Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
Scaling up the Digitalization of the Public Distribution System: A COVID-19 Pandemic Impetus

Ramesh Kumar*, L. Ganapathy**, Ravindra Gokhale***, Manoj Kumar Tiwari****

*Operations and Supply Chain Management, National Institute of Industrial Engineering (NITIE), Mumbai, India. (e-mail: rameshkr8190@gmail.com).

**Operations and Supply Chain Management, National Institute of Industrial Engineering (NITIE), Mumbai, India. (e-mail: lganapathy@nitie.ac.in).

***Operations and Supply Chain Management, National Institute of Industrial Engineering (NITIE), Mumbai, India. (e-mail: rgokhale@nitie.ac.in).

****National Institute of Industrial Engineering (NITIE), Mumbai, India, Indian Institute of Technology Kharagpur, Kharagpur, India. (e-mail: mk09@hotmail.com).

Abstract: Food grain is an essential commodity that requires proper procurement, transportation, storage, and distribution with easy access to needy people. Therefore, The Indian government has established a Public Distribution System (PDS) to distribute the food grain across the country. This study emphasizes the need for digitalization of PDS and how the COVID-19 accelerates the digitalization of PDS. We proposed a three-layer conceptual framework: food grain supply chain network, digital processes automation and digital technologies. We collaborate the three-layer perspectives to ensure food security during the COVID-19 pandemic and reduce the food grain leakage in PDS. This study also supports the United Nations Sustainable Development Goals, and National Food Security Act aims to achieve the Zero Hunger goal. The proposed research will assist policymakers, institutions, and the government in implementing the digitalization of PDS for greater efficiency and transparency during a pandemic. Furthermore, this work may help to achieve the ambitious "Digital India" programme, which aims to improve India’s online infrastructure and electronic services.

Keywords: Covid-19, Digitalization, Public Distribution System, Supply Chain, Food Grain.

1. Introduction

Indian public distribution system is one of the world's largest food grain distribution networks. It provides subsidized food grains to more than 800 million, which is about two-thirds of India's population. It covers more than 500,000 fair-price shops across the country (WFP, 2019). For the year 2021-22, the Indian government has allocated Rs 2,42,836 crore, equivalent to 7% of the central government’s annual budget (MCA, 2021). To manage the process of entire food grain movements from farmers to the targeted beneficiary, two major stakeholders involved are the central government and the state government. The Food Corporation of India (FCI) operates on behalf of the central government for the movement of food grain from procurement from farmers to storage at the central warehouse. Similarly, the state governments will be responsible for the pickup of the food grain from the central warehouse to delivery to the targeted beneficiary (NFSA, 2021)

COVID-19 outbreak was first reported in Wuhan, China, on 8 December 2019 (WEF, 2020) spread rapidly to other parts of the world soon. India's first case was reported in Kerala on 30 January 2020 and started a terrible loss of human life (WHO, 2020). Laborde, Martin, and Vos (2021) estimated that almost 150 million people globally fall into extreme poverty and food insecurity due to the impact of COVID-19 pandemics. To prevent the spread of coronavirus, The government of India initiated the first lockdown on 25th March 2020 for 21 days, the second on 3rd May 2020 for 19 days, the third for 14 more days until 17th May 2020, and again until 31st May 2020. Then, the unlock down has started with some relaxation to acquire the normal situation.

To ensure and stop food leakage.

To ensure the food security of India.

Promoting the NSFA and SDGs program

Easy access to needy people.

Minimize the wastage of food grain.

Reform the PDS with more transparency

Fulfil the uncertain demand for food grain

Figure 1: Need for digitalization in the PDS
The COVID-19 pandemic was one of the major driving forces to accelerate the digitalization of the public distribution system in the early stage. Likewise, Figure 1 reveals the major need for digitalization in the public distribution system. The digitalization of PDS ensures food leakage, and food security and enables easy access to needy people. It also promotes the NSFA and United Nations Sustainable Development Goals. To ensure food security in India, the government has also accelerated the public distribution system more towards digitalization. The major initiatives of digitization are Fair price shop automation, Aadhar (Universal Identification Number) seeding of ration cards, Digitization of ration cards, online allocation of food grains and direct cost transfer. These digital initiatives will reform the PDS with more transparency in the food supply chain.

Figure 2 illustrates the critical challenges faced by the public distribution system during the COVID-19 pandemic. We have considered two types of situations. First, the normal situation challenges like managing and distributing the food grain of 800 million beneficiaries required a huge infrastructure of transportation and warehouses. In the second situation, during COVID-19 the critical challenges faced by PDS are labour shortage, driver unavailability, travelling restrictions, high demand of food grain at fair price shops, and maintaining the social distancing. In addition, the challenges of the government to implement the Pradhan Mantri Garib Kalyan Anna Yojana and the One Nation One Ration Card scheme.

We explore the three-level integration to support the digitization of PDS using a food supply chain network, Digital process automation and cutting-edge technologies. The main objective of our study aims to ensure food security, and food leakage and reduce the food wastage of PDS This paper consists of five main sections; We first describe the research background of PDS and the food supply chain literature. We then proposed a conceptual framework for the digitalization of the PDS, followed by insights and implications. The last section presents the conclusion of the study.

2. Research Background

This section has categorized the relevant literature on food supply chain digitalization into two groups. The first is the Evolution of the Public Distribution System, and the second is Digitalization in the Food supply chain.

2.1 Evolution of the Public Distribution System

The rationing system in India was established in 1939 during World War by the British government from Bombay to solve food scarcity. Eventually, it expanded and evolved with significant changes by India's Government over a period, as depicted in Figure 3. The system was first introduced to distribute the food grain from Bombay city and later extended to other major cities like Kolkata, Delhi, Chennai, Hyderabad, and Bangalore. In 1943, thirteen cities came under the rationing system and gradually increased to almost 700 cities/towns by the end of 1946. The ration system was reformed in 1960 into the public distribution system to minimize food grain shortages and to ensure the food grain distribution in India's urban poverty areas. In 1965, the central government established the Agriculture Prices Commission and the Food Corporation of India (FCI) to increase the domestic procurement, storage, and transportation of food grains. The main objective of FCI was to buy the food grains from poor farmers at an effective support price and distribute it through the PDS over the country. In 1992, the Public Distribution System (RPDS) was revamped to improve food access. In 1997, the government proposed the Targeted Public Distribution System (TPDS), to provide subsidized food grain to low-income families through a channel of fair price shops. In December 2000, Antyodaya Anna Yojana (AAY) was launched to target 2.5 cores families.

In September 2013, the parliament passed the National Food Security Act (NFSA). NFSA was an improvisation of the TPDS scheme with the legal right to access adequate quantity and quality of food grains at subsidized prices to live a life with
dignity. Poor families were categorized into Antyodaya Anna Yojana (AAY) and Priority Household (PHH) to get 35 kg and 5 kg food grains per month at a highly subsidized price. In 2015 United Nations designed the seventeen Sustainable Development Goals (SDGs) to ensure a better future for the We focus on NSFA, and the 2nd goal of SDGs (Zero Hunger) is to achieve food security by digitalizing the PDS. In subsequent years, the Government of India has taken more initiative toward the digitalization of PDS through Aadhaar enabled Public Distribution System (AePDS) scheme in 2017 and the Integrated Management Public Distribution System (IMPDS) in 2018. The primary purpose of IMPDS was to create a centralized database for the nationwide portability and de-duplication of ration cards.

| Rationing system started in India | 1939 |
|----------------------------------|------|
|                                 | 1960 |
| Public Distribution System      |      |
|                                 | 1965 |
| Creation of Food Corporation of India |      |
|                                 | 1992 |
| Revamped Public Distribution System |      |
|                                 | 2000 |
| Antyodaya Anna Yojana (AAY)     |      |
|                                 | 2013 |
| National Food Security Act      |      |
|                                 | 2017 |
| Aadhaar enabled Public Distribution System |      |
|                                 | 2018 |
| Integrated Management of public distribution system |      |
|                                 | 2020 |
| One Nation One Ration Card      |      |

Figure 3: Evolution Public Distribution System in India

Millions of migrant workers across the country are facing food insecurity because of the COVID-19 pandemic. This could lead to them insisting on travelling, exposing them to health risks, and hastening the spread of the COVID-19 virus. The labour shortage due to the travel restrictions and fear of infections, the food supply chain was severely disrupted during the pandemic. To address this issue, the government launched two programmes in 2020, First, the One Nation One Ration Card (ONORC), and second, Pradhan Mantri Garib Kalyan Anna Yojana (PMGKAY). ONORC system will allow migrant workers and their family members to lift their entitled food grain from any fair price shop across the country. Under this plan, the distribution and demand are highly probabilistic and require a more robust implementation of IT-driven systems at each FPSs. PM-GKAY Scheme was initially launched on 26 March 2020 to fight against hunger during the COVID-19 pandemic. The first phase of the scheme ((PM-GKAY-I) started from April to June 2020 and was further extended in the second phase up to November 2020. This scheme provides 5 kg grains and 1 kg pulses for free under PDS as part of "Atmanirbhar Bharat" to offer free food grains to migrants and the poor. The scale of food grain distributions during the covid 19 pandemic turns out to be one of the largest food security programs globally.

2.2 Digitalization in the Food supply chain.

Annoesi et al. (2021) expressed that food supply chains increasingly rely on digital technology and big-data-based solutions to improve supply chain performance and visibility. Likewise, Kittipanya-Ngam and Tan (2020) have explored a Thailand food supply chain case by proposing a framework to support technology capability and digital infrastructure. The framework elements are accessibility, efficiency, legal culpability, transparency, and traceability. Olan et al. (2021) have explored artificial intelligence (AI) technologies to support operational and financial challenges in global food suppliers. Li, Lee, and Gharehgoliz et al. (2021) have studied the blockchain technologies of the food supply chain to improve system transparency, security, efficiency and reduce the transaction time and cost. Likewise, Casino et al. (2021) presented the blockchain-enabled food supply chain traceability by considering four performance parameters: efficiency, trust, quality and resilience. Kumar et al. (2020) reviewed the various modelling techniques and solution approaches for supply chain network problems. Mogale et al. (2020) have deliberated the mathematical model for food grains procurement using supply chain network design.

COVID-19 pandemic was one of the most impactful crises and critically affected the food supply chain during the COVID-19 pandemic (Singh et al., 2021). It spread to over 200 nations and provinces worldwide and provoked a drastic economic downfall after the vital inflation (IMF, 2020). Burgos and Ivanov (2021) explore the food retail supply chain using the digital twin approach to improve the resiliency and recovery strategies of COVID-19 disruption. Ghohami-Zanjani et al. (2021) explored resilience in the food supply chain network design and analyzed the impact of epidemic disruptions.

The literature reveals that more studies are required to design a conceptual framework to recommend and analyze the digitalization of the food supply chain. Thus, we have proposed a conceptual framework for the digitalization of the Public Distribution System. As per my knowledge, no more papers exist to address the food security challenges during COVID-19 and strengthen the digitalization of the public distribution system.
3. Conceptual Framework

In this study, we proposed a conceptual framework for ensuring food security during COVID-19 and stopping food grain leakage in the PDS. The conceptual framework consists of three layers. The upper layer is the food grain supply chain network, the middle layer is Digital process automation, and the lower layer is Digital technology. The details of each layer are mentioned in the following.

3.1 Food Grain Supply Chain Network

The food grain supply chain network is the integration of farmers, procurement centers, central warehouses, state warehouses, district warehouses, fair price shops, and targeted beneficiaries. The supply chain can generally consist of three types of flow: Physical flow, Information flow, and financial flow. In the case of the food grain supply chain, physical flow deals with the flow of food grains in a forward direction, the financial flow as money in a reverse direction, whereas information flow in both ways share related information among procurement centers, warehouses, and other supply chain facilities. The food grain supply network consists of four primary activities, procurements, storage, transportation, and distribution, as illustrated in the upper layer of Figure 4. The farmers sell the grains at the procurement center or local mandi; the procurement center temporarily collects and stores and sends them to the central warehouse by train or truck. Central warehouse stores on a large scale and sends it to state warehouses. State warehouses ship to district warehouses and from district warehouses to fair price shops by trucks according to the required demand. Finally, the targeted beneficiaries collect the food grain from fair price shops every month.

3.2 Digital Process Automation

Digital process automation consists of the multiple activities involved in handling the food grain, from procuring to reaching targeted beneficiaries with modern and digital devices, as mentioned in the middle layer of Figure 4. We classify the major processes of PDS into four stages: Procurement, Storage, Transportation, and Distribution. Each process consists of digital devices to make it more efficient and transparent. The procurement process contains smart packaging, Artificial Intelligence (AI) based quality inspections, and electronic e-invoice for adequately procuring and packaging food grains from farmers. Next, the storage system required smart storage with a vacuum lifter and inventory monitoring for efficient storage and to minimize food grain wastage. Likewise, the transportation process plays a crucial role in the food grain supply chain. The devices like smart maps, routing planning, and Radio Frequency Identification (RFID) trucks enable to transport food grain efficiently. The last process is distribution, which consists of digital payment, Aadhar seeding with biometric devices. These digital processes will help automate the PDS and reduce food grain leakage and food security.
3.3 Digital technology

In the lower layer of Figure 4, we illustrate the digital technology for digitalizing the public distribution system. The cutting-edge technologies are blockchain, digital twin, Internet of Things (IoT), Big Data, Artificial Intelligence (AI) and cloud computing. These technologies will be interconnected and widely applied in four primary digital process automation of PDS to improve quality, efficiency, transparency, and traceability. Kayikci et al. (2022) propose a blockchain-enabled framework to address the challenges of traceability, trust, and accountability in the food supply chain. Similarly, Agrawal et al. (2022) developed a blockchain framework for the supply chain collaboration with smart contracts. Tao, Wang and Zhu (2022) analyze the impacts of optimal pricing and quality decisions between two supplier players using blockchain technology. Thus, digital technology plays a vital role in making PDS more efficient. To create trust and transparency, there is also a critical need to increase the digital information and communication among the farmers, Mandi, warehouses, FPS, and targeted beneficiaries.

Over the last decades, the food supply chain has increasingly adopted digital technologies because of globalization and digitalization. In recent years after the COVID-19 pandemic, the pace at which digital technology applications have accelerated to manage the critical challenges of the food supply chain, such as food security, food leakage and food wastage.

4. Implications

More than 75% of the rural populations rely on the public distribution of food grain. To take care of dependency and making more efficient, the Indian government started implementing digitalization in PDS by exploring digital technology, digital infrastructure, and digital supply chain. Digital infrastructure provides a collaborative ecosystem of PDS to enhance convenience services across the urban and rural areas. A new and applicable roadmap is needed to address the operational and strategic decision of the food grain supply chain in response to the urgency imposed by the next wave of COVID-19 or a new pandemic.

The government of India started the "Digital India" campaign in 2015 to provide and enhance the digital infrastructure in rural areas to enable the digitalization in PDS, linking biometric information Unique Identification (UID) number with Aadhaar and PAN cards to identify the right targeted beneficiary. The linking information of migrant labours supports the execution of the One Nation One Ration Card. The proposed framework will help effective communication between the central and state governments. The primary benefits of digitalization of the PDS are the following: (i) Direct benefit transfer to beneficiaries, (ii) implementation of the One Nation One Ration Card (ONORC) scheme, (iii) End-to-end computerization of PDS and (iv) Aadhaar enabled e-KYC of beneficiaries at fair price shop. In the pandemic situation, the truck drone delivery system is an alternate option for the contactless delivery of food grain, but it is costly to deploy.

5. Conclusions

In this paper, we propose a three-layer conceptual framework: Food grain supply chain network, Digital process automation, and digital technology. The integration and collaboration of three-layer promote digitalization in the public distribution system. The digitalization of PDS will revamp and strengthen the PDS to make it more transparent, cost-effective, and responsive. This study focuses on ensuring food security during the COVID-19 pandemic by supporting the NSFA and SDGs programme and stopping the food grain leakage in PDS. The challenges of the COVID-19 pandemic accelerated the adoption of digitalization in the PDS to redesign the food grain supply chain with digital processes and technology. The proposed conceptual framework will help in enforcing the digitalization of the PDS. It will also help administrators and policymakers to deploy a similar public supply chain. The proposed work will assist in drafting the digitalization policy of PDS and support the "Digital India" initiative.

References

Agrawal, T.K., Angelis, J., Khilji, W.A., Kalaiarasan, R. and Wiktorsson, M., 2022. Demonstration of a blockchain-based framework using smart contracts for supply chain collaboration. International Journal of Production Research, pp.1-20.

Annosi, M.C., Brunetta, F., Bimbo, F. and Kostoula, M., 2021. Digitalization within food supply chains to prevent food waste. Drivers, barriers and collaboration practices. Industrial Marketing Management, 93, pp.208-220.

Burgos, D. and Ivanov, D., 2021. Food retail supply chain resilience and the COVID-19 pandemic: A digital twin-based impact analysis and improvement directions. Transportation Research Part E: Logistics and Transportation Review, 152, p.102412.

Casino, F., Kanakaris, V., Dasaklis, T.K., Moschuris, S., Stachtiaris, S., Pagoni, M. and Rachaniotis, N.P., 2021. Blockchain-based food supply chain traceability: a case study in the dairy sector. International Journal of Production Research, 59(19), pp.5758-5770.

Choudhury, P., Koo, W.W., Li, X., Kishore, N., Balsari, S. and Khanna, T., 2020. Food Security and Human Mobility During the COVID-19 Lockdown. Harvard Business School Technology & Operations Mgt. Unit Working Paper, (20-113), pp.20-113.

Gholami-Zanjani, S.M., Klibi, W., Jabalameli, M.S. and Pishvaae, M.S., 2021. The design of resilient food supply chain networks prone to epidemic disruptions. International Journal of Production Economics, 233, p.108001.

IMF, 2020. International Monetary Fund The great lockdown: Worst economic downturn since the Great Depression, Accessed 25 February 2021, Available at https://blogs.imf.org/2020/04/14/the-great-lockdown-worst-economicdownturn-since-the-great-depression.
Kayikci, Y., Subramanian, N., Dora, M. and Bhatia, M.S., 2022. Food supply chain in the era of Industry 4.0: Blockchain technology implementation opportunities and impediments from the perspective of people, process, performance, and technology. Production planning & control, 33(2-3), pp.301-321.

Kittipanya-Ngam, P. and Tan, K.H., 2020. A framework for food supply chain digitalization: lessons from Thailand. Production Planning & Control, 31(2-3), pp.158-172.

Kumar, R., Ganapathy, L., Gokhale, R. and Tiwari, M.K., 2020. Quantitative approaches for the integration of production and distribution planning in the supply chain: a systematic literature review. International Journal of Production Research, 58(11), pp.3527-3553.

Laborde, D., Martin, W. and Vos, R., 2021. Impacts of COVID-19 on global poverty, food security, and diets: Insights from global model scenario analysis. Agricultural Economics, 52(3), pp.375-390.

Li, K., Lee, J.Y. and Gharreghozli, A., 2021. Blockchain in food supply chains: a literature review and synthesis analysis of platforms, benefits and challenges. International Journal of Production Research, pp.1-20.

MCA, 2021. Ministry of Consumer Affairs, Food and Public Distribution, Government of India 2021-22, Accessed 24 December 2021, Available at https://www.indiabudget.gov.in/doc/eb/sbe14.pdf

Mogale, D.G., Ghadge, A., Kumar, S.K. and Tiwari, M.K., 2020. Modelling supply chain network for procurement of food grains in India. International Journal of Production Research, 58(21), pp.6493-6512.

NFSA, 2021. National food security portal, Department of food and public distribution Government of India Accessed 25 December 2021, Available at https://nfsa.gov.in/portal/PDS_page

Olan, F., Liu, S., Suklan, J., Jayawickrama, U. and Arakpogun, E.O., 2021. The role of Artificial Intelligence networks in sustainable supply chain finance for food and drink industry. International Journal of Production Research, pp.1-16.

Singh, S., Kumar, R., Panchal, R. and Tiwari, M.K., 2021. Impact of COVID-19 on logistics systems and disruptions in food supply chain. International Journal of Production Research, 59(7), pp.1993-2008.

Tao, F., Wang, Y.Y. and Zhu, S.H., 2022. Impact of blockchain technology on the optimal pricing and quality decisions of platform supply chains. International Journal of Production Research, pp.1-15.

United Nations, 2016. Department of Economic and Social Affairs, Statistics Division, Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture, Accessed 30 December 2021, Available at https://unstats.un.org/sdgs/report/2016/goal-02/

WEF, 2020. World Economic Forum, Key milestones in the spread of the coronavirus pandemic, Accessed on 25 December 2021, available at https://www.weforum.org/agenda/2020/04/coronavirus-spread-covid19-pandemic-timeline-milestones/

WFP, 2019. World Food Programme., Decentralized Evaluation End-line Evaluation of the Target Public Distribution Reforms Project in Bhubaneswar (Odisha), Accessed 28 December 2021, Available at https://reliefweb.int/sites/reliefweb.int/files/resources/WFP-0000110510.pdf.

WHO, 2020. World Health Organization Impact of COVID-19 on people's livelihoods, their health, and our food systems, Accessed 25 December 2021, Available at https://www.who.int/news/item/13-10-2020-impact-of-covid-19-on-people's-livelihoods-their-health-and-our-food-systems.