable products (Ali et al., 2021 [53]).

The public sector needs to provide funds for investments in fundamental infrastructure to enable cold chain expansion (i.e. energy, roads) to increase the value of high-quality, nutritious food production, handling, and consumption. Governments should restrict disincentives and participate in infrastructure components that are currently lacking in their cold chain development efforts (Kitinoja, 2013[55]).

D. Research and Development

Supporting research and development of cutting-edge innovations like better stock management tracking systems can contribute to more efficiency in the FSC in the future (Thyberg and Tonjes, 2016 [59]).

VIII. CONCLUSION

This study provides an in-depth review of the existing literature on the FSC, technology applications in improving FSCM, key challenges associated with technology adoption, and interventions that may help overcome these challenges.

A lack of adequate and effective FSCM exacerbates food loss and waste. Such losses have been discovered to be primarily caused by elements in the food supply chain (FSC), such as a lack of transportation and distribution systems, insufficient processing and packaging, and insufficient storage facilities and techniques (Chauhan et al., 2018 [5]).

By enhancing FSC performance, information technology can significantly contribute to reducing food waste and loss. According to Kaipia et al. (2013)[6], an effective information exchange system and on-time deliveries can increase FCC performance, while van Donselaar et al. (2006)[7] illustrated how supermarkets can reduce food perishability by enhancing the intelligence of automated shop ordering systems.

Using data-driven decision technology for FSCM, such as Cloud Computing, Big Data Analytics, and IoT, can result in enhancements that render the food supply chain more resilient and sustainable (Zhong et al., 2017 [9]).

IoT can enhance FSCM by reshaping and upgrading it to become smarter and add more value. RFID has also been demonstrated to be a crucial technology in FSCM, offering the advantages of traceability and temperature control.

However, despite the advantages, developing countries face various barriers to the widespread adoption of IoT technology in the FSCM, which include technical, financial, social, operational, educational, and governmental barriers.

Various initiatives in the areas of training and development, policy development, infrastructure and research can overcome these challenges.

This paper contributes to the current literature on food supply chain management, particularly the stream on the use of technology in FSCM. It serves as a valuable resource for students, researchers, and

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professionals in the food supply chain.

Future research could focus on the feasibility of constructing IoT with RFID in the areas of linking firm resources to big data analytics skills and innovative thinking, as well as extracting valuable data and insights for strategic decision-making (Shashi, Centobelli, Cerchione, & Ertz, 2021 [14]).

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REFERENCES

1. Krishnan, R., Agarwal, R., Bajada, C. and Arshinder, K. (2020), "Redesigning a food supply chain for environmental sustainability – an analysis of resource use and recovery", Journal of Cleaner Production, Vol. 242, p. 118374, Elsevier [CrossRef]
2. Gustavsson, J., Cederberg, C., Sonesson, U., Otterdijk, R. v., & Meybeck, A. (2011). Global Food Losses and Food Waste – Extent, Causes and Prevention. Food and Agriculture Organization of the United Nations.
3. FAO (2020), "The state of food security and nutrition in the world", available at: http://www.fao.org/3/ ca9692en/CA9692EN.pdf (accessed 12 November 2020).
4. Li, D., Wang, X., Chan, H.K., and Manzini, R. (2014). Sustainable food supply chain management. *International Journal of Production Economics, 152*, 1–8. [CrossRef]
5. Chauhan, A., Debnath, R. M., & Singh, S. P. (2018). Modelling the drivers for sustainable agri-food waste management. Benchmarking: An International Journal, 25(3), 981-993. [CrossRef]
6. Kaipia, R., Dukovska-Popovska, I., & Loikkanen, L. (2013). Creating sustainable fresh food supply chains through waste reduction. International Journal of Physical Distribution & Logistics Management, 43(3), 262-276. doi:10.1108/IJPDLM-11-2011-0200 [CrossRef]
7. Van Donselaar, K., Van Woensel, T., Broekmeulen, R.A.C.M. and Fransoo, J. (2006), "Inventory control of perishables in supermarkets", International Journal of Production Economics, Vol. 104 No. 2, pp. 462-472. [CrossRef]
8. Rosenlund, J., Nyblom, Å., Ekholm, H. M., & Sörme, L. (2020). The emergence of food waste as an issue in Swedish retail. British Food Journal, 122(11), 3283-3296. doi:10.1108/BFJ-03-2020-0181 [CrossRef]
9. Zhong, R., Xu, X., & Wang, L. (2017). Food supply chain management: systems, implementations, and future research. industrial Management & Data Systems, 117(9), 2085-2114. doi:10.1108/IMDS-09-2016-0391 [CrossRef]
10. Stangherlin, I. D., & Barcellos, M. D. (2018). Drivers and barriers to food waste reduction. British Food Journal, 120(10), 2364-2387. doi:10.1108/BFJ-12-2017-0726 [CrossRef]
11. Torero, M. (2020), "Without food, there can be no exit from the pandemic", Nature, Vol. 580 No. 7805, pp. 588-589, Springer Science and Business Media LLC. [CrossRef]
12. UNDESA (2015), "World population projected to reach 9.7 billion by 2050", available at: www.un.org/en/development/desa/news/population/2015-report.html
13. FAO. (2019). "The state of food and agriculture". 10.10 am. Food waste index report. Retrieved from http://www.fao.org/3/ca6030en/
14. Shashi, Centobelli, P., Cerchione, R., & Ertz, M. (2021). Food Cold Chain Management: What We Know and What We Deserve. Supply Chain Management: An International Journal, 26(1), 102–135. doi:10.1108/SCM-12-2019-0452 [CrossRef]
15. We Eat Responsibly (2019) "Hunger in a time of waste", available at: www.eatresponsibly.eu/en/foodwaste/4#section-hunger
16. Brandenburg, M. and Rebs, T. (2015), "Sustainable supply chain management: a modelling perspective", Annals of Operations Research, Vol. 229 No. 1, pp. 213-252. [CrossRef]
17. Tsolakis, N.K., Keramydas, C.A., Toka, A.K., Aidonis, D.A. and Iakovou, E.T. (2014), "Agrifood supply chain management: a comprehensive hierarchical decision-making framework and a critical taxonomy", Biosystems Engineering, Vol. 120 No. 1, pp. 47-64. [CrossRef]
18. Khan SA, Dar AH, Bhat, SA et al. (2020) High intensity ultrasound processing in liquid foods. *Food Rev Int.* pp. 1–25 https://doi.org/10.1080/87559129.2020.1768404
19. Govindan, K., Jafarian, A., Khodaverdi, R. and Devika, K. (2014), "Two-echelon multiple-vehicle location–routing problem with time windows for optimization of sustainable supply chain network of perishable food", International Journal of Production Economics, Vol. 152, pp. 9-28. [CrossRef]
20. Parwez, S. (2014), "Food supply chain management in Indian agriculture: issues, opportunities and further research", African Journal of Business Management, Vol. 8 No. 14, pp. 572-581. [CrossRef]
21. Negi, S., & Anand, D. N. (2014). Supply Chain Efficiency: An Insight from the Fruits and Vegetables Sector in India. Journal of Operations and Supply Chain Management, 7(2), 154 – 167. [CrossRef]
22. Ben-Daya, M., Hassini, E. and Bahroun, Z. (2019), "Internet of things and supply chain management: a literature review", International Journal of Production Research, Vol. 57 Nos 15-16, pp. 4719-4742, Taylor and Francis. [CrossRef]
23. Bourlakis, M. and Matopoulos, A. (2010), "Trends in food supply chain management", Delivering Performance in Food Supply Chains, Vol. 185, pp. 511-527, Elsevier. [CrossRef]
24. Affia, I., Yani, L. P., & Aamer, A. (2019). Factors Affecting IoT Adoption in Food Supply Chain Management. 9th International Conference on Operations and Supply Chain Management. Vietnam.
25. La Scalia, G., Settanni, L., Micale, R. and Enea, M. (2016), "Predictive shelf life model based on RF technology for improving the management of food supply chain: a case study", International Journal of RF Technologies: Research and Applications, Vol. 7 No. 1, pp. 31-42, IOS Press. [CrossRef]
26. Aung, M.M. and Chang, Y.S. (2014), "T*raceability in a food supply chain: safety and quality perspectives", Food Control, Vol. 39 No. 1*, pp. 172-184, Elsevier BV. [CrossRef]
27. James, S.J. and James, C. (2010), "The food cold-chain and climate change", Food Research International, Vol. 43 No. 7, pp. 1944-1956. [CrossRef]
28. Göransson, M., Nilsson, F. and Jevinger, Å. (2018), "Temperature performance and food shelf-life accuracy in cold food supply chains: insights from multiple field studies", Food Control, Vol. 86, pp. 332-340. [CrossRef]
29. Liu, G., 2013. Food Losses and Food Waste in China: A First Estimate. OECD Food, Agriculture and Fisheries Papers, p. 30.
30. Joshi, R., Banwet, D. K., & Shankar, R. (2009). Indian Cold Chain: Modelling the Inhibitors. British Food Journal, 111(11), 1260-1283. doi:10.1108/00070700911001077 [CrossRef]
31. Aamer, A. M. (2018). An Application of Lean Assessment in a Cross-Docking Distribution Centre. International Conference on Industrial Engineering and Operations Management. Bandung, Indonesia.
32. Astill, J., Dara, R.A., Campbell, M., Farber, J.M., Fraser, E.D.G., Sharif, S. and Yada, R.Y. (2019), "Transparency in food supply chains: a review of enabling technology solutions", Trends in Food Science and Technology, Vol. 91, No. December 2018, pp. 240-247. [CrossRef]
33. Ciulli, F., Kolk, A. and Boe-Lillegraven, S. (2019), "Circularity brokers: digital platform organizations and 119 waste recovery in food supply chains", *Journal of Business Ethics, Vol. 1*, pp. 1-33.
34. Abdel-Basset, M., Manogaran, G. and Mohamed, M. (2018), "Internet of Things (IoT) and its impact on supply chain: a framework for building smart, secure and efficient systems", Future Generation Computer Systems, Vol. 86, pp. 614-628, Elsevier B.V. [CrossRef]
35. Fadhel, A. W. (2021, March). Closed-Loop Sustainable Food Supply Chain Management: Design of Network Models for

Efficient Operations. Boston, Massachusetts: Northeastern University.
36. Qi, L., Xu, M., Fu, Z., Mira, T. and Zhang, X. (2014), “C2SLDS: a WSN-based perishable food shelf-life prediction and LSFO strategy decision support system in cold chain logistics”, Food Control, Vol. 38, pp. 19-29. [CrossRef]
37. Patil, R.G., Birhade, V., & Jadhav, V. (2017). Innovative Food Packaging.
38. Aiello, G., Scalia, G.L. and Micale, R. (2012), “Simulation analysis of cold chain performance based on time-temperature data”, Production Planning & Control, Vol. 23 No. 6, pp. 468-476. [CrossRef]
39. Chauhan, Youthika. (2020). Food Waste Management with Technological Platforms: Evidence from Indian Food Supply Chains. Sustainability. 12. 8162. 10.3390/su12198162. [CrossRef]
40. Thi, N. B., Kumar, G., & Lin, C.-Y. (2015). An overview of food waste management in developing countries: Current status and future perspective. Journal of Environmental Management, 157, 220-229. [CrossRef]
41. Xu, W., Zhang, Z., Wang, H., Yi, Y. and Zhang, Y. (2020), “Optimization of monitoring network system for Eco safety on Internet of Things platform and environmental food supply chain”, Computer Communications, Vol. 151, pp. 320-330, Elsevier B.V. [CrossRef]
42. Verdouw, C., Sundmaeker, H., Tekinerdogan, B., Conzon, D. and Montanaro, T. (2019), “Architecture framework of IoT-based food and farm systems: a multiple case study”, Elsevier B.V., *Computers and Electronics in Agriculture*, Vol. 165, doi: 10.1016/j.compag.2019.104939. [CrossRef]
43. Hong, I.H., Dang, J.F., Tsai, Y.H., Liu, C.S., Lee, W.T., Wang, M.L. and Chen, P.C. (2011), “An RFID application in the food supply chain: a case study of convenience stores in Taiwan”, *Journal of Food Engineering*, Vol. 106 No. 2, pp. 119-126. [CrossRef]
44. Haddud, A., DeSouza, A., Khare, A., & Lee, H. (2017). Examining potential benefits and challenges associated with the Internet of Things integration in supply chains. Journal of Manufacturing Technology Management, 28(8), 1055–1085. [CrossRef]
45. Ben-Daya, M., Hassini, E. and Bahroun, Z. (2019), “Internet of things and supply chain management: a literature review”, International Journal of Production Research, Vol. 57 Nos 15-16, pp. 4719-4742, Taylor and Francis. [CrossRef]
46. Lee, I. and Lee, K. (2015), “The internet of things (IoT): applications, investments, and challenges for enterprises”, *Business Horizons*, Vol. 58 No. 4, pp. 431-440, Elsevier. [CrossRef]
47. Alonso, R.S., Sitton-Candanedo, I., Garcıa, O., Prieto, J. and Rodríguez-Gonzalez, S. (2020), “An intelligent Edge-IoT platform for monitoring livestock and crops in a dairy farming scenario”, Elsevier B.V., Ad Hoc Networks, Vol. 98, doi: 10.1016/j.adhoc.2019.102047. [CrossRef]
48. Mustafa, F. and Andreescu, S. (2018), *“Chemical and biological sensors for food-quality monitoring and smart packaging”*, Foods, Vol. 7 No. 10, doi: 10.3390/foods7100168. [CrossRef]
49. Aryal, A., Liao, Y., Nattuthurai, P. and Li, B. (2019), “The emerging big data analytics and IoT in supply chain management: a systematic review”, *Emerald Group Publishing, Supply Chain Management*, Vol. 25 No. 2, pp. 141-156, doi: 10.1108/SCM-03-2018-0149. [CrossRef]
50. Ndraha, N., Hsiao, H.I., Vlajic, J., Yang, M.F. and Lin, H.T.V. (2018), “Time-temperature abuse in the food cold chain: review of issues, challenges, and recommendations”, Food Control, Vol. 89, pp. 12-21, Elsevier, July. [CrossRef]
51. Brad, B. and Murar, M. (2014), “Smart buildings using IoT technologies”, Stroitel’stvo Unikal’nyh Zdanij i Sooruzenij; Construction of Unique Buildings and Structures, Vol. 5 No. 5, p. 15.
52. Bouzembrak, Y., Kluche, M., Gavai, A. and Marvin, H.J.P. (2019), € “Internet of Things in food safety: literature review and a bibliometric analysis”, Trends in Food Science and Technology, Vol. 94, pp. 54-64, Elsevier, December. [CrossRef]
53. Ali, A., Xia, C., Ismaiel, M., Ouattara, N., Mahmood, I., & Anshiso, D. (2021). Analysis of determinants to mitigate food losses and waste in the developing countries: empirical evidence from Egypt. Mitigation and Adaptation Strategies for Global Change, 26-31. [CrossRef]
54. Galli, Francesca & Prosperi, Paolo & Favilli, Elena & D'Amico, Simona & Bartolini, Fabio & Brunori, Gianluca. (2020). How can policy processes remove barriers to sustainable food systems in Europe? Contributing to a policy framework for agri-food transitions. Food Policy. 96. 101871. 10.1016/j.foodpol.2020.101871. [CrossRef]
55. Kitinoja L (2013) Use of cold chains for reducing food losses in developing countries. The Postharvest Education Foundation (PEF) *White Paper* No. 13-03.
56. *MOFPI* − Ministry of Food Processing Industries, Government of India, S., 2014. Fruits & Vegetables, Retrieved from http://foodprocessingindia.co.in/fruits- and-vegetables.html. (accessed 17.12.15).
57. World Food Programme. (2015). *Zero loss for zero hunger*. Retrieved from https:// documents.wfp.org/stellent/groups/public/documents/reports/wfp289788.pdf?_ ga=2.67622809.98308502.1535752981-572602855.1535752981.
58. Moraes, C. C., Costa, F. H., Pereira, C. R., & Silva, A. L. (2021). Food Loss and Waste in Food Supply Chains. A systematic literature review and framework development approach. Journal of Cleaner Production, 295, 120-124. [CrossRef]
59. Thyberg, K.L., Tonjes, D.J., 2016. Drivers of food waste and their implications for sustainable policy development. *Resour. Conserv. Recycl.* 106, 110–123. https://doi.org/10.1016/j.resconrec.2015.11.016. [CrossRef]

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