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How Important are Digital Technologies for Urban Food Security? A Framework for Supply Chain Integration using IoT

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Abstract

This paper aims to understand the role of digital technologies in food system innovations for healthy food access and waste reduction. It seeks to expand the knowledge of commercial food system interventions from the industrial supply side for improving public and planetary health. For this, we review the literature on urban food supply chains and synthesize the findings (from 33 screened articles) into thematic clusters. The first iteration of the review gives an overview of food supply chain problems and possible Industry 4.0-based solutions. Four technology intervention opportunities for integrated supply chains emerge from the literature, namely digital platforms, enterprise information systems, traceability systems, and blockchain. Findings indicate limited empirical research on supply chain digitalization for healthy food access. Therefore, this position paper presents a framework for supply chain integration in urban food systems, emphasizing digital technology interventions and the research directions for food supply chain digitalization.

Keywords: Urban food supply chains; Digital supply chains; Food system innovations; Systems engineering; Requirements analysis; Information sharing; Real-time systems; Review; Perspective

1. Introduction

1.1. Urban food security challenges

The world has an urban population of close to 56% (of the total), which is estimated to touch 68% by 2050, according to the United Nations (UN). With the growing urban population, food provisioning is increasingly becoming challenging in many parts of the world. Urban food security is mainly about access to food rather than its actual availability [1] and food provisioning is lately becoming an essential topic of discussion in urban policy worldwide. However, several gaps in the policy prevent an effective policy implementation for urban food security. Wiskerke writes [2]

> *Urban food security failure is seen as a production failure instead of a distribution, access and affordability failure, constraining interventions in the realm of urban food security.*

Healthy food access is a critical element of urban food security, and often healthy food (e.g. fresh fruit and vegetable) is also the least processed and most sustainable to the environment. Food manufacturers play an essential role in improving healthy food

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supply, and commercial food systems have the potential to drive systemic change for healthy food access [3]. In this regard, effective supply chain management provides the right lens into the flow of food from the source to the cities and becomes a significant part of the solution to fight food insecurity [1].

Furthermore, 1/3rd of the food produced in the world gets wasted, which exposes the inefficiencies of food supply and distribution [4]. Food waste and loss also indicate that urban food insecurity may not be as much about inadequacies in food production as it is about access. Food supply chain inefficiencies impact urban food systems negatively; therefore, there should be efforts to improve the performance of supply chains. In addition, food waste directly contributes negatively to urban food security and the environment.

Commercial food systems (e.g. food manufacturers, food retailers) are an essential element of urban food systems as they are responsible for the food supply, and their actions are crucial in materializing the goals of future urban food systems. Even though several initiatives are focusing on the behavioral side of food consumption, supply-side innovations are equally essential to transform a food system into a healthier and more sustainable one. Sustainable food system innovations are expected to use new technologies as part of systemic change to achieve the UN's sustainable development goals [5]. The below sketch (see Fig. 1) presents our focus area for this paper:

Fig. 1. Research focus for food system innovations

Owing to modern computing technologies and data harvesting mechanisms, food system innovations could be planned and executed using digital technologies from the industrial supply side.

1.2. Digital technologies in urban food supply chains

Digital technologies in food supply chains include a broad range of tools, such as cloud computing technologies, blockchain, the Internet of Things (IoT), big data analytics, sensor technologies, etc., that improve supply chain performance [6]. Buyukozkan et al. [7] write that digitally connected supply chains are not "*about whether the products or services are physical or digital, but it is the way the supply chain is managed*" and suggest many benefits of digitalization in supply chains are still untapped. Digital supply chains offer flexibility and efficiency to today's complex activities in the chain due to the following distinct features [7]:

- Speed—the ability to react quickly to demand and deliver in a short period
- Flexibility—the ability to respond and minimize disruptions, for example, caused by the COVID-19 pandemic
- Global connectivity—the ability to build international hubs to supply goods and services locally
- Real-time inventory—efficient monitoring of stock levels in warehouses and distribution centers
- Intelligent—self-learning and autonomous decision-making for automated execution of operations
- Transparency—the ability to anticipate and plan for disruptions through visibility
- Cost-effective—digitalization enables cost-efficiency for organizations
- Scalability—the ability to quickly reconfigure supply chains and scale them up or down
- Innovative—the ability to be open to change
- Proactive—the ability to anticipate demands and offer solutions (e.g. operational intelligence to satisfy consumers)
- Eco-friendly—the ability to extend eco-friendly process capabilities in the supply chain

Food loss and waste are major global challenges and have been an important research stream in the literature on food supply chains. Several studies have highlighted the importance of digitalization for food waste reduction. Chauhan [8] states that poor management of perishable food items needs immediate attention, and managers should aid in developing infrastructures to implement new technologies such as IoT for waste reduction.

To leverage the full potential of digital technologies in urban food systems, it is first essential to understand the currently available digital solutions and what they can offer to solve some of the pressing challenges of the urban food supply chains. Motivated by this need, the paper reviews the operations management literature in urban food supply chains to study the role of digital technologies in addressing some of the current supply chain inefficiencies.

Section 2 presents the background on enablers of supply chain visibility and flexibility and formulates the research question for this paper. Section 3 presents the methodology, and Section 4 groups the findings from the review into key groups. Section 5 critically discusses the findings and our research position to counter urban food insecurity. Finally, the conclusions are drawn in Section 6, where future research avenues are presented.

2. Enabling supply chains integration for visibility and flexibility

Supply chain integration is a capability that can be defined as the degree to which a manufacturer strategically collaborates with its supply chain partners [9], for example, through information integration. The Industry 4.0 paradigm aims to achieve end-to-end digital integration throughout a product's entire value chain across different companies, mainly using IoT [10]. There are many benefits of supply chain integration in urban food systems to address food security concerns, and some of them are:

- **For visibility**: Food supply chain visibility is a result of stakeholders making the information accessible on the food from "farm to fork," and this can include information on agricultural production, shipping, processing, and manufacturing, packaging, storage conditions, consumer preferences, etc. [11]. It ensures the traceability and transparency of product flows.
- **For flexibility**: Supply chain flexibility, which is synonymous with manufacturing flexibility, is a firm's capabilities comprising volume flexibility, mix flexibility (e.g. product variety), and customer satisfaction [12]. Supply chain flexibility supports customer responsiveness and ensures the delivery of food products in the event of disruptions.

Digitalization is one of the many methods of achieving transparent and flexible supply chains, and real-time information sharing through IT systems improves stakeholder coordination [13]. Therefore, information sharing is a prerequisite for supply chain integration; however, fostering a digital mindset and organizational culture is crucial for this transformation.

Furthermore, in a food system context, the problem of supply chain integration is even more severe as it is an interplay of several complex systems such as agriculture, consumer preferences, etc. Therefore, an inter-organizational collaboration of stakeholders in a supply chain (e.g. for information sharing) is essential for solving the urban food security problems [13]. The below figure (see Fig. 2) presents a framework for supply chain management of digital supply chains [7], where we highlight the dimensions of supply chain integration.

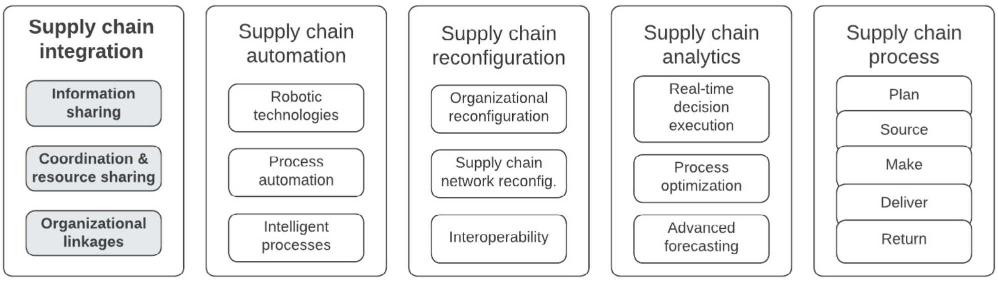

Fig. 2. A framework for the supply chain management of digital supply chains [7]

A recent example of supply chain integration in the digital era is from the COVID-19 pandemic times when digital marketplaces successfully delivered food to consumers during the lockdowns. In such a situation, businesses that are digitally native (online first) could operate with ease, whereas other companies had to undergo business model evolutions to adapt to the disruptions [14]. Furthermore, digital platforms have evolved rapidly in the food business, and there are still knowledge gaps on how they impact the food system landscape [14]. In addition, micro-retailers and the informal sector operating locally are also highly relevant to urban food security [1]. However, there are limited studies that offer empirical insights into their role.

We believe that E-commerce and digital innovations can potentially transform food systems into healthy and sustainable ones. It is well understood that digital technologies are enablers of supply chain integration; however, their roles in improving healthy food access are still not well documented. To explore this gap, we first need to understand the problems of food supply chains and the possible digital solutions. Therefore, we study the following question in this paper:

RQ: *How might healthy food access and food waste reduction be supported through supply chain integration using digital technologies?*

3. Methodology

This paper studies the latest research contributions in digitalization for urban food supply chains. We use the results from the first iteration of a systematic review strategy (see Fig. 3) and identify the usefulness of digital technologies from the literature. The literature review was conducted mainly through Google Scholar, using the IEEE and Scopus databases. We also retrieved a few industry white papers from various general search results. In addition, we have consulted publicly available studies from our project partners and not-for-profit government agencies such as the Food Standards Agency. Our emphasis was on the most recent literature from 2018 – 2022. We have prioritized inductive and abductive studies over deductive that either focus on quantitative modeling or company-centric action research.

The keywords used for the search were 'urban food supply chains,' 'food supply chains,' and 'digital food supply chains. Since the focus was on operations management contributions, we excluded articles focusing exclusively on health and policy-oriented contributions. Exclusion criteria also included articles written in languages other than English. We identified 86 peer-reviewed scientific papers, including journal articles, book chapters, and conference proceedings. We have also identified five industry reports in the initial phase to understand the phenomenon in practice. Finally, we considered 33 articles eligible that we deemed highly relevant to answer the research question of this paper. We managed the references using Mendeley and performed a qualitative synthesis to write about the role of various digital technologies in urban food supply chains. This synthesis also led to the development of thematic clusters for this topic. The figure below (see Fig. 3) shows different stages of our review process, and Table 1 presents the literature mapping under four key categories. Finally, we synthesize our findings into a framework for supply chain integration in urban food systems.

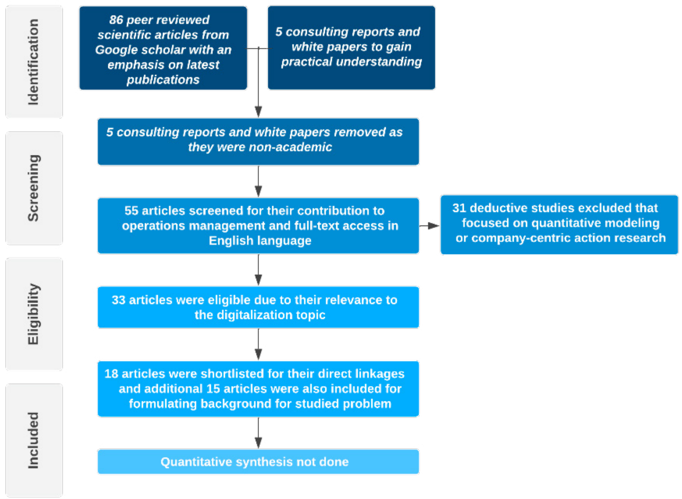

Fig. 3. Criteria for selection of articles in different phases of a systematic review [15]

4. Findings

4.1. Links between digital technologies and urban food supply chains from the literature

Table 1 presents the literature mapped into themes based on its relevance to each group. Out of the 33 eligible articles, we only used 18 articles for mapping as they had direct linkages with the sub-themes. The content from the articles relevant to the themes and their issues is elaborated on in Section 4.2.

Table 1. Articles on digital technologies with links to themes

Thematic clusters	**Sub-themes**	Guo (2020) [16]	Chauhan (2021) [8]	Annosi (2021) [17]	Astill (2019) [11]	Powell (2022) [18]	Srai (2022) [19]	Tuomala (2020) [1]	Kelepouris(2007) [20]	Dabbene (2014) [21]	Paciarotti (2021) [22]	Zhong (2017) [23]	Hart (2021) [14]	Casino (2020) [24]	Belaud (2019) [25]	Kayicksi (2020) [26]	Vieira (2020) [13]	Nicholson (2020) [27]	Stranieri (2021) [28]
Objectives	Healthy food access	*			*			*		*			*					*	
	Sustainability				*						*	*			*		*		
Problems	Food waste		*	*													*		
	Out-of-stock																		*
Digital solutions	Digital platforms	*	*		*		*				*		*				*		
	Distributed computing				*	*								*		*			*
	Sensing technologies				*				*	*									
Systems engineering approaches	Links to Industry 4.0 & IoT	*	*	*	*	*			*	*		*			*	*			
	Supply chain integration			*	*		*					*				*	*		
	Systems analysis & design								*			*			*	*			
Methods	Conceptual								*				*	*	*				
	Empirical			*		*	*									*	*		
	Review	*	*		*			*		*	*	*						*	*

4.2. Synthesis of literature on urban food supply chains, clustered into themes

4.2.1. Theme 1: Objectives of urban food supply chains

4.2.1.1. Healthy food access (variety, affordability, last-mile delivery)

The early days of the COVID-19 pandemic are one of the most recent examples of the challenges faced for healthy food access. Many cities went into lockdowns with people quarantined. Social distancing measures caused difficulties to the logistic and fresh-food supply systems that restricted the in-person shopping of traditional supply methods (e.g. agricultural markets and supermarkets) due to the risk of infection [16]. E-commerce models played an essential role in ensuring food access to urban residents during severe disruptions in the COVID-19 pandemic [16].

Food safety is a major concern for healthy food access that can be addressed through product traceability. Traceability in food supply chains concerns the ability to trace the history of food products, their origin, and their characteristics, mainly by obtaining information from the upstream activities of the supply chain for various reasons such as compliance with regulations, quality control, and food safety, etc. [21]. Dabenne et al. [21] write that the theory on supply chain optimization techniques for traceability is well developed; however, there are some unexplored aspects, such as improving traceability systems by engaging all the stakeholders of the supply chain [21].

Despite the consensus on the importance of digital solutions for healthy food access, there are no in-depth studies on the cost-effective design and implementation of information systems for healthy food access.

4.2.1.2. Sustainability

Awareness of sustainability issues has been rising over the last couple of decades, and food supply chain actors such as farmers, food manufacturers, and policymakers are equally interested in it. Sustainability in food supply chains can be improved by minimizing environmental impacts by reducing food waste, recycling, and sharing facilities through coordinated development [23]. Sustainability can also be enhanced in food handling, storage, and delivery using the physical internet, which is an open global logistics that converts physical objects into digital items [23]. However, the literature shows that data-driven decision-making can enable sustainable and adaptive supply chains. Sustainability is an active and a broad research topic we do not study in this paper; however, we explore solutions to reduce food waste in supply chains, which directly contributes to sustainability.

4.2.2. Theme 2: Problems of urban food supply chains

4.2.2.1. Food waste

Food loss and waste are a grand challenge of the 21st century, which is food not eaten, and the UN estimates that about one-third of the food produced in the world is thrown away. Food waste reduction is a prominent area of research in food supply chains, and several studies have examined technological solutions in food production, distribution, and retailing. Chauhan et al [8] proposed operational solutions such as shelf-life strategies, digitalization, and upgrading logistics systems and found gaps in infrastructural developments for IoT implementation to curb food waste. Vieira et al. [13] conducted empirical research on a Sao Paulo case and named the lack of supply chain coordination as a critical reason for food waste. The authors present digital business platforms as a solution to bridge gaps between production and consumption.

4.2.2.2. Out-of-stock

The out-of-stock problem relates to customer responsiveness issues where there is an inadequate supply of food products at the retailer despite high demand. Improving supply chain flexibility with robust production planning and inventory control is essential for meeting consumer demands. The out-of-stock situation negatively affects retailers and is prevalent in fresh food products with low shelf life. In this regard, Stranieri [28] study the role of traceability systems, such as blockchain technology, for food volume and delivery flexibility to improve customer satisfaction.

4.2.3. Theme 3: Digital solutions

4.2.3.1. Digital platforms

Digital platforms are transformative and powerful technologies that have found their way from the information technology field into information systems literature [29]. In simple terms, a digital platform is an internet-based software system that allows different users to exchange information. From a socio-technical view, it is a collection of technical elements, such as software (predominantly apps) and hardware, along with the associated organizational process and standards [29]. Recent studies have proven the application of digital platforms in agri-food supply chains to increase the bargaining power of smallholders [19]. One such study addresses the policy tensions in 2020 Indian agricultural reforms and proposes digital platform-based solutions (for a reconfigured digital marketplace) to support the role of farmer-producer organizations [19]. Cane et al. [30] also conclude that digital platforms are essential tools to reduce food waste as they can build synergies with different supply chain parties (farmers, food producers, retailers, consumers, and activists) involved in sustainable agri-food models. A recent report from the Food Standards Agency [14] studied the role of digital platforms in the food business and presented online platforms as customer-centric systems with solid data and digital capabilities (e.g. Facebook, Just Eat, Deliveroo).

4.2.3.2. Distributed computing paradigms and blockchains

Blockchain technologies are gaining momentum to make data accessible to different supply chain parties through a digital platform. Astill et al. [11] write that a “blockchain is a technology that provides the ability to make transactions on a public or private ledger accessible to diverse groups or people, without the need for an official third party to monitor the transactions.” Powell et al. [18] propose blockchain for solving traceability problems in food supply chains and present IoT as an effective data-gathering tool for its implementation. Blockchains can improve data integrity and enhance supply chain coordination; however, there are limited studies on the practical challenges of blockchain implementation in food ecosystems.

4.2.3.3. Sensing technologies

Astill [11] presents an overview of the technological enablers of transparency in food supply chains from the IoT perspective. The data acquisition technologies include sensors that are hardware devices capable of collecting, processing, analyzing, and storing data [11]. These sensors range from biosensors that can, for example, measure and send temperature from livestock to smart sensors used in industrial food processing. Sensor technologies combined with the new computational capabilities can guarantee greater traceability and control in the food supply chain. Literature in the past has studied the application of radio frequency identification (RFID) for traceability in food supply chain management. Kelepouris et al. [20] propose an information infrastructure for RFID-enabled traceability and system architecture with interoperable interfaces and a standard implementation. However, there are knowledge gaps in systems architectures and formal models for traceability systems for urban food supply chains in IoT.

4.2.4. Theme 4: Systems engineering approaches

4.2.4.1. The usefulness of Industry 4.0 principles and the Internet of Things (IoT)

Industry 4.0 (or the fourth industrial revolution) vision promises to address global challenges through improved productivity and efficiency in manufacturing supply chains. Industry 4.0 is synonymous with Industrial IoT, which is defined as [31]

> *“A system comprising networked smart objects, cyber-physical assets, associated generic information technologies and optional cloud or edge computing platforms, which enable real-time, intelligent, and autonomous access, collection, analysis, communications, and exchange of process, product and/or service information, within the industrial environment, so as to optimise overall production value. This value may include improving product or service delivery, boosting productivity, reducing labour costs, reducing energy consumption, and reducing the build to-order cycle.”*

The smart factory is a central concept of Industry 4.0 and has emerged as a popular research stream in no time. Many companies worldwide have reported benefits from Industry 4.0 principles to steer their digitalization projects for improving customer responsiveness. A recent example is Moderna’s digital factories that successfully delivered COVID-19 vaccines to the world within short product life cycles [32].

Implementing cost-effective traceability systems is a significant challenge in food supply chains [26]. Information exchange through paper-based systems in a non-standardized format is highly unreliable for maintaining food safety and may prevent tracing the food product right from its origin.

Kayickci et al. [26] propose blockchain for resolving challenges such as traceability, trust, and accountability in the food industry. Industry 4.0-based technologies such as IoT, blockchain, and artificial intelligence tools can be highly beneficial for improving supply chain visibility through IoT for efficient data acquisition and analysis. However, there are research gaps in applying Industry 4.0-based solutions for food supply chains. Ben-daya et al. [33] state that empirical research is scarce in the IoT application for supply chain management.

Chauhan et al. [8] review the operational solutions for preventing food loss and waste in supply chains and propose digitalization and upgrading logistics systems. The authors also frame one of the potential research questions for the future as “What are the advantages and disadvantages of using Industry 4.0 technologies for food loss and waste reduction?”

4.2.4.2. End-to-end supply chain integration

End-to-end integration in supply chains can refer to inter-organizational integration of the information technology (IT) systems along the supply chain for seamless information exchange in real-time. The term "connected enterprises" [34] was previously used to present the idea of digitally connecting independent supply chain parties that can enable responsiveness and collaborative production planning.

There are several ways to achieve paperless information exchange between food system stakeholders, and traditionally it happens through electronic data interchange, advanced shipping notifications, fax, and emails. However, for real-time information exchange, especially in time-sensitive businesses such as fresh food, it is essential to develop enterprise information systems that can deliver end-to-end solutions in real-time. Inter-organizational collaboration, for example, between manufacturers and wholesalers, can be achieved using next-generation enterprise resource planning (ERP) and manufacturing execution systems (MES). The below figure (see Fig. 4) shows different flows (information, product, and demand) in the supply chain:

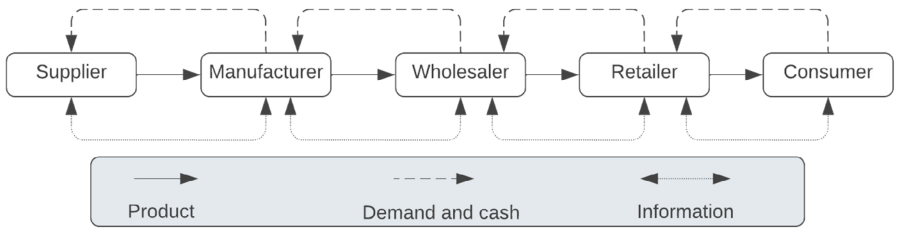

Fig. 4. Supply chain flows [35]

In this regard, MES, an enterprise information system, can provide real-time product-centric data from the factory shop floor. Furthermore, MES can improve supply chain traceability due to its functionalities, such as *genealogy* and *product tracking* throughout a fresh food product's ordering, manufacturing, and delivery process [35]. Therefore, enterprise information systems must be designed and operationalized using modern integration and computing principles for interoperability between supply chain actors. In addition, standardized and flexible information systems can also enable supply network reconfigurability.

4.2.4.3. Systems analysis and design

Zhong gives an overview of the systems and their implementation in food supply chain management and categorizes the IT systems as traceability systems and decision-making systems [23]. Research in food supply chain management reveals that information and communication technologies enhance decision-making across agri-supply chains [36]. Trienekens et al. [37] write about the functions of information systems for transparency and identify data storage and processing requirements for various business processes (e.g. order management, warehouse management, manufacturing, and freight management) in food supply chains. The authors present an integrated information system architecture that is flexible to meet information exchange requirements between actors such as consumers, producers, and the government. However, the traditional supply network structure may no longer be suitable in IoT for supporting food supply chain operations, due to the increasing number of heterogeneous digital devices, sensors, etc., along the supply chain [23]. Therefore, we argue that further research is needed in information systems development using IoT for food supply chain management.

5. Discussion

Several companies are merging their business and IT strategies [38] and turning into digital enterprises. Even large e-commerce companies such as Amazon are turning to data to expand their future business capabilities by leveraging digital supply chains [7]. Similarly, food supply chains are increasingly adopting digital technologies to tackle urban food security challenges. However, Chauhan [8] sheds light on how digitalization-related studies are lacking to an extent, especially around the usage of IoT for reducing food loss and waste. Kamble et al. [39] also highlight the importance of IoT for planning food waste management of products that exceed their shelf life but state that the adoption of IoT in food retail supply chains is still nascent. These findings from the literature prompt us to incorporate IoT principles in considering digital solutions for food supply chains.

Through the below framework (see Fig. 5), we answer the research question of how healthy food access and food waste reduction might be supported through supply chain integration. The framework is synthesized from the literature analysis and connects urban food security problems with possible digital solutions. Furthermore, it also shows how these IoT-enabled technologies lead to value creation through new operating models and mechanisms for value capture through new business models.

Practitioners in the food industry can use the framework to develop their Industry 4.0 strategies in supply chains. For example, practitioners can explore the use of digital technologies to enhance traceability and demonstrate product authenticity (e.g. organic food produce). Further, they can use such technologies to reduce waste, shorten lead times, and thereby reduce food losses. These interventions should lead to cost improvements for producers, and product quality and affordability enhancements for consumers.

Digital platforms provide practitioners with pathways for connecting multiple producers for supply-side synergy opportunities (e.g. product volume aggregation), demand-side synergy for retailers and consumers, and supply-demand-side synergies to ensure efficient communication between producers and consumers [19]. The framework below sets out the role of digital technologies in support of supply chain integration and interaction.

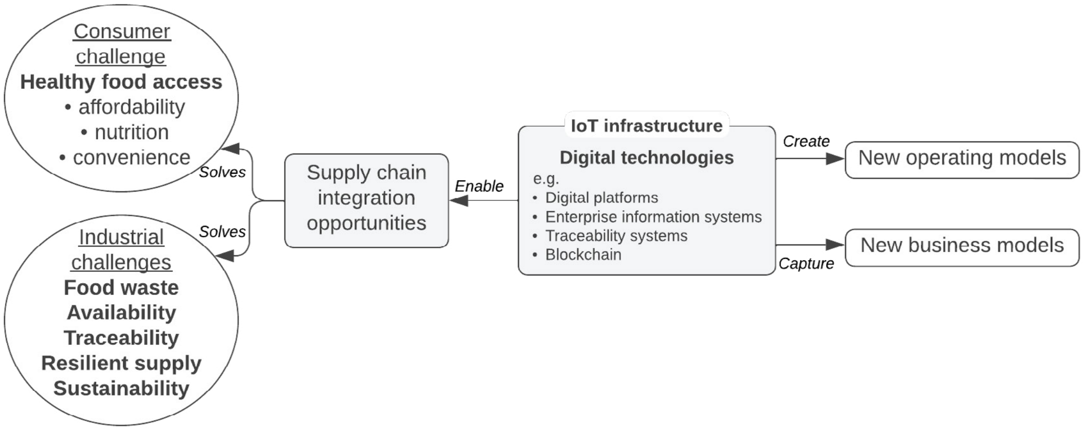

Fig. 5. A Framework for supply chain integration using IoT in urban food systems

Our literature analysis indicates that stakeholder collaboration in a food supply chain is a prominent feature for bringing positive outcomes for urban food systems. However, several factors can prevent supply chain coordination and information visibility, and often it can be down to the attitude and openness of companies on how they perceive and adapt to the data-intensive world. Developing a digital mindset takes effort, and a large body of research concludes that leaders with a digital mindset can better steer organizations for success and create a resilient workforce in this digital age [40].

In the context of supply chain flexibility, Lorentz et al. [41] advocate the proactive design of international supply networks for food manufacturers and present market-related frameworks to discuss the role of supply chain management. This approach can be relevant for designing shorter food supply chains that simplify complex distribution mechanisms and support access to nutritious, locally sourced fresh food.

Healthy food affordability is intrinsic to urban food security. However, poorer residents of cities often find it difficult to consume healthy diets due to the inflated costs of fresh fruit and vegetables. Research suggests that poor dietary choices can be remedied through fiscal interventions in food provisioning since fruits and vegetables can sometimes be 40% more expensive than is efficient [42].

Large retailers play a crucial role in solving the food waste crisis, and one study suggests the following four strategies for food waste reduction for groceries [43]:

- Upgrading the inventory systems using advancements in automation and software capabilities for inventory management to reduce excess inventory, especially perishable food products
- Collaborating with farmers to reduce agricultural food waste as there is a problem of excess production and a large amount of food produced on the farms is unharvested
- Modifying and eliminating the practices around throwing away fresh fruit and vegetable due to the high cosmetic standards and prematurely discarding food due to the misinterpretation of "best by" dates
- Collaborating with consumers and engineering campaigns for waste reduction

From an industrial supply side, Industry 4.0-based digital technologies can promote waste reduction through effective production planning and inventory control. This requires advanced information systems that can orchestrate supply chain operations efficiently. Future research in information systems interventions for food security can include analysis and design of innovative online systems using real-world cases in food value chains.

6. Conclusions

We explored the role of digital technologies in solving some of the emerging problems around urban food security and reviewed the literature on urban food supply chains. Using thematic analysis, we learned that research highlights the shortcomings of digital technologies incompatible with the heterogeneous networked architectures in IoT. Even though there is a rich literature on food supply chains for sustainability goals, we deduced from our analysis that there are knowledge gaps in digital food supply chains for public health. There are limited studies on information systems development for healthy food access from an industrial supply perspective, suggesting opportunities for interdisciplinary research, particularly between academics from public health and epidemiology disciplines and those in supply chain operations management. From a supply chain operations perspective, methodologies that examine supply chain reconfiguration enabled by the digital infrastructure can provide insights on changes in bargaining power and equity between producers (e.g. farmers, food processors), supply chain intermediaries (e.g. wholesalers, co-packers), retailers and consumers.

With this position paper, we attempt to highlight the role of supply chain coordination using IoT to address the pressing issues of food provisioning and food waste in urban environments. Based on the findings, we synthesize a framework (see Fig. 5) for food supply chain integration using IoT and present research directions for supply chain innovations with end-to-end digital integration.

Our framework on integrated supply chains can prompt food systems thinkers to embrace IoT principles to design resilient supply chains that can handle disruptions and food shortages. The paper presents several examples of IoT applications and argues the need for Industry 4.0-based solutions to improve the urban food system.

We mainly focused on poor health and waste as the unwanted outcomes of food systems, but there are other undesirable ecological outcomes (e.g. pollution due to plastic packaging) that we deemed out of scope in this paper. Future work in this area can study how IoT-based integrated supply chains can address sustainability challenges to reduce unwanted costs on the food system. Therefore, we stress that designing digital solutions for urban food security is a socio-technical problem that requires an interdisciplinary problem-solving approach.

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