

Using blockchain technology to drive operational excellence in perishable food supply chains during outbreaks

Blockchain for
operational
excellence

Yasanur Kayikci

*Science Policy Research Unit, University of Sussex Business School,
Brighton, UK, and*

Damla Durak Usar and Batin Latif Aylak

Industrial Engineering, Turkish-German University, Istanbul, Turkey

Received 16 January 2021

Revised 12 July 2021

20 September 2021

24 November 2021

Accepted 30 November 2021

Abstract

Purpose – This paper aims to explore the potential of blockchain technology (BT) to support the operational excellence in perishable food supply chain (PFSC) during outbreaks, by doing use-case analysis.

Design/methodology/approach – A systematic literature review is performed to determine the dimensions of operational excellence in the food supply chain (FSC), then a single use-case analysis is conducted to explore the potential of blockchain in order to achieve operational excellence for PFSC during the pandemics by applying context, interventions, mechanism and outcomes (CIMO) logic.

Findings – The findings of this study reveal that blockchain capabilities such as immutability and transparency, visibility, traceability, integration and interoperability, disintermediation and decentralisation, smart contracts and consensus mechanism provide better sustainable operational excellence outcomes for PFSCs to be more responsive, flexible, efficient and collaborative to cope with the impacts of COVID-19.

Research limitations/implications – This research employs only one real case with multiple PFSC participants. Statistical generalisation is not possible at this stage of the research. However, the findings are not restricted to this single use-case.

Practical implications – This study provides a research direction to explore the potential of BT to achieve operational excellence in the PFSC during outbreaks and generates prescriptive knowledge for better managerial decision-making across the PFSC during outbreaks.

Originality/value – This research conducts semi-structured interviews with different participants in one blockchain ecosystem to understand multiple participants' perspectives of operational excellence within PFSC.

Keywords Operational excellence, Perishable food supply chain, Blockchain technology, COVID-19, Outbreaks, DSR, CIMO-logic

Paper type Research paper

1. Introduction

The emergence of the COVID-19 outbreak has drastically disrupted all industries and business sectors around the world. The first wave uniquely impacted food-related industries in particular, including the perishable food supply chain (PFSC) from farm to fork with lockdown restrictions and containment measures causing significant changes in the business discipline of many companies in the food industry (Hamilton *et al.*, 2020). From producers to customers, keeping the food product safe and free from contamination, fresh for the duration of its shelf life and at good quality remains a big challenge amid pandemics (Sehnem *et al.*, 2019; Chin, 2020).

Heck *et al.* (2020) describe the impact of the COVID-19 on food supply chains (FSCs) as a crisis of interrupted connections between supply and demand, where consumers have no physical access to food and producers are deprived of marketing outlets due to lockdowns



restrictions. The upstream supply chain (SC) was giving away or dumping their produce due to the perishable nature of the produce, while consumers were facing difficulties in accessing food to meet their daily dietary requirements (Chin, 2020). Furthermore, COVID-19 also caused high absenteeism in workplaces, as the absence of skilled workers has resulted in labour shortages (Gray, 2020). In several countries, many containers had to wait in quarantine at ports or terminals. This caused the cessation of logistic activities, extended cycle times and increased product expiry risks. The deterioration rate and demand uncertainty of perishable food products such as fruits and vegetables, dairy, fish, meat and frozen items trigger a lot of unsold products to be disposed of and product shortages at retailers (Yang *et al.*, 2017a). Supply chain (SC) mismatch increases the environmental pollution due to onward disposal of expired products (Griffin *et al.*, 2009).

As food companies strive for operational excellence in the pandemic, they must be prepared to respond quickly and easily to changing business conditions and to changing prospective customers' behaviour (Bumblauskas *et al.*, 2020). COVID-19 caused a sudden change in consumption patterns such as consumer panic buying and hoarding behaviour concerning key items (Serman and Dogan, 2015; Hobbs, 2020; Naeem, 2021a, b). The customers seek alternative supply sources during outbreaks because of product shortages (Gonçalves *et al.*, 2005). Home delivery has become more important since most customers prefer online shopping due to the perceived risk of infection with the virus (Seth, 2020). Many consumers have switched to buying frozen foods as an alternative to closed restaurants, which increased the pressure on PFSC (OECD, 2020).

The grocery stores' response to new consumer preferences has not been enough to prevent waiting times of several days to access very popular grocery pickup and delivery options (Gray, 2020). Access to reliable and timely information about upcoming risks and their impact on customer behaviour is very important for PFSC management (Göbel *et al.*, 2015). Amidst COVID-19 consumers are concerned about food hygiene (Abiral and Atalan-Helicke, 2020) and consider doing more to understand how and where the products originate (Bumblauskas *et al.*, 2020). However, they often can lack transparency about their second- and third-tier suppliers and beyond (Abeyratne and Monfared, 2016).

In recent years, an extensive body of research, which studies the ripple effect due to natural or man-made disasters, evaluates the resilience of the FSCs and SCs in general and presents decision aids on this subject, has emerged (e.g. Ivanov *et al.*, 2015; Dolgui *et al.*, 2018). However, the COVID-19 pandemic was unprecedented, and the disruption impact on the PFSC was huge. Moreover, the COVID-19 pandemic has a diverse range of impact on PFS such as *operational factors* among others production shutdown, price variation of perishable products, cash flow constraints, poor delivery reliability, increased transportation costs, *behavioural factors* among others panic buying and stockpiling, fear of violation of social distancing guidelines, less physical buying and government policy, regulations such as closure or limited operation of mandis, restriction on import-export and lockdowns, *technological and infrastructural factors* among others poor transportation network, low area coverage of E-commerce platforms for perishable goods, information distortion and poor packaging capabilities, which are all interrelated (Shanker *et al.*, 2021). Thus, the topic of how to cope and recover from the effects of the pandemic and to adapt to the "new normal" became most important for the PFSC. SC coordination, SC responsiveness, information and resource sharing and digitisation of the process are key to a resilient FSC amid the COVID-19 pandemic (Kumar and Singh, 2021). Mishra *et al.* (2021) emphasised proactive and reactive practices to cope with disruptions, which require implementing knowledge management tools. Implementation of emerging technologies such as Internet of Things (IoT), Artificial Intelligence/Machine Learning (AI/ML), wireless sensor networks, Big Data Analytics (BDA), cloud computing and blockchain can improve the efficiency, quality, traceability, safety and visibility of PFSC (Kayikci, 2018, 2020; Liu *et al.*, 2020; Köhler and Pizzol, 2020; Saurabh and Dey, 2021). There is growing interest in applying

blockchain technology (BT) to SC operations (Lim *et al.*, 2021; Chaudhuri *et al.*, 2021), and Kopyto *et al.* (2020) predict that this technology will be widely applied in future supply chain management (SCM) systems by 2035 since it provides beneficial orientation and stimulates perspectives for decision-makers throughout the SC.

BT is one of the emerging technologies in the era of Industry 4.0., which is defined as “a digital, decentralized and distributed ledger in which transactions are logged and added in chronological order with the goal of creating permanent and tamperproof records” (Treiblmaier, 2018, p. 547). BT is an innovative technology that can provide end-to-end visibility and track food products or batches at all stages across the PFSC, moving from harvesting to processing, storage, distribution to retailing (Subramanian *et al.*, 2020) and can contribute to improving operational excellence (Upadhyay, 2020). BT has the potential to enhance product safety and security; improve quality management; reduce illegal counterfeiting; improve sustainable SCM; advance inventory management and replenishment; reduce the need for intermediaries; impact new product design and development; and reduce the cost of SC transactions (Cole *et al.*, 2019). Thus, BT impacts the profit and/or return on investment of SCs and fosters better information management along with the FSC due to improved information accessibility, availability, and sharing (Stranieri *et al.*, 2021). However, as Cole *et al.* (2019) pointed out, the state of practice and research surrounding blockchain is immature and there is little evidence in the literature that blockchain has the potential to drive operational excellence in the PFSC during outbreaks (Stranieri *et al.*, 2021). Our motivation is to reveal the generative mechanisms underlying operational excellence during an outbreak, propose design solutions, and provide empirical evidence showcasing the potential BT as a solution support tool. Therefore, this study focuses on the following research questions:

- RQ1. What are the dimensions for operational excellence in PFSC during outbreaks? and
- RQ2. How is the potential of BT to drive operational excellence in the PFSC during outbreaks?

We employ Design System Research (DSR) to understand the problems caused by the COVID-19 outbreak from different SC participants’ perspectives and to evaluate the potential of blockchain solutions to the relevant field problem and therefore generate prescriptive knowledge for better managerial decision-making across the PFSC during outbreaks. We aim to analyse the blockchain potential for operational excellence in PFSC ecosystems during the COVID-19 outbreak and generate prescriptive knowledge for outbreaks in general. We are interested in solving a field problem, which is a specific and important issue and requires a pragmatic validity of designs, generalising the design, and examining the (social) mechanisms producing system performance. DSR aims to cultivate a deep understanding of the field problem and to produce improvement-oriented knowledge. DSR is conducted to contextualise and test the problem in context, the design, expected outcomes and the material and social mechanisms producing these outcomes in the intended application domain (Van Aken, 2007; Van Aken *et al.*, 2016).

DSR has descriptive/explanatory and design/testing components. In this study the initial descriptive/explanatory framework is derived from a review and analysis of the extant literature on operational excellence and blockchain capabilities. A single use-case based on a context, interventions, mechanism and outcomes (CIMO) logic configuration (Denyer *et al.*, 2008) is used to evaluate the blockchain capabilities to drive operational excellence across PFSC during outbreaks. Case study data are matched with the initial framework to see how relevant and useful blockchain-driven solutions produce desired outcomes in PFSC ecosystems. The design propositions are obtained by balancing empirical knowledge based on use-case analysis with theoretical knowledge from the literature of operational excellence in PFSC and BT.

Subsequently, a sensitivity analysis is performed to validate the design propositions and identify which SC partners contribute significantly to the operational excellence in PFSC during outbreaks. Figure 1 presents an overall view of the research design.

The novelty of this research is that different participants in one blockchain ecosystem are interviewed to understand multiple participant perspectives of operational excellence within PFSC. There is no research conducted to the best of our knowledge, which links operational excellence in PFSC with blockchain capabilities. The significant contribution of this study is to provide a deep understanding of operational challenges, risks and inefficiencies in PFSC caused by COVID-19 and present a great insight to companies into developing and implementing their blockchain-driven solutions to achieve operational excellence through blockchain capabilities, particularly during outbreaks.

The rest of the paper is organised as follows: Section 2 presents the systematic literature review related to operational excellence in the PFSC during outbreaks and blockchain capabilities on operational performance in the PFSC. Section 3 gives a brief theoretical background to CIMO-logic and single case study method and explains the use-case selection, data collection and analysis procedure in detail. Section 4 analyses the use-case and develops the framework of operational excellence in PFSCs using CIMO-logic. Section 5 derives the design propositions and performs the sensitivity analysis. Section 6 discusses the theoretical and practical implications of the findings. Section 7 concludes with future research directions.

2. Literature review

The spread of the COVID-19 outbreak has severely impacted the operational capabilities of many companies in the PFSC. In order to capture the relevant articles, the systematic literature review approach suggested by Yadav and Desai (2016) is adopted in this section. The structured keyword search was conducted on the ISI Web of Science (WoS) database. We are confident that we have reached a holistic coverage on operational excellence indicators of PFSC in the context of outbreaks in general and COVID-19 in particular, since WoS database is known to have comprehensive coverage of high impact journals published in Springer, IEEE, Elsevier, Taylor & Francis, etc. The following search strings were searched to be in title, abstract and keywords:

String 1. {"food supply chain" OR "food" OR "agriculture" OR "agri-food" AND "supply chain" AND "outbreak" OR "COVID-19" OR "coronavirus" OR "pandemic" OR "epidemic" OR "disaster" AND "operational excellence" OR "operational performance"}

String 2. {"blockchain" AND "food supply chain" OR "food" AND "supply chain" AND "operational excellence" OR "operational performance"}

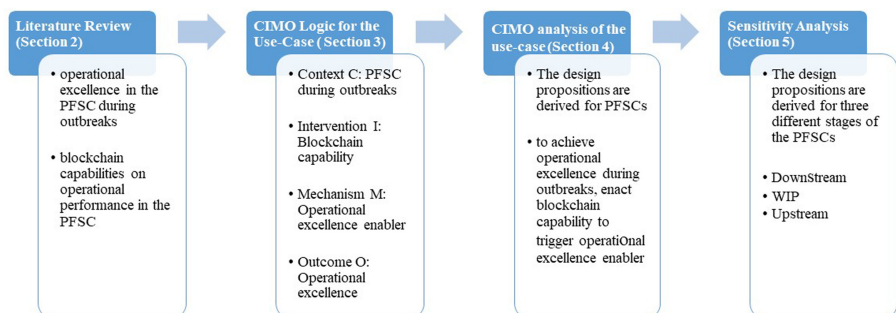


Figure 1.
Research design

Source(s): Based on Denyer *et al.* (2008)

The first search string is aimed to extract the operational excellence enablers in PFSCs during an outbreak. The second search string is used to collect the blockchain capabilities which drive operational excellence in PFSCs. We restricted our search to the years of 2015–2021. String 1 returned 10,853, and string 2 returned 9,497 articles. We refined our search by including articles strictly from operational research management science, industrial engineering, multidisciplinary engineering, business and management fields and restricted the number of articles to 2,348 and 1,449. After removing duplicates and filtering for peer-reviewed impact factor publications, 1965 and 736 articles remained for evaluation. We further eliminated articles by reviewing the titles of these articles to assess if they fit our research questions and restricted the number of articles to 343 and 97. We then reviewed the abstracts of these articles to assess if they fit our research questions and restricted the number of articles to 122 and 73. At this point, we cross-checked the number of articles that returned in both searches and determined that 27 articles appeared in both samples. Thereby, the final number of articles we have reviewed reached 168. [Figure 2](#) represents the review process adopted for this study.

We categorised our findings from the literature review in terms of sustainable operational excellence outcomes, operational excellence enablers and blockchain capabilities, which will be explained in the below subsections.

2.1 Sustainable operational excellence for PFSCs

2.1.1 Economic outcomes. Due to the outbreak, food producers are struggling to meet their normal operating costs, such as paying staff wages, paying the rent of factories and warehouses, covering utility bills, interest charges on bank loans and other operating expenses due to reduced cash inflow. Thus, PFSC is threatened by layoffs and reduction in trade with SC partners resulting in closure or limited operations of distributors and trading partners ([Chowdhury et al., 2020](#); [Heck et al., 2020](#)). In these dire conditions, the PFSC has to achieve economic operational excellence. We have uncovered three research clusters: production planning and inventory management, quality and customer orientation, profitability and pricing.

Companies within PFSC aim to position their brands to maintain stakeholder confidence in their ability to produce safe and wholesome food and establish brand equity ([Manning, 2007](#)). It is vital to optimising the quality and freshness of the food delivered ([Musavi and Bozorgi-Amiri, 2017](#); [George et al., 2019](#); [Bumblauska et al., 2020](#); [Behnke and Janssen, 2020](#)). In the COVID-19 era, food safety and hygiene have gained importance. Thus, the ability to supply transparency for hygiene factors ([Bastian and Zentes, 2013](#)) has become key operational excellence. [Zhang and Su \(2020\)](#) studied coordination mechanisms to improve quality visibility throughout PFSC and evaluated the impact of different contracts on quality visibility and associated costs.

The strategic aim of PFSCs is to increase revenue and profitability ([Heard et al., 2018](#)). [Balaji and Arshinder \(2016\)](#) provide practical insights for improved profitability. A strategic pricing strategy facilitates the maximisation of channel profit ([Chen et al., 2019](#); [Yang et al., 2017b](#)). [Feng et al. \(2020\)](#) explored alternative pricing strategies under supply disruptions and concluded that pure price adjustments are more advisable since they do not increase customer's order variability and reduce firm profits. [Wang and Zhao \(2021\)](#) showed that all SC participants benefit from collective cold chain investments and pricing strategies. [Hanukov et al. \(2021\)](#) determined pricing strategies based on customer preferences in a game-theoretic framework, where they simultaneously considered revenue from selling food, sojourn and balking costs, capacity costs and costs associated with food deterioration.

[Hendalianpour \(2020\)](#) suggested that consumer preferences are influenced by price and freshness of products and developed a game-theoretic model for pricing and lot-sizing decisions. [Gholami-Zanjani et al. \(2021\)](#) proposed a model for location-allocation and

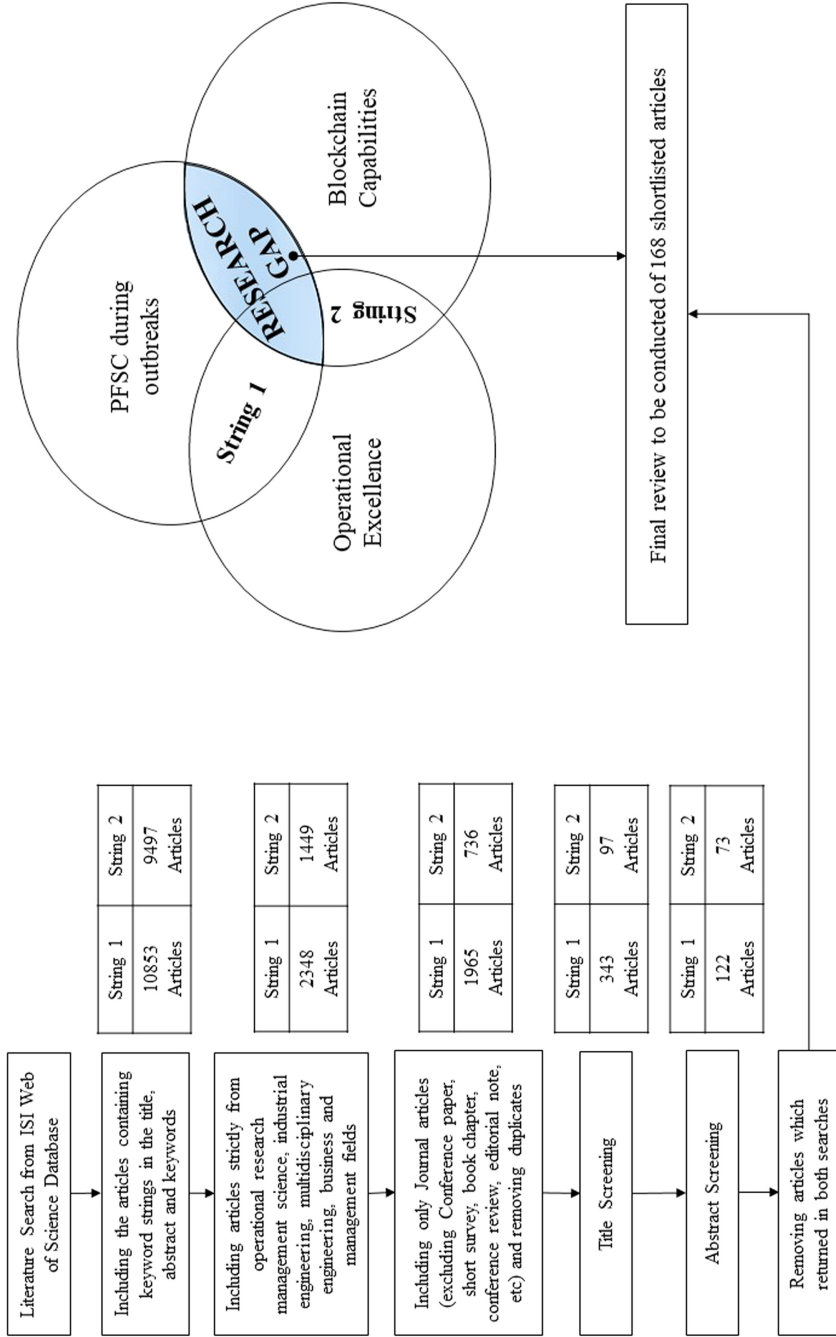


Figure 2.
Flowchart for article selection

inventory-replenishment decisions of PFSCs under ripple effects and identified readiness, flexibility and responsiveness as SC risk mitigation strategies.

2.1.2 Social outcomes. The socio-economic impact of COVID-19 is difficult for most vulnerable populations, as their purchasing power and access to markets have been disrupted due to the pandemic (Heck *et al.*, 2020). Price fluctuations caused by supply-demand shocks can lead to malnutrition and food poverty, in the long-term, health impacts on children and the vulnerable (Abiral and Atalan-Helicke, 2020; Hamilton *et al.*, 2020). Food security, defined as the constant availability of food (Chin, 2020; Deaton and Deaton, 2020; Heck *et al.*, 2020), becomes an important worldwide concern facing developed and developing countries.

The social aspects of PFSCs can be categorised predominantly into human capital management, corporate social responsibility, collaboration, fair-trade and ethical practice. Khan *et al.* (2021) focused on employment in the PFSC and identified work-life balance and a safe and healthy working environment as key indicators. According to Toussaint *et al.* (2020), good social practices along the PFSC can be achieved through communication, transparency and commitment of all SC participants.

Since improving one stakeholder positively affects the entire system, collaboration behaviour improves quality performance and increases the mutual benefits of the SC participants (Dania *et al.*, 2020). Moon *et al.* (2020) explored alternative contracts between partners in PFSC by considering the impact of fairness and found that the revenue sharing strategy combined with investment cost-sharing provided the highest benefits for PFSC. Moreover, Daghar *et al.* (2021) pointed out that collaborative interorganisational relationships facilitate SC risk mitigation. Hernandez-Martinez *et al.* (2021) analysed socially responsible practices between suppliers and buyers in smallholder PFSC and identified the settings under which total SC profit increased by reducing the double marginalisation effect and resulting in equitable outcomes for all participants. The optimal markdown model was developed for perishable food pricing to optimise the food retailer revenue, and aspects were evaluated in terms of price fairness perception (Wang *et al.*, 2016).

Consumers place great importance on ethical practices in eggs, meat and dairy products. Consumers preferred a reliable welfare-certified product, although it was costly (Spain *et al.*, 2018). Eberhardt *et al.* (2021) evaluated whether consumers' subjective knowledge about fair-trade food products and the reliability of perceived information influence purchase intention, and reported that perceived fairness positively influences purchase intention.

2.1.3 Environmental outcomes. COVID-19 has caused air, soil, water and environmental pollution due to an increase in medical waste, random disposal of personal protective equipment, increase in municipal waste and decrease in recycling activities (Rume and Islam, 2020). The literature of the environmental impact of PFSCs consists mainly of reducing energy consumption and CO₂-emissions, mitigating food loss and waste (FLW) and reducing pollution due to packaging. Different studies have been carried out considering the reduction of CO₂-emissions throughout the SC (Bortolini *et al.*, 2015; Bozorgi *et al.*, 2014; Camanzi *et al.*, 2017; Gallo and Accorsi, 2017; Govindan *et al.*, 2014; Haass *et al.*, 2015; Musavi and Bozorgi-Amiri, 2017; Rahimi *et al.*, 2017; Wang *et al.*, 2017). The cold SC has received special attention from researchers due to its high CO₂-emissions generated during temperature-controlled storage and transportation activities (Adekomaya *et al.*, 2016). Saif and Elhedhli (2016) modelled the cold SC design problem by considering capacity, transportation, inventory costs and global warming impact. As'ad *et al.* (2020) determined the optimal lot size by comparing the operational cost and carbon footprint performance under alternative carbon cap policies. Liljestrand *et al.* (2015) proposed a decision support tool with the aim of carbon footprint reduction, which incorporates the logistics network's complexity by analysing the patterns in the shipment statistics. Cannas *et al.* (2020) proposed a roadmap to support the shift to intermodal rail-road transportation in the dairy SC to reduce CO₂-emissions, while

Melkonyan *et al.* (2020) explored alternative distribution network configurations to reduce the CO₂-emissions caused by last-mile logistics of food products.

Rohm *et al.* (2017) emphasised the importance of understanding consumer behaviour to encourage food waste reduction. Makhmal *et al.* (2021) suggested that the normalisation of suboptimal produce could address the food waste problem. Kandemir *et al.* (2020) proposed a simulation model to reduce food waste by considering different household dynamics like purchasing, storage, consumption. Borrello *et al.* (2017) evaluated the consumer's willingness to participate in strategies to reduce food waste. Dossa *et al.* (2020) found that verticalised operations and partnerships between buyers and suppliers facilitate circular economy practices. Lombardi and Costantino (2020) emphasised the importance of building a sense of community for better food redistribution. Mallidis *et al.* (2020) proposed a quantitative decision-making tool that optimises a retailer's replenishment policy to minimise discarded perishables. Ciulli *et al.* (2020) revealed the importance of digital platform organisations, bridging waste generators and potential receivers in the FSC. Sundgren (2020) analysed the potential of different SC structures to distribute surplus food.

Sumrin *et al.* (2021) pointed out the increasing packaging and related waste all along the supply process and called for eco-design innovation in packaging. Hrabec *et al.* (2020) proposed a model to optimise municipal solid waste management applying modern circular economy principles, intending to increase the amount of food waste recycled and used for energy recovery and decrease the amount of waste sent to landfills.

2.2 Operational excellence enablers for PFSCs

2.2.1 Responsiveness. In the COVID-19 era, food accessibility and availability (Abiral and Atalan-Helicke, 2020; Chin, 2020; Deaton and Deaton, 2020) became primary concerns. Around the globe, consumers face problems in finding basic necessities in the stores, reserving delivery time slots, items missing from online orders and late refunds (Abiral and Atalan-Helicke, 2020). Thus, the responsiveness of the FSC has become even more crucial. Responsiveness is defined as SC's ability to recover from the disruptions and react swiftly to changing conditions through capacity expansion, backup supplier, or product import (Gholami-Zanjani *et al.*, 2021). Responsiveness is measured as customer response time, fill rate, shipping errors, product lateness, customer complaints (Stranieri *et al.*, 2021). Due to the perishable nature of the produce, the time spent from farm to fork is through reduction of down time/dwell time (Bumblauska *et al.*, 2020) and minimisation of total customers waiting time (Esmaili and Sahraeian, 2017) particularly important. Zanoni and Zavanella (2012) documented that the impact of the storage time is costly for FSCs. Thus, the SC has to become more responsive while remaining cost-efficient. Construction of lean SCs with few tiers, few transactional intermediaries minimise the idle time during transportation, distribution, storage and delivery (Bastian and Zentes, 2013). Moreover, eliminating intermediaries and auditors enables lower costs and increased efficiency (Bumblauska *et al.*, 2020).

2.2.2 Efficiency. The literature is rich regarding the improvement of cost efficiency in PFSC. The main body of research is focused on minimisation of the total cost (Saif and Elhedhli, 2016; Accorsi *et al.*, 2017), operating cost (Bortolini *et al.*, 2015), logistics costs (Govindan *et al.*, 2014), total travel cost (Esmaili and Sahraeian, 2017), transportation cost (Musavi and Bozorgi-Amiri, 2017; Wang *et al.*, 2017). A nascent stream is concerned with the triple bottom line (Bozorgi *et al.*, 2014) analysed the trade-offs involved in making inventory decisions based on minimising emissions versus minimising cost. Rahimi *et al.* (2017) aim to optimise total inventory and transportation costs taking distribution service levels and environmental footprint into consideration.

2.2.3 Flexibility. FSCs have to focus on capacity building and flexibility to prevent supply disruptions (Siddh *et al.*, 2018). Ramos *et al.* (2021) propose a conceptual model based on the dynamic capability view (DCV) theory to analyse SC capabilities during the COVID-19

pandemic and utilising partial least square regression and a fuzzy-set qualitative comparative analysis conclude, that organisational flexibility is a driver of higher agility in agri-FSCs, which positively affects SCM performance. Personnel scheduling is the biggest organisational challenge during the COVID-19 pandemic. The companies need to determine schedules that divide the employees into mutually exclusive groups to reduce the risk of contagion (Zucchi *et al.*, 2020). COVID-19 absenteeism, particularly in highly specialised job roles, further complicates the matter (Gray, 2020). Due to lockdowns and travel restrictions, supply-demand mismatch and the risk of product expiry have increased. In order to preserve the shelf life of products (Gallo and Accorsi, 2017), shelf space allocation has to be investigated (Yang *et al.*, 2017b), and products have to be either rotated within the store or else rotated between stores, from low-traffic stores to stores with higher sales volumes (Chowdhury *et al.*, 2020).

2.2.4 Collaboration. Jiang and Zhao (2014) advocated that collaboration drives the commercial value accumulation of information technologies in downstream processes. If companies within the SC try to maximise their profits, they settle for suboptimal outcomes. Thus, the aim of the FSC should be to increase the profits of the whole SC, which requires collaboration and cooperation (Bumblauska, 2020). Ramos *et al.* (2021) pointed out that external and internal SC integration directly impacts the responsiveness of agri-FSCs during the COVID-19 pandemic, while Kumar *et al.* (2021) identified collaborative management as one of the top risk mitigation strategies for PFSC during the current pandemic.

Collaboration based on blockchain is helpful to lessen information asymmetry between upstream and downstream enterprises and effectively reduces the bullwhip effect by improving synergies throughout the FSC (Xue *et al.*, 2021). Moreover, SC collaboration among food producers, processors and distributors is of most importance for the food safety of the end consumers (Lu *et al.*, 2021).

Alongside vertical integration, horizontal collaboration becomes important for operational excellence (Borrero, 2019; Juma *et al.*, 2019; Bumblauska *et al.*, 2020). Moreover, collaboration and cooperation should be in the public-private partnerships. Farmers and small producers benefit from collective action and public-private partnerships to face competition from large producers (Narrod *et al.*, 2009; Rais *et al.*, 2019).

2.2.5 Information. Ding *et al.* (2014) present empirical evidence that information quality, strategic alliance, trust and commitment positively affect food quality and highlight information quality as a key determinant. Chaudhuri *et al.* (2018) point out that continuous monitoring of conditions can support real-time decisions on food quality and lifecycle management and provide historical information to understand patterns for redesigning the FSC. Yu *et al.* (2018) emphasised the importance of both internal and external information integration so that FSC can be reactive and proactive to risks. Thus, SC data's accuracy, accessibility, and actuality and efficient exchange of current data within the company and between SC partners (Bastian and Zentes, 2013) gained importance. Companies jeopardise the transparency and traceability of the PFSC by hiding information from their stakeholders, which they perceive as directly affecting their competitive advantage, sustainability and efficiency (Mangla *et al.*, 2021a). Although information sharing improves the FSC performance, it introduces new issues regarding data security (Fernando *et al.*, 2018; Fitzgerald *et al.*, 2018; Richey *et al.*, 2016).

2.2.6 Technology. New technologies such as IoT, cyber-physical systems and smart, connected products, facilitated the development of digital SCs and smart operations (Fazili *et al.*, 2017; Liao *et al.*, 2017; Minner *et al.*, 2017; Strozzi *et al.*, 2017; Tran-Dang *et al.*, 2017). Radio Frequency Identification (RFID) technology can be used to track and trace perishable food, while IoT sensors can be used to measure temperature and humidity during storage and transportation (Alfian *et al.*, 2020). Smart packaging technologies such as sensors, indicators and data carriers monitoring the quality and the freshness of perishable foods. These

technologies provide a dynamic output about the quality and safety of the produce, extend products' shelf life and reduce food waste (Beshai *et al.*, 2020).

IoT-based delivery planning systems can formulate delivery routing, detect unexpected incidents and re-route accordingly (Tsang *et al.*, 2021). A layered architecture model was proposed for the internet of Perishable Logistics (Pal and Kant, 2019). Kappelman and Sinha (2021) proposed to use big data mining techniques to determine optimal supplier selection, which reduces the rate of rejected products and maximises the SCs expected profit.

SC digital twin enables the simulation of various scenarios to assess the critical risks caused by force majeure and operational risks inherent to PFSC (Kumar *et al.*, 2019), their impacts and the duration and recovery policies (Barykin *et al.*, 2020). Deep learning can be employed for operational tasks such as plant disease detection, fruit counting, yield estimation (Fountsop *et al.*, 2020). Osmanoglu *et al.* (2020) proposed a blockchain-based solution for yield estimation, which identifies inefficiencies and enables planning precautions in advance. BT records, stores, validates and secures real-time activity data of PFSCs and connects the PFSC to financial institutions, increasing the likelihood of getting a loan (Rijanto, 2021). In Table 1 we summarise the excellence enabler constructs, variables and main references.

2.3 Blockchain capabilities for operational excellence in PFSCs

Blockchain is regarded as the next giant in the technology world, and it is studied in many applications in business processes and sectors. It includes secure handling and storing of records. Blockchain is an essentially distributed database of records of public ledgers of all transactions that is duplicated and distributed across the entire network. BT assures system robustness by providing transparency in information flow and stability to data, decreases overall costs in the SC like documentation fee, stationery expenditure, manpower, electricity, facility and time, improves overall performance in terms of efficiency, effectiveness and speed by standardisation and reduction in complexity of the job, facilitates improved data safety and decentralisation, improves traceability, visibility and identification of issues, facilitates compliance with laws and policies, enable streamlined invoicing and improve inventory management, increases customer satisfaction, facilitates better documentation and data management and improves quality by elimination of human error and availability of full information (Yadav and Sing, 2020; Chaudhuri *et al.*, 2021).

The benefits of blockchain were highlighted in SCM with the help of a literature review, along with the opinions of experts from the agricultural sector (Mukherjee *et al.*, 2021). Furthermore, the key factors were identified and analysed for Information Communication Technology (ICT) applications for the sustainable growth of Small and Medium Enterprises (SMEs) in the Indian food sector. Grey based Decision-Making Trial and Evaluation Laboratory technique was applied for analysis of factors (Singh *et al.*, 2019). The impact of BT in agriculture and FSC was examined and presented on existing ongoing projects and initiatives and discussed overall implications, challenges and potential, with a critical view over the maturity of these projects (Kamilaris *et al.*, 2019).

Empirical evidence demonstrates that blockchain can contribute to the business process to reduce cost and enhance operational efficiency (Holotiuk *et al.*, 2019; Oh and Shong, 2017). Similarly, other research papers (Ahmed and Broek, 2017; Sander *et al.*, 2018; Bumblauskas *et al.*, 2020) showed that the adoption of BT enables traceability and transparency. BT is a value of technology in SC management to extend traceability, transparency, SC digitalisation and disintermediation, improved data security and smart contracts (Wang *et al.*, 2019a, b, c). Shoaib *et al.* (2020) prioritise accessibility, overall efficiency, trackability and traceability as the most important success factors of a blockchain-based SC.

2.3.1 *Traceability/visibility.* FSCs can increase food safety and mitigate fraud through traceability (Juma *et al.*, 2019; Katsikouli *et al.*, 2020; Bumblauska *et al.*, 2020; Behnke and Janssen, 2020; George *et al.*, 2019), provenance/authenticity (Bumblauska *et al.*, 2020),

Construct	Variables	Main references
Responsiveness	Product availability	Abiral and Atalan-Helicke (2020), Chin (2020), Deaton and Deaton (2020)
	Customer response time	Gholami-Zanjani <i>et al.</i> (2021), Stranieri <i>et al.</i> (2021), Esmaili and Sahraeian (2017), Bumblauska <i>et al.</i> (2020)
	Food and loss waste	Tian (2016), Astill <i>et al.</i> (2019), Astarita <i>et al.</i> (2020)
	Food recall	Bumblauska <i>et al.</i> (2020), Qian and Papadonikolaki (2021), Duan <i>et al.</i> (2020)
Efficiency	Cost efficiency	Zanoni and Zavanella (2012), Govindan <i>et al.</i> (2014), Bozorgi <i>et al.</i> (2014), Bortolini <i>et al.</i> (2015), Saif and Elhedhli (2016), Camanzi <i>et al.</i> (2017), Accorsi <i>et al.</i> (2017), Rahimi <i>et al.</i> (2017), Esmaili and Sahraeian (2017), Wang <i>et al.</i> (2017), Musavi and Bozorgi-Amiri (2017), Patidar and Agrawal (2020)
	Elimination of intermediaries and auditors	Zhu (2017), Bumblauska <i>et al.</i> (2020)
	Energy consumption and GHG emission	Zanoni and Zavanella (2012), Haass <i>et al.</i> (2015), Bozorgi <i>et al.</i> (2014), Govindan <i>et al.</i> (2014), Bortolini <i>et al.</i> (2015), Saif and Elhedhli (2016), Liljestrand <i>et al.</i> (2015), Adekomaya <i>et al.</i> (2016), Accorsi <i>et al.</i> (2017), Camanzi <i>et al.</i> (2017), Rahimi <i>et al.</i> (2017), Ghadge <i>et al.</i> (2017), Wang <i>et al.</i> (2017), Gallo and Accorsi (2017), Musavi and Bozorgi-Amiri (2017), Cannas <i>et al.</i> (2020), Jouzdani and Govindan (2021), Melkonyan <i>et al.</i> (2020)
	Resource recovery and efficiency	Hrabec <i>et al.</i> (2020), Kandemir <i>et al.</i> (2020), Krishnan <i>et al.</i> (2020), Mallidis <i>et al.</i> (2020)
Flexibility	Life cycle management	Gallo and Accorsi (2017), Yang <i>et al.</i> (2017a), Chowdhury <i>et al.</i> (2020), Hendarianpour (2020)
	Shelf space management	Gallo and Accorsi (2017), Gholami-Zanjani <i>et al.</i> (2021)
	Personel scheduling	Siddh <i>et al.</i> (2018), Chowdhury <i>et al.</i> (2020), Heck <i>et al.</i> (2020), Gray (2020), Moon <i>et al.</i> (2020), Zucchi <i>et al.</i> (2020)
Collaboration	Coordination	Zhang and Su (2020)
	Collaboration (Vertical/Horizontal)	Borrero (2019), Juma <i>et al.</i> (2019), Bumblauska <i>et al.</i> (2020), Dania <i>et al.</i> (2020), Daghar <i>et al.</i> (2021), Dossa <i>et al.</i> (2020), Kumar <i>et al.</i> (2021), Lu <i>et al.</i> (2021), Ramos <i>et al.</i> (2021), Wang and Zhao (2021)
	Public private Partnership Fairness/Fair trade	Narrod <i>et al.</i> (2009), Pant <i>et al.</i> (2015), Rais <i>et al.</i> (2019), Wang <i>et al.</i> (2016), Tao <i>et al.</i> (2019), Katsikouli <i>et al.</i> (2020), Bumblauska <i>et al.</i> (2020), Hernandez-Martinez <i>et al.</i> (2021)
Technology	Food safety and fraud threat	Wang and Yue (2017), Juma <i>et al.</i> (2019), Katsikouli <i>et al.</i> (2020), Bumblauska <i>et al.</i> (2020), Behnke and Janssen (2020), George <i>et al.</i> (2019)
	Food quality	Musavi and Bozorgi-Amiri (2017), George <i>et al.</i> (2019), Bumblauska <i>et al.</i> (2020), Behnke and Janssen (2020)
Information	Plant safety and hygiene	Bastian and Zentes (2013), Bumblauska <i>et al.</i> (2020)
	Accuracy, accessibility and actuality of SC data	Bastian and Zentes (2013), Xiao and Yang (2017), Galvez <i>et al.</i> (2018), Borrero (2019), Katsikouli <i>et al.</i> (2020), Bumblauska <i>et al.</i> (2020), Behnke and Janssen (2020), Mangla <i>et al.</i> (2021a, b)
	Data security	Richey <i>et al.</i> (2016), Fernando <i>et al.</i> (2018), Fitzgerald <i>et al.</i> (2018)
	Digital continuity	Fazili <i>et al.</i> (2017), Liao <i>et al.</i> (2017), Minner <i>et al.</i> (2017), Qu <i>et al.</i> (2017), Strozzi <i>et al.</i> , 2017, Tran-Dang <i>et al.</i> (2017), Yang <i>et al.</i> (2017a, b)

Table 1.
Operational excellence
enablers

implementation of food safety pre-warning systems (Wang and Yue, 2017). Food quality management can be improved after blockchain adoption (Chen *et al.*, 2021).

Blockchain plays an important role in preventing expired and mishandled food from reaching customers in the medium and long-term. The potential impact of BT is reduced food waste (Yiannas *et al.*, 2018). The ability to share information among SC partners ensures timely product picking, processing and distribution. As a result, pipeline inventory, spoilage and energy consumption are reduced (Yakavenka *et al.*, 2018). Food spoilage problems can be reduced by planning the best delivery routine and shortening delivery time for perishable food (Kayikci *et al.*, 2020).

This year, consumers in North America stocked food at home during the COVID-19 pandemic. The demand has risen almost 30% from a year ago. The increase in demand also creates delays in the SC that lead to food contamination. This technology would help the food industry spot contamination and fraud by tracking material from production to consumer. Currently, many companies have created blockchain solutions for global food and agricultural SCs (George *et al.*, 2019).

Another important issue in the PFSC is a food recall, which causes costs due to additional operational activities and damages brands' equity. Recalls are due to operational mistakes, including contamination, mislabelling, undeclared ingredients, biological causes. Traceability systems are designed to assure safe and good quality food while reducing the costs of food recalls (Bumblauska *et al.*, 2020; Qian and Papadonikolaki, 2021) and improving recall efficiency (Duan *et al.*, 2020). Blockchain applications enable transparency in labelling, presentation and advertising of foodstuffs, GMO labelling (Bastian and Zentes, 2013), minimising consumers' concerns about the authenticity of their intended purchase (Hughes *et al.*, 2019), and they enhance and sustain consumer-based brand equity (Boukis, 2019).

2.3.2 Immutability and transparency. Food security can benefit from BT transparency, relatively low transaction costs, and instant implementation (Ahmed and Broek, 2017). The immutability of the data means that blockchain can protect the data from any tampering and prevent data corruption. For instance, an SC partner can add a record but cannot edit or change it. The consumer can query a product's digital record and verify credence claims. Thus, blockchain implementations enhance consumer trust and contribute to the integrity of the FSC (Keogh *et al.*, 2020). Furthermore, BT enables efficient use of resources, reducing inefficient processes in the SC (Katsikouli *et al.*, 2020) and FLW (Astill *et al.*, 2019).

2.3.3 Integration/interoperability. In the blockchain context, interoperability means connecting multiple blockchains to access information and act on it by changing the state of the own or another blockchain. Blockchain interoperability is critical for scaling within the SC ecosystem and for mass adoption (Kayikci *et al.*, 2020). However, interoperability is not easily assured since the FSC cannot be fully digital due to physical goods (Rogerson and Parry, 2020). Furthermore, as blockchain networks exist in different formats using different terminologies, coding languages, consensus algorithms and privacy measures, there are no standard and regulation in blockchain applications (U4SSC, 2020).

Developing general standards for data collection and sharing increases the interoperability among FSC actors and improves data accessibility and accuracy (Kamble *et al.*, 2020). However, this is not an easy task since the FSC operates in a complex worldwide environment. The development of blockchain-related regulations and laws is challenged by overlapping and conflicting regulations and various laws at the national level (Galvez *et al.*, 2018).

2.3.4 Smart contracts. Continuous real-time data tracking is facilitated through smart contracts across the SC, which accelerates time-consuming activities of operations management and payments (Varriale *et al.*, 2021). Moreover, smart contracts can lead to short task completion time, more simplicity and enhanced jobs (Wang *et al.*, 2020). The automation provided by the deployment of the smart contracts (Casino *et al.*, 2019, 2021) model removed hidden costs and paper load from the FSC traceability process. BT and smart

contracts provide several advantages for fair-trade throughout the SC (Kang and Indra-Payoong, 2019). A blockchain-based credit evaluation system, which gathers credit evaluation text from traders by smart contracts on the blockchain, was provided to strengthen the effectiveness of supervision and management in the FSC (Mao *et al.*, 2018).

2.3.5 Consensus mechanism. All parties in the SC agree to network verified transactions (Wang *et al.*, 2020). Integrating with IoT, the use of BT with appropriate consensus mechanisms in various SC echelons would enable big data management, improved connectivity, intellectual property rights and efficient SC contacting (Dutta *et al.*, 2020). Ontologies were used for blockchain design to determine food supply provenance (Kim *et al.*, 2018). BT is proposed as a way to organise records in a distributed manner by means of consensus mechanism (Gao *et al.*, 2018; Benčić *et al.*, 2019).

2.3.6 Asset management. Blockchain technologies provide a new data storage and verification architecture. The firm's assets, business contracts and transactions can be protected in this way (Rijanto, 2021). BT provides proficient asset management (O'Leary *et al.*, 2017). It was proposed that BT empowers cybersecurity and enables better performance in asset management than centralised IoT systems (Kshetri *et al.*, 2017). BT also provides asset management by means of its proof-of-concept algorithm, which assures transparency, reliability and efficiency (Cholewa *et al.*, 2017). Model-driven engineering (MDE) helps reduce risks by combining proven code snippets as per the model specification, which is easier to understand than source code. Therefore, an approach was presented for integrated MDE across business processes and asset management (Lu *et al.*, 2021).

2.3.7 Disintermediation/decentralisation. The appeal and primary feature of blockchain is its decentralisation and disintermediation. Decentralisation refers to removing control and decision-making power from a central authority (individual, organisation, or group) and transferring it to a distributed network (Kayikci, 2020). Therefore, blockchain requires a decentralised architecture and system. Disintermediation is a functional feature of blockchain and its affiliated technology, smart contract, operates on a peer-to-peer network to remove intermediaries (Subramanian *et al.*, 2020). Besides, it also reduces transaction costs and secures transaction, auditability and data provenance (Tönnessen *et al.*, 2020). Saurabh and Dey (2021) find that disintermediation is one of the most important capabilities influencing the BT adoption-intention decision in the grape wine SC.

2.3.8 Data standardisation/security/sharing. Every transaction powered by digital technologies is recorded in the blockchain with proper data standards (e.g. QS1) (Kamilaris *et al.*, 2019), where the different algorithms in blockchain provide data security (Kayikci *et al.*, 2020; Duan *et al.*, 2020). Blockchain can lead to more data sharing through the usage of other technologies (e.g. sensors) (Behnke and Janssen, 2020). The more data is shared, the higher is the value of the blockchain (Kayikci *et al.*, 2020). In particular, blockchain-based systems that integrate FSCs gather information on various food products and generate and ensure food safety standards for governments (Ali *et al.*, 2017). Furthermore, blockchain helps empower audit and management traders and prevent the sale of illegal products (Tse *et al.*, 2017; Heinrich *et al.*, 2019).

Figure 3 illustrates the stakeholders involved in the PFSC, which includes farmers, distributors, packers, producers, processors, manufacturers, wholesalers, retailers and consumers, the relations of operational excellence enablers, and blockchain capabilities to sustainable operational excellence outcomes of PFSC during pandemics.

3. Methodology

Case studies are often used for inductive exploration of yet unknown phenomena, i.e. theory generation. Empirical research, traditionally used for theory building, theory testing and explanation, has received recent additional focus from researchers interested in discovery

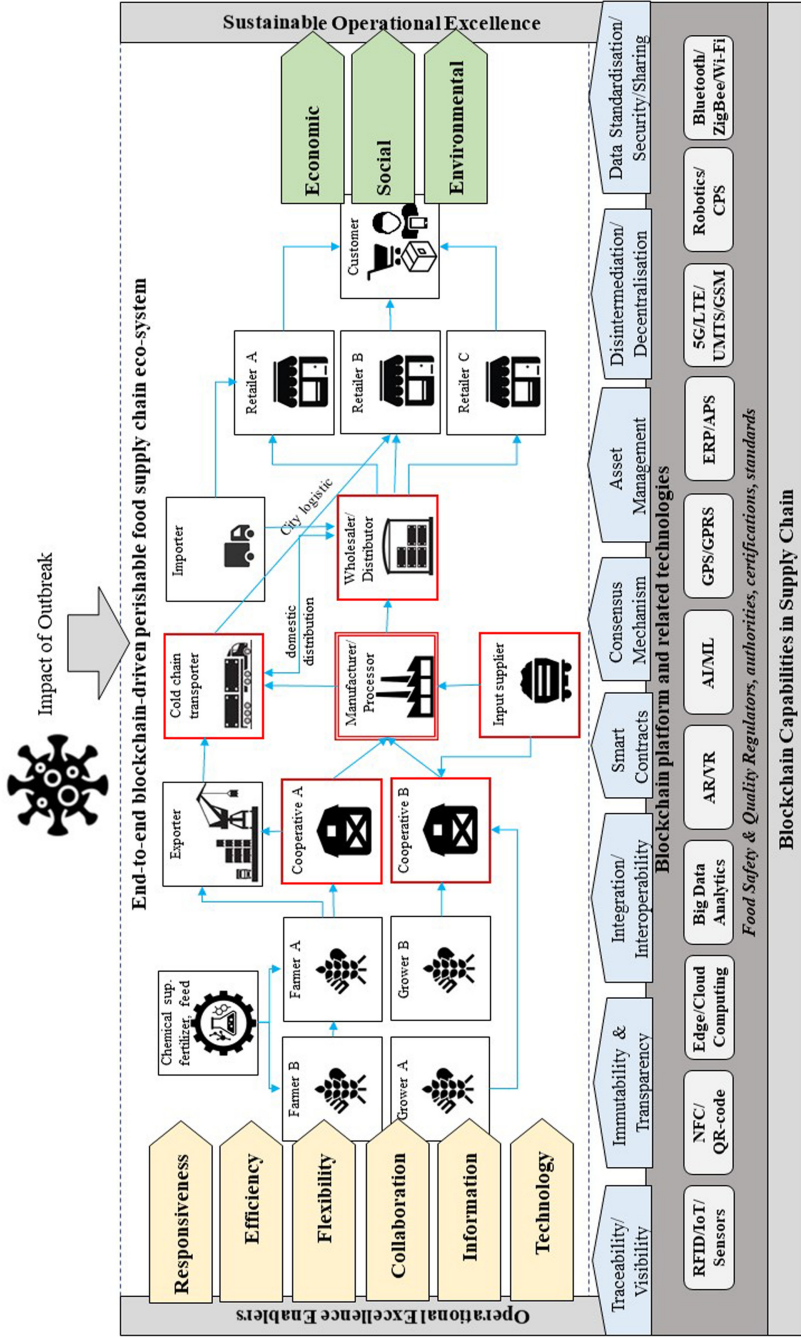


Figure 3. System dynamics of PFSC during outbreaks

and problem solving, leading to a distinction between explanatory and exploratory research. The aim of explanatory research is to construct and demonstrate an explicit and novel theoretical contribution, while exploratory research is interested in improving the solution design and demonstrating its practical utility with empirical evaluation (Holmström *et al.*, 2009).

Our aim is to explore the potential of blockchain to achieve operational excellence for PFSCs during the pandemics and to generate prescriptive knowledge on how to achieve this. Thus, our research interest is in solving a practical problem, and our knowledge interest is pragmatic. Our exploratory research approach proposes a rudimentary solution design based on a systematic literature review and subjects the rudimentary solution design to empirical testing. Thus, DSR is appropriate for our research purposes. DSR is conducted under different scientific research rubrics such as action science, action research, action innovation research, participatory action research, participatory case study, academe-industry partnerships and the like (Holmström *et al.*, 2009).

This study uses a single use-case based on a CIMO-logic to evaluate the blockchain capabilities to drive operational excellence across PFSC during outbreaks. The single case study context is always unique. The empirical examination must always be balanced with a more general theoretical examination. The case selection is based on access and appropriateness of the case selected for the specific study. The study critically investigates a specific technology in the PFSC, mainly BT. This study selects a paradigmatic case where blockchain implementation is taken for granted. The research protocol and data collection are discussed openly to ensure traceability. Information about coding procedures and analysis is laid out in detail to ensure truth value. The study's general theoretical aim and interest and the study's result can be analytically generalised through CIMO-logic ensuring transferability. The generative mechanisms underlying operational excellence during an outbreak are revealed, and the blockchain capabilities are evaluated (Gammelgaard, 2017).

3.1 CIMO-logic

Prescriptive knowledge has a central role in design science research and follows the logic of the design propositions. Design propositions created with CIMO-logic contain information on what to do (intervention), in which situations (context), to offer some understanding of why this happens (a mechanism) and to produce what effect (outcome) (Pawson and Tilley, 1997). Thus, CIMO-logic enables a deep understanding of a system's social and technological components and lets the researcher develop propositions on how to improve the system performance in practice under the rubric of scientific research (Denyer *et al.*, 2008).

On the one hand, CIMO-logic is employed to extract knowledge from the literature review in various contexts (e.g. Rajwani and Liedong, 2015; Holmström *et al.*, 2017; Pilbeam *et al.*, 2019; Bin Makhshen *et al.*, 2020). For these studies, research outcomes are design propositions to develop a research agenda. On the other hand, CIMO-logic is employed in order to extract knowledge from literature review and case study in various contexts (e.g. Ivert and Jonsson, 2014; Santti *et al.*, 2017; Brusset and Bertrand, 2018; Costa *et al.*, 2020; Konietzko *et al.*, 2020; Tanila *et al.*, 2020; Reich *et al.*, 2021). For these studies, outcomes are design propositions to develop solution-oriented guidelines that are actionable in practice. Table 2 summarises the various application areas of CIMO-logic.

Since the intent of CIMO-logic in the later research stream aligns with our aim, we will formulate design propositions using the existing published research base and the use-case as well. The problems in PFSC during outbreaks (context), their interventions and outcomes have been narrated by the PFSC participants. As researchers, our task is to link their interventions to outcomes following CIMO-logic. We unearth intervention types by asking which blockchain capability has facilitated this intervention. We address the mechanisms

Authors	Application area
Rajwani and Liedong (2015)	To present evidence of the impact of Corporate political activity on firm value through a literature review using CIMO-logic
Holmström <i>et al.</i> (2017)	To evaluate the potential of direct digital manufacturing-based practices through a literature review using CIMO-logic
Pilbeam <i>et al.</i> (2019)	To design safer working interventions through a literature review using CIMO-logic
Bin Makhshen <i>et al.</i> (2020)	To explore the role of ambidexterity and coopetition in designing resilient fashion supply chains through a literature review using CIMO-logic
Ivert and Jonsson (2014)	To investigate how advanced planning and scheduling systems support planning tasks and when to be used in sales and operations planning through single-case study using CIMO-logic
Santti <i>et al.</i> (2017)	To explore the effects of business model development project activities on organisational culture through multi-case study using CIMO-logic
Brusset and Bertrand (2018)	To provide a methodology to evaluate the weather effects on supply chains and design the relevant bespoke financial instrument to mitigate the effects of adverse weather through multi-case study using CIMO-logic
Costa <i>et al.</i> (2020)	To design an collaborative networks between industrial business associations and SME mediated by digital platforms through case study using CIMO-logic
Konietzko <i>et al.</i> (2020)	To identify principles for circular ecosystem innovation through case study using CIMO-logic
Tanila <i>et al.</i> (2020)	To explain the value formulation of digital health interventions through multi-case study using CIMO-logic
Reich <i>et al.</i> (2021)	To develop a solution framework for global supply chain network design problem through case study using CIMO-logic

Table 2.
Studies using application areas of CIMO-logic

through which the intended outcomes have been achieved. We identify the specified generative mechanisms by asking which this blockchain capability has activated operation excellence enabler. We generate prescriptive knowledge from use-case analysis and synthesising previously published research. Figure 4 depicts the rudimentary solution design based on our systematic literature review.

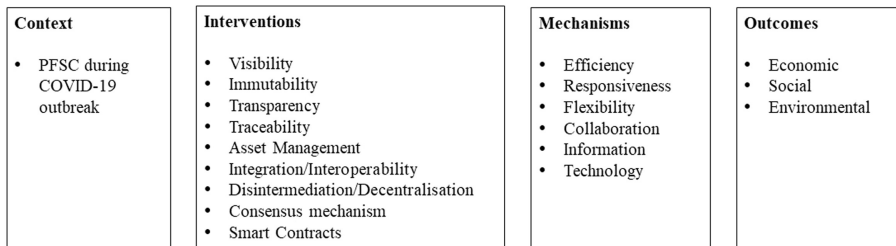
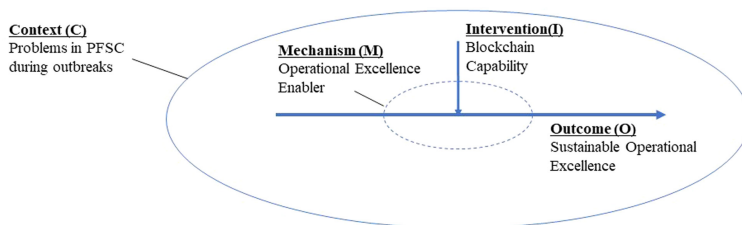


Figure 4.
CIMO-configuration for use-case

3.2 Single case study method and use-case selection

In this research, a single case study method was employed by incorporating semi-structured interviews to collect and analyse empirical data to search for blockchain potential to achieve operational excellence in PFSCs during the pandemic. Case studies on blockchain applications are an appropriate approach to systematically transfer industry experience to benefit in developing empirical (theory building and testing) and design science (design and evaluation) research (Treiblmaier, 2019). In PFSC, blockchain use-cases go beyond ensuring food safety and adding operational excellence to the entire ecosystem (Subramanian *et al.*, 2020). Therefore, we used a single case study to analyse the potential of blockchain from the multiple PFSC participants' perspectives in the same blockchain ecosystem.

We searched the potential use-cases in the agriculture and food sectors on the internet to support the purpose of our study. More than 20 start-up companies were identified and two appropriate companies out of them were selected as blockchain use-case candidates to pursue the study and analyse operational excellence aspects. We contacted the company speakers through LinkedIn. At the end, one company responded and agreed to participate in our study. The selected company is a technology company and one of the leading front lines of the intersections between blockchain and agriculture. The company is headquartered in the USA and strives to provide blockchain platform solutions for agriculture and FSCs with a range of customer segments, including farmers, food processors, distributors, consumer packaged goods manufacturers, groceries, retailers and large industry associations. The company implements blockchain solutions in different food products such as cocoa, coffee, palm oil, sugarcane, barley. The value of the BT of this company allows an ecosystem of participants by digitising the trusted journey of the food product to verify transactions and share, record and exchange data securely, transparently, decentralisedly and efficiently in a distributed ledger system and provide it to the stakeholders. This is necessary for the FSC to profoundly change and improve industry objectives for sustainability, spoilage, reduction, safety, nutrition and quality. Therefore, the case company as a food and farm blockchain provider makes an ideal candidate for in-depth exploration of blockchain potential to drive operational excellence in PFSC during COVID-19 outbreaks.

After having discussion with the blockchain provider, we decided to use one of the FSCs they were working on as a case study. The interviews were held with the blockchain provider and five ecosystem participants from different tiers of the same blockchain ecosystem within a single use-case. Firstly, we contacted the business development manager of the blockchain provider, and five ecosystem participants, namely one farmer, one cooperative, one food processor, one retailer, and one logistics provider, and invited them for an interview. The FSC is a global cocoa SC, which produces high-quality chocolates for international markets. The farmer is Ecuador's cocoa farmer, the cooperative is Ecuador's cocoa cooperative, the food processor is a Swiss factory worker, the retailer is a German retailer and the logistics provider is a Danish transport company. The pandemic-related lifestyle changes and consumption behaviours affect the demand pattern of cocoa. According to the disclosed information in this use-case, the total demand for cocoa has increased up to 21% compared to 2019, while cocoa production has decreased due to pandemic related operational bottlenecks and severe disruptions. Because of this supply-demand mismatch, the use-case is a suitable and informative example for analysing the operational excellence of blockchain-based PFSC during outbreaks.

The online interviews took place in between December 2020 and January 2021. After having confirmations, we sent a brief email with the objective of our research aim and interview protocol. A semi-structured interview protocol based on findings from the literature review was conducted. Since the participants were not online at the same time, the interviews were planned asynchronously. Each interview was held with a professional and took almost an hour. During the interviews, the authors were present and took notes to ensure that the content of interviews was not compromised. The participants were assured that there are no right or wrong answers

to reduce social desirability bias. Furthermore, the response anonymity was maintained to minimise apprehension in evaluation. After completion of the interviews, to minimise the reporting bias a summary transcript was provided to each interviewee within a few days for the validation and all were acknowledged and approved by emails.

The transcript for each interview was prepared and analysed in-depth by two researchers independently, and disagreements were resolved by involving the third researcher, in order to assure inter-rater reliability. We read the notes and examined them carefully according to CIMO-logic methodology. The contexts, interventions, mechanisms and outcomes were identified from the interview transcripts. We discussed the analyses and finalised them. At the end, the findings of the research, developed propositions and frameworks were also verified with the interviewees to ensure validity of the data collection and analyses. Figure 5 depicts the flowchart for use-case analysis.

4. CIMO analysis of the selected use-case

4.1 FLW

The pandemic has disrupted the SCs globally and caused heavy wastage problems at the different stages of the PFSC from post-harvesting, production, processing, transportation and storage to pre-consumer stages. The food loss occurs during early and middle stages (close to the farm), whereas the food waste occurs during the retail and post-consumer stages (close to the fork). Due to lockdowns, travel restrictions and border controls, the perishable products either remained in the field or had to wait in containers on the way or were not sold out within their lifecycle at retailers'. BT provides solutions for SC participants to detect and communicate inefficiencies in PFSC and certify if the information holds true on the

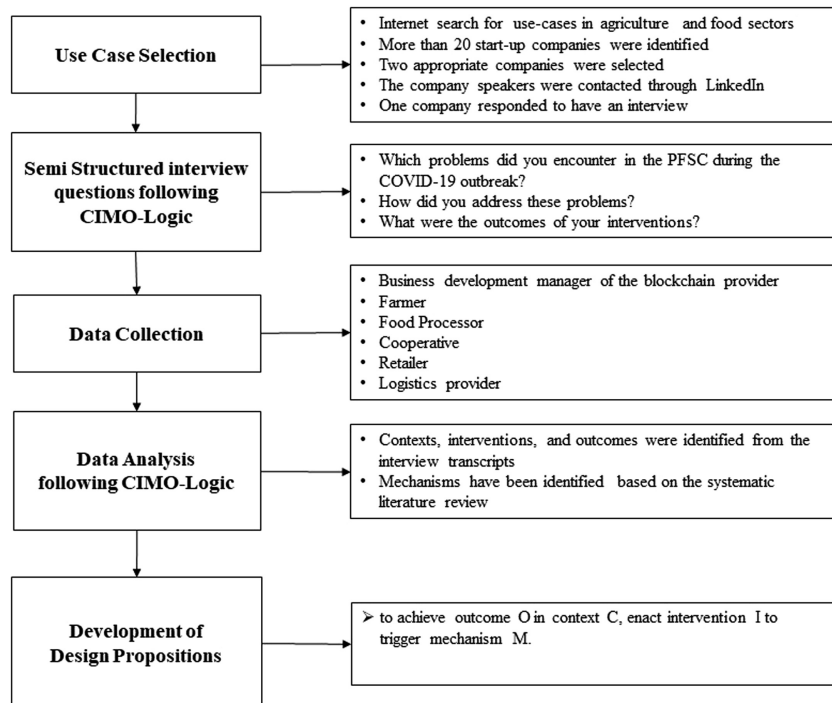


Figure 5.
Flowchart for use case analysis

blockchain system. BT enables promoting and strengthening farmers' organisation to balance the COVID-19 caused supply and demand changes by sharing available capacities and collecting possible demands. In this way, producer organisations have responded in different ways to the challenges of COVID-19 by demonstrating the power of collective action. Additional yields can be announced on the blockchain, and a networked landscape of buyers will be instantly informed, and supply and demand can be matched. Consumers access quality produce, while farmers increase their profits. Instant knowledge of product's exact origin, treatment, quality, handling and age enables improved lifecycle management.

4.2 Food quality and safety

During the pandemic, the health of the soil, plants, animals, people and the environment need to be ensured. So that the possible problems including food fraud, food safety, what constitutes quality and even issues like food spoilage can be prevented. Blockchain records precision water, soil and pest control, measures, and provides insights such as how much fertiliser is applied and how it affects the quality of the produce. The SC participants can be alerted of incompatibilities by real-time tracking and tracing perishable products powered by BT. So that they can manage food safety, food quality, inventory and product freshness to prevent food waste. BT promotes product quality differentiation against situation changes caused by COVID-19.

Beyond the information about physical products, consumers want to have visibility on ethical and sustainable practices. The blockchain ledger holds information such as food safety certification, organic certification, soil quality, animal welfare practices and carbon certification. Moreover, the blockchain enables visibility on the origin of food and what is in food and on who handled the food. Thus, in the case of COVID-19 incidents among PFSC participants, contamination risk can be predicted, and possible contaminated food and packaging can be identified in seconds. Together with IoT sensors, BT can capture the environment in which the food was grown, transported and processed, which improves transparency on food safety and hygiene and builds consumer trust.

4.3 Food recalls

Food products can be contaminated during harvesting, manufacture, delivery, or while stored. While no problems of COVID-19 transmission through food or packaging have been encountered, BT offers opportunities to detect potential contamination exposures and enable faster and more efficient food recalls due to quality assurance failures or distribution issues. Only the tainted or contaminated food is discharged as opposed to the standard operating procedure of the mass recall, where distributors, retailers and consumers had to discard perfectly safe food because it happened to coexist in time with a small amount of tainted or contaminated food. Standard tracking systems in companies involving phones, faxes and emails take days to track unsafe food, while BT enables the digitisation of the movement of food along with the SC by creating the digital twin of the physical movement as a virtual model of the process, product and service, and can track the amount and movement of unsafe food in seconds.

4.4 COVID-19 absenteeism

There is concern that operations could be adversely affected if a significant proportion of food production and distribution employees are unable to work due to illness or government restrictions. Due to COVID-19 absenteeism, crops were left in the field, food producers were unable to utilise their full capacity and shipping and distribution of perishable foods were interrupted, which increased FLW and increased out-of-stock events. Since blockchain also tracks employee data, it can predict the infection risk among employees and identify possible bottlenecks in the operations. Thus, BT provides PFSC participants the means to develop

contingency plans e.g. capacity building through outsourcing or eliminating stock-outs through alternative sourcing.

4.5 Disparate systems

The PFSC is challenged by fragmentation and complexities, which lead to opaqueness and inefficiencies. Blockchain allows the ecosystem to have one source of data and connects the disparate systems and actors in the ecosystem. BT connects the disparate systems and increases the accuracy of the records by providing integrity within PFSC. Blockchain can enhance interoperability within the systems. There are different IT landscapes in PFSC that do not communicate well with each other. Blockchain will provide the ability to unify these disparate systems through interoperability that can facilitate end-to-end visibility throughout the PFSC. In this way, the use of BT at all levels in the ecosystem helps agricultural stakeholders make evidence-based decisions and alerts.

4.6 Financing, operating costs, liquidity

Due to economic stagnation caused by the COVID-19 the economic problems inherent to the PFSC, such as securing loans especially for small farmers and producers, optimising operating costs and maintaining liquidity for all SC participants, have been intensified even more.

Blockchain records data on previous loans and enables forecasts on produce based on historical data, which can be provided to banks and other lending agencies. Through visibility, the likelihood of securing a loan increases, which improves the livelihoods of small farmers and producers. Blockchain records precision water, soil and pest control measure, which enables farmers and producers to identify inefficiencies, and allows decreased input and labour cost. Blockchain utilises smart contracts to shorten the time between fulfilment and receipt of payment leading to better cash flows and reducing layoffs and bankruptcy risk. In addition, BT connects ecosystem participants with government agencies to facilitate their access to credits or subsidies and insurance companies to protect them against contamination or other pandemic-related exposures.

In [Table 3](#), we classify the problems faced by PFSC participants during outbreaks, propose an intervention type to invoke the generative mechanisms to solve the problems, and evaluate whether the desired outcomes have been delivered.

5. Results

5.1 Sustainable operational excellence outcomes

Blockchain-driven PFSC offers greater potential to achieve operational excellence for ecosystem participants in performance and lifecycle assessment and validation. The blockchain mechanism enables monitoring the perishable food product throughout the entire lifecycle in every stage of the SC and collecting and analysing relevant data to overcome potential inefficiencies and operational risks and obstacles. We outline the specific blockchain capabilities in terms of economic, social and environmental sustainability aspects that impact the operational excellence of the PFSC ecosystem. In terms of this result, the study is in line with [Martinez et al. \(2019\)](#), suggesting that BT improves the efficiency of the process, reduces the number of operations, reduces the average time of orders in the system, reduces workload, shows traceability of orders and improves visibility to various SC participants.

5.1.1 Economic. COVID-19 has severely disrupted PFSCs globally. The ecosystem participants from farmers to retailers faced sudden, unexpected, and simultaneous shocks both on the demand and supply side, triggering financial vulnerability. In this use-case, the blockchain platform improves economic sustainability to combat the operational and financial problems caused by COVID-19. The mechanism improves operational

Blockchain for operational excellence

Context <i>narrated by PFSC participant</i>	PFSC participant	Intervention <i>narrated by PFSC participant</i>	Intervention Blockchain capabilities <i>synthesized from previously published research</i>	Mechanism Operational excellence enablers <i>synthesized from previously published research</i>	Outcome Sustainable operational excellence outcomes <i>narrated by PFSC participant</i>
Food Loss	Farmer, Cooperative, Food Processor, Retailer	Additional yields can be announced on the blockchain	Immutability and Transparency	Information, Technology	Supply and demand are matched Consumers access quality produce, while farmers increase their profits
Food Loss and Waste	Food Processor, Retailer, logistics provider	Digital twin of the PFSC can be created	Immutability and Transparency, Integration/ Interoperability	Collaboration, Efficiency	It provides solutions for users in order to detect and communicate inefficiencies in fresh products and certify the information holds true on the blockchain system
Life Cycle Management and Shelf Management	Food Processor, Retailer	Digital twin of the PFSC can be created	Traceability, Asset Management	Responsiveness, Flexibility	instant knowledge on product's exact origin, treatment, quality, handling, and age
Food Quality	Farmer, Cooperative, Food Processor, Retailer, Logistics Provider	Precision water, soil, and pest control measures can be recorded	Traceability	Information, Technology	Farmers get information on everything from temperature, soil quality to humidity and how it affects the quality of the produce
Food Provenance and Fraud Threat	Food Processor, Retailer	Digital twin of the FSC can be created, blockchain ledger hold information on organic certification	Traceability, Disintermediation/ Decentralisation	Information, Technology	Consumers understand the origin of their food, who handled the food and what is in their food
Fairness and Fair-Trade	Farmer, Cooperative, Food Processor, Retailer	blockchain ledger hold information on sustainable practices and animal welfare practices	Transparency, Visibility	Information, Technology	Alignment with consumer values, brand equity

(continued)

Table 3.
CIMO analysis of the single use case for the supply chain participants

Context <i>narrated by PFSC participant</i>	PFSC participant	Intervention <i>narrated by PFSC participant</i>	Intervention Blockchain capabilities <i>synthesized from previously published research</i>	Mechanism Operational excellence enablers <i>synthesized from previously published research</i>	Outcome Sustainable operational excellence outcomes <i>narrated by PFSC participant</i>
Food Safety and Hygiene	Farmer, Cooperative, Food Processor, Retailer, Logistics Provider	Together with IoT sensors the environment in which the food was grown, transported and processed can be captured	Visibility, Traceability	Information, Technology	Consumer trust
Food Safety and Hygiene	Farmer, Cooperative, Food Processor, Retailer, Logistics Provider	the blockchain ledger holds information on who handled the food	Visibility, Traceability, Smart Contracts	Responsiveness	In case of COVID- 19 incidents among PFSC participants, possible contaminated food and packaging can be identified in seconds
Food Recall	Food Processor, Retailer, Logistics Provider	Digital twin of the PFSC can be created	Traceability, Integration/ Interoperability	Responsiveness	Enables more faster and efficient food recalls. Only the tainted or contaminated food is discharged as opposed to the standard operating procedure of the mass recall
COVID-19 Absenteeism	Farmer, Cooperative, Food Processor, Retailer, Logistics Provider	Blockchain ledger holds information on employees and can predict the infection risk among employees and identify possible bottlenecks	Visibility, Traceability	Flexibility	Contingency plans to prevent stock out occurrences due to COVID- 19 Absenteeism
Disparate Systems	Retailer	It allows the ecosystem to have one source of data	Immutability and Transparency, Integration/ Interoperability, Data Standardisation/ Security/Sharing	Collaboration, Efficiency, Information, Technology	It offers interoperability for all participants

Table 3.

(continued)

Context narrated by PFSC participant	PFSC participant	Intervention narrated by PFSC participant	Blockchain capabilities synthesized from previously published research	Intervention	Mechanism Operational excellence enablers synthesized from previously published research	Outcome Sustainable operational excellence outcomes narrated by PFSC participant
Financing	Farmer, Cooperative	Data on previous loans and forecast on produce based on historical data can be provided to banks and other lending agencies	Immutability and Transparency	Immutability and Transparency Integration/ Interoperability, Consensus mechanism	Collaboration, Technology, Information	Access to loan, improve livelihoods of small farmers and producers
Operating Costs	Farmer, Cooperative	Precision water, soil, and pest control measures can be recorded	Immutability and Transparency	Immutability and Transparency	Efficiency	Decrease input and labour costs through precision water, soil, and pest control measures
Liquidity	Farmer, Cooperative, Retailer	Utilize smart contracts to shorten the time between fulfilment and receipt of payment	Smart Contracts, Consensus Mechanism	Smart Contracts, Consensus Mechanism	Collaboration	Improves livelihoods of small farmers and producers

Table 3.

responsiveness and promotes flexibility in business processes. If coronavirus is caught in food at retailers', blockchain enables efficient food recall, instead of recalling entire products, it can quickly identify which batches are affected and where they are distributed. In this way, recall costs can be reduced. This blockchain-enabled recall process is also important for other possible food contaminations (e.g. *salmonella* bacteria, norovirus, aflatoxins), so that contaminated batches are monitored along PFSC while products are quickly recalled and the society can be protected from any foodborne diseases (Kayikci *et al.*, 2020). Furthermore, by including temperature and humidity in the blockchain record, the safety of a particular perishable food shipment and storage can be proactively tracked and traced (Kayikci *et al.*, 2020). This can protect all connected processes in the PFSC system before any sudden event occurs. Farmers need to optimise their operating costs with higher crops, lower livestock losses, less water usage and utilise their capacities through smart contracts which facilitate the collaboration of cross-organisational business processes to reduce the heavy impact of a pandemic. In particular, the consensus mechanism allows proof checking and enables participants cheaper and faster access to affordable financing and liquidity in funds.

5.1.2 Social. COVID-19 pandemic has caused employee absenteeism. The shortage of skilled staff from field workers to truck drivers to senior managers can greatly affect the efficiency of PFSC. Therefore, there is a need to predict employee absenteeism during COVID-19. In this use-case, the blockchain platform improves social sustainability to combat absenteeism problems caused by COVID-19. The blockchain tracks employees' health conditions and their infection risk and identifies possible absenteeism resulting in bottlenecks, and warns the entire system to take prompt measurements (e.g. staff sharing). Furthermore, blockchain can also improve animal welfare and animal health, support animal safety and control production

including pharmaceuticals, antibiotics, vaccines, genomics and toxicology etc., for food safety. Blockchain can help facilitate transparency for direct trade and assure consumers, that farmers or cooperatives are paid a fair price for commodities (Chaudhuri *et al.*, 2021).

5.1.3 Environmental. During the COVID-19 pandemic, almost all companies involved in PFSC have experienced significant environmental problems, particularly FLW. In this use-case, the blockchain platform improves environmental sustainability to combat ecological problems caused by COVID-19. The mechanism enables food traceability and transparency along the lifecycle in the entire PFSC. The available inventory can be monitored through asset management. If necessary, the surplus food can be circulated by redistribution and reallocation in the ecosystem. This can help to avoid FLW and also can be prevented from being dumped. Also, this use-case enables the carbon-neutral, eco-labelled and environmentally friendly practices to enable tracing of carbon footprints throughout the PFSC.

5.2 Propositions

The design propositions are derived for PFSCs that can support different types of generative mechanisms of operational excellence: responsiveness, flexibility, efficiency, technology, information and collaboration. Here, it is essential that the blockchain solution instantly monitors the state of the SC during outbreaks to identify inefficiencies and take corrective actions such as timely redistribution/reallocation of excess food and disintermediation and overcome potential operational risks and obstacles such as operational bottlenecks, product shortages, food fraud and safety, cessation of logistic activities, COVID-19 absenteeism. Table 4 shows the formation of design propositions based on CIMO-logic. The propositions cover the vertical and horizontal aspects of CIMO. Specifically, we used a format shown in Figure 5 as “to achieve outcome *O* in context *C*, enact intervention *I* to trigger mechanism *M*” for developing propositions. As a result, we propose the following five propositions:

- P1.* To achieve food safety during outbreaks, enact blockchain capabilities, visibility, traceability, disintermediation/decentralisation and smart contracts to trigger operational excellence enablers’ information, technology and responsiveness.
- P2.* To achieve food accessibility during outbreaks, enact blockchain capabilities, immutability and transparency, traceability, and integration/interoperability to trigger operational excellence enablers’ efficiency, responsiveness, flexibility, information, technology and collaboration.
- P3.* To achieve food security during outbreaks, enact blockchain capabilities, immutability and transparency, integration/interoperability, consensus mechanism, smart contracts to trigger operational excellence enablers’ technology, information and collaboration.
- P4.* The blockchain-driven PFSC solution enables ecosystem participants to identify inefficiencies during outbreaks through real-time status monitoring to achieve operational excellence
- P5.* The blockchain-driven PFSC solution enables ecosystem participants to anticipate possible operational risks and obstacles during outbreaks and execute contingency plans to achieve operational excellence.

5.3 Sensitivity analysis: perspectives of three PFSC operational stages

Sensitivity analysis is used to examine the impact of using different thresholds, such as different decision-makers and/or different sub-attributes, on the result. In this study, the perspectives of different decision-makers involved in the three operational stages of PFSC

Blockchain for operational excellence

Context 1	Interventions	Mechanisms	Outcomes
Food quality	Primary capabilities: Visibility, traceability	Detect → Information, technology	Economic: Brand equity Social: Food safety
Food provenance and fraud threat	Supporting capabilities: Smart contracts, Disintermediation/ Decentralisation	React → Responsiveness	Environmental: Minimisation of food waste
Food safety and hygiene			
Food recall			
Context 2	Interventions	Mechanisms	Outcomes
Supply-demand mismatch	Primary capabilities: Immutability and transparency, traceability	Detect → Information, technology	Economic: No supply-demand mismatch Social: Food accessibility
Food loss and waste	Supporting capabilities: Integration/ interoperability	React → Efficiency, responsiveness, flexibility, collaboration	Environmental: Minimisation of food waste
Life cycle management and shelf management			
Production planning and personnel scheduling			
Context 3	Interventions	Mechanisms	Outcomes
Financing	Primary capabilities: Immutability and transparency	Detect → Information, technology	Economic: Better financing, lower operating costs, improved liquidity
Operating costs	Supporting capabilities: Integration/interoperability, consensus mechanism, smart contracts	React → Collaboration	Social: Food security
Liquidity			

Table 4.
The formation of design propositions

were used to validate the propositions in the frame of sensitivity analysis. The outcomes from the whole PFSC and three operational stages for upstream PFSC (farmer and cooperative), Work in Progress (WIP) (food processor) and downstream PFSC (retailer and logistics provider) were analysed for the validation of propositions. For instance, the whole PFSC condition considers blockchain capabilities and operational excellence outcomes with all PFSC stakeholders, while the upstream PFSC condition considers blockchain capabilities and operational excellence with only upstream stakeholders. [Table 5](#) summarises the analysis of the whole PFSC with three operational stages of PFSC for the aforementioned five propositions and the details are depicted in [Appendix](#).

Proposition #	Whole PFSC	PFSC stages		
		Upstream	WIP	Downstream
P1	Complete	Partial	Complete	Complete
P2	Complete	Partial	Complete	Complete
P3	Complete	Complete	No evidence	Partial
P4	Complete	Complete	Partial	Partial
P5	Complete	Complete	Partial	Partial

Table 5.
Sensitivity analysis

Proposition 1 has been fully supported by WIP and downstream PFSC, while upstream PFSC provides partial support. WIP and downstream PFSC are held accountable on every aspect of food safety, whereas upstream PFSC is not responsible for food provenance and food threat and food recall, leading them to enact a limited set of blockchain capabilities to ensure food safety across the PFSC.

Proposition 2 has been fully supported by WIP and downstream PFSC, while upstream PFSC provides partial support. WIP and downstream PFSC are held accountable on every aspect of food accessibility, whereas upstream PFSC is not responsible for lifecycle management and shelf management, leading them to enact a limited set of blockchain capabilities to ensure food accessibility across the PFSC.

Proposition 3 has been supported by upstream PFSC, whereas downstream PFSC provides partial support. Upstream PFSC is challenged by all aspects of food security and enacts blockchain capabilities to ensure food security throughout the PFSC, while upstream PFSC enacts blockchain capabilities such as consensus mechanisms and smart contracts to ensure liquidity. There is no evidence that WIP enacts blockchain capabilities to detect and react to inefficiencies to ensure food security.

Proposition 4 and 5 have been supported by all decision-makers regarding two operational excellence dimensions. All decision-makers enact blockchain capabilities to detect food safety and food accessibility problems and execute contingency plans accordingly. However, there is only partial support from the upstream PFSC for the food security dimension.

6. Discussion and implications

The pandemic not only had a disruptive effect on the FSC but also exacerbated existing problems inherent to the PFSC. Before the pandemic, the FSC was already entangled with deep rooted economic, social and environmental challenges (Kumar *et al.*, 2019). The extensive literature review by Li *et al.* (2021) asserts that BT enables visibility, transparency, interoperability and efficiency and is beneficial for overcoming these challenges. Thus, our results align with the literature on blockchain capabilities and operational excellence in FSC in general.

Following most recent studies on operational excellence in FSC during outbreaks (Kumar and Singh, 2021; Kumar *et al.*, 2021; Mishra *et al.*, 2021), the present study postulates that flexibility, collaboration and responsiveness to identify inefficiencies and anticipate possible operational risks and obstacles is essential to develop SC resilience during outbreaks. Kumar and Singh (2021) identify the interrelatedness of operational, logistical, financial and socio-economic impacts of COVID-19 and determine the possible strategies for improving the resilience of the agri-FSCs as SC correlation, SC responsiveness, coordination between stakeholders, information, and resource sharing, digitisation of the process, which are in turn all interlinked. Mishra *et al.* (2021) emphasise proactive and reactive implementations to cope with disruptions. According to Mishra *et al.* (2021) proactive demand-side practices are trust-building and transparent communication, proactive supply-side practices are supplier resilience, collaboration with competition, long term contracts, implementation of knowledge management tools and reconfiguration of SC network design, proactive logistics side practices are logistics capabilities, security and transparency are most important. Kumar *et al.* (2021) propose that collaborative management, proactive business continuity planning and financial sustainability are the top risk mitigation strategies for PFSC during the current pandemic.

Similar to Kumar and Singh (2021), Kumar *et al.* (2021) and Mishra *et al.* (2021) we provide a nuanced overview of the complexity of the PFSC and design solutions for operational excellence during an outbreak; and find similar results regarding COVID-19 impacts and coping mechanisms. Furthermore, we evaluated the potential of a practical tool for

operational excellence utilising real data from use-cases and demonstrated that various blockchain capabilities facilitate key operational excellence drivers reactively and proactively. Most notably, this real case revealed that blockchain-based collaboration between stakeholders along the cocoa SC during the pandemic resulted in around 25% cost reduction, 17% revenue growth and 15% sourcing efficiency and productivity increase.

The theoretical implication of this research is that in-depth systematic literature review and CIMO-logic methodology based on a real blockchain-driven PFSC solution were used to demonstrate the blockchain capabilities driving operational excellence in PFSC during outbreaks. The findings will provide insight into the mechanisms that deliver the outcomes of sustainable operational excellence. In this research, the blockchain capabilities driving operational excellence in PFSC were analysed from the perspective of a qualitative study (use-case). This can also be analysed from the perspective of quantitative studies by applying a wide range of simulation, modelling and numerical analyses techniques as a theoretical background.

The managerial implication of this research is that the findings of the presented study will help companies in PFSC understand the potential operational challenges, risks and inefficiencies caused by any outbreak such as COVID-19. Moreover, the companies in the food industry will gain great insight into developing and implementing their own blockchain-driven solutions, particularly during outbreaks. As companies are often sceptical about whether BT can add value in achieving operational excellence. With the finding of this study, it will be possible for them to understand the potential of the blockchain better, keeping in mind that this study focuses on a real case where BT is already implemented, and the design propositions apply to PFSC, where BT is adopted to some extent. We are aware that, like any other new technology adoption, BT is not immune to cultural barriers such as resistance to change and organisational inertia, which can either complicate the transition period or hinder the adoption of new technology altogether. However, we would like to refer the reader interested in the new adaptation of technologies in FSC such as blockchain and artificial intelligence in FSC to [Vivaldini \(2021\)](#) and [Dora et al. \(2021\)](#), respectively.

As demonstrated by [Mangla et al. \(2021b\)](#) the most prominent societal implications of BT for delivering Sustainable Development Goals (SDGs) as providing safe food, promoting good health and better well-being for all. The COVID-19 pandemic has unprecedented and far-reaching effects on economic, social and environmental systems, with the immediate threats to SDG1-No Poverty due to economic recession, layoffs and bankruptcy; SDG2-Zero Hunger due to increased food insecurity; SDG3-Good Health and Well-Being due to food accessibility and safety; SDG8-Decent Work and Economic Growth due to layoffs and bankruptcy; SDG13-Climate Action and SDG14-Life Below Water due to increased single-use packaging by increased food hygiene concerns; SDG15-Life on Land due, to increased food waste caused by the demand-supply mismatch. The developed CIMO-logic framework can guide governments and policy makers pointing out which operational excellence parameters of PFSC should be promptly driven by blockchain capabilities in the event of an outbreak. Hence, this study also provides social implications of implementing blockchain-based solutions to achieve SDGs.

7. Conclusion and future research

In this research, we conducted a structured literature review to identify operational excellence enablers and blockchain capabilities and also analysed a real single use-case through CIMO-logic involving semi-structured interviews with different stakeholders to reveal blockchain capabilities to drive operational excellence PFSC during outbreaks.

COVID-19 pandemic disrupted the functioning of markets, institutions and social capital, and weakened the resilience of food systems unlike any other natural disaster, such as

drought, floods and pests, and had unprecedented and far-reaching economic, social and environmental impacts on PFSCs. The PFSC has to rely on collaboration, technology and information sharing to become more responsive, flexible and efficient to cope with the impacts of COVID-19. BT benefits all stakeholders in the agri-food system (global cocoa SC), as its implementation can help improve SC performance such as reducing crop losses, improving yields, decreasing transaction time and cost, optimising product storage, avoiding food contamination and spoilage, improve recall efficiency, manage operational risks and maximise profits and provide sustainability benefits such as promote fair trade, track carbon emissions, minimise FLW. Blockchain capabilities, such as traceability/visibility, immutability and transparency, integration/interoperability and smart contracts facilitate the identification of inefficiencies and anticipation of possible operational risks and obstacles and execute contingency plans during outbreaks.

The blockchain-driven PFSC ecosystems have greater potential than other solutions to achieve operational excellence. However, the level of integration, automation and data sharing among trusted ecosystem stakeholders on the blockchain platform plays a major role in revealing blockchain capabilities. The more data is shared, the higher the value of the blockchain. Its development, especially in terms of data interoperability for cross-blockchain interactions, will facilitate seamless data transactions between different food ecosystems, thereby enabling greater operational excellence. Furthermore, the use of other emerging technologies and digital tools such as sensors, IoT, AI/ML in blockchain platforms can foster integration and automation and further increase the capabilities of blockchain to drive operational excellence in PFSC. Governmental regulations are also important to disseminate the use of BT to establish food safety standards and food security. In this way, PFSC can be better monitored, protecting public health, balancing capacities and preventing food waste during outbreaks.

The main limitation of this research is that only one real case is employed. Thus, statistical generalisation is not possible at this stage of the research. However, the findings are not restricted to this single case. DSR provides an in-depth understanding of the topic and requires pragmatic validity based on saturated evidence. The CIMO-logic-based framework and the propositions of this study can be adapted to the other food-related SCs such as agriculture, dry food, dry legumes, since the operational excellence enablers derived in this study are food-related.

The findings of this study are presented based on the current state-of-art of blockchain. As an emerging technology, BT is still in its infancy, and therefore, it has some technical shortcomings. The sooner this technology matures, the more the blockchain capabilities will drive operational excellence in PFSC. As new technology adoption, BT adoption is not immune to cultural barriers along the SC and within the organisation. This study focuses on a real case where BT has been adopted and derives the design propositions based on the assumption that the PFSC already adopted BT to some extent. However, a fruitful future research avenue is examining various barriers to adopting BT in PFSC and corresponding solution mechanisms.

In addition, this study analyses the blockchain capabilities as a response to COVID-19 pandemic in the PFSC context. On the one hand, the perishable food sector is not the only sector affected by the pandemic. The research design of this study can be applied to other system-relevant sectors as well by reproducing sector-specific operational excellence drivers. On the other hand, BT is not the only emerging technology to mitigate the disruptive effects of the COVID-19 pandemic. Thus, the research design can evaluate the capabilities of emerging technologies such as AI, IoT and automation to drive operational excellence across PFSC during outbreaks. In this research, SC participants of one blockchain-driven PFSC ecosystem have been interviewed. Thus, the analyses have been conducted from multiple participant perspectives within one of the PFSCs. For future research, more use-cases can be added to compare different blockchain-driven PFSC ecosystems in terms of their blockchain

capabilities and observe interactions among SC partners within one ecosystem and interactions among different ecosystems.

This study focuses heavily on the forward flow of perishable goods due to two reasons. First, due to the COVID-19 pandemic, there are more pressing matters to tackle in the forward SC compared to the backward SC. Second, the packaging of cocoa products is not recyclable and reclaimable, and the investigated cocoa SC does not engage in circular economy activities. COP 26 has emphasised nature's critical role in achieving the goal of limiting global temperature rises to 1.5 C and called upon more action towards preserving our oceans and land to mitigate climate change. Thus, post-pandemic the transition to a circular economy has utmost urgency, and evaluating blockchain capabilities for driving operational excellence regarding circular economy is a noteworthy future research avenue.

References

- Abeyratne, S.A. and Monfared, R.P. (2016), "Blockchain ready manufacturing supply chain using distributed ledger", *International Journal of Research in Engineering and Technology*, Vol. 5 No. 9, pp. 1-10.
- Abiral, B. and Atalan-Helicke, N. (2020), "Trusting food supply chains during the pandemic: reflections from Turkey and the U.S", *Food and Foodways*, Vol. 28 No. 3, pp. 226-236.
- Accorsi, R., Gallo, A. and Manzini, R. (2017), "A climate driven decision-support model for the distribution of perishable products", *Journal of Cleaner Production*, Vol. 165, pp. 917-929.
- Adekomaya, O., Jamiru, T., Sadiku, R. and Huan, Z. (2016), "Sustaining the shelf life of fresh food in cold chain – a burden on the environment", *Alexandria Engineering Journal*, Vol. 55 No. 2, pp. 1359-1365.
- Ahmed, S. and Broek, N. (2017), "Blockchain could boost food security", *Nature*, Vol. 550 No. 7674, p. 43.
- Alfian, G., Syafrudin, M., Farooq, U., Ma'arif, M.R., Syaekhoni, M.A., Fitriyani, N.L., Lee, J. and Rhee, J. (2020), "Improving efficiency of RFID-based traceability system for perishable food by utilizing IoT sensors and machine learning model", *Food Control*, Vol. 110 No. 107016, pp. 1-11.
- Ali, M.H., Zhan, Y., Alam, S.S., Tse, Y.K. and Tan, K.H. (2017), "Food supply chain integrity: the need to go beyond certification", *Industrial Management and Data Systems*, Vol. 117 No. 8, pp. 1589-1611.
- As'ad, R., Hariga, M. and Shamayleh, A. (2020), "Sustainable dynamic lot sizing models for cold products under carbon cap policy", *Computers and Industrial Engineering*, Vol. 149, doi: [10.1016/j.cie.2020.106800](https://doi.org/10.1016/j.cie.2020.106800).
- Astarita, V., Giofrè, V.P., Mirabelli, G. and Solina, V. (2020), "A review of blockchain-based systems in transportation", *Information*, Vol. 11 No. 1, doi: [10.3390/info11010021](https://doi.org/10.3390/info11010021).
- Astill, J., Rozita, A., Malcolm, C., Jeffrey, M.F., Evan, D.G.F., Shayan, 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, pp. 240-247.
- Balaji, M. and Arshinder, K. (2016), "Modeling the causes of food wastage in Indian perishable food supply chain", *Resources, Conservation and Recycling*, Vol. 114, pp. 153-167.
- Barykin, S.Y., Bochkarev, A.A., Kalinina, O.V. and Yadykin, V.K. (2020), "Concept for a supply chain digital twin", *International Journal of Mathematical, Engineering and Management Sciences*, Vol. 5 No. 6, pp. 1498-1515.
- Bastian, J. and Zentes, H. (2013), "Supply chain transparency as a key prerequisite for sustainable agri-food supply chain management", *The International Review of Retail, Distribution and Consumer Research*, Vol. 23 No. 5, pp. 553-570.
- Behnke, K. and Janssen (Marijn), M.F.W.H.A. (2020), "Boundary conditions for traceability in food supply chains using blockchain technology", *International Journal of Information Management*, Vol. 52, doi: [10.1016/j.ijinfomgt.2019.05.025](https://doi.org/10.1016/j.ijinfomgt.2019.05.025).

- Bencić, F.M., Skočir, P. and Žarko, I.P. (2019), "DL-tags: DLT and smart tags for decentralized, privacy-preserving, and verifiable supply chain management", *IEEE Access*, Vol. 7, pp. 46198-46209.
- Beshai, H., Sarabha, G.K., Rathi, P., Alam, A.U. and Deen, M.J. (2020), "Freshness monitoring of packaged vegetables", *Applied Sciences*, Vol. 10, p. 21, doi: [10.3390/app10217937](https://doi.org/10.3390/app10217937).
- Bin Makhshen, Y., Rafi-ul-Shan, P.M., Bashiri, M., Hasan, R., Amar, H. and Khan, M.N. (2020), "Exploring the role of ambidexterity and coopetition in designing resilient fashion supply chains: a multi-evidence-based approach", *Journal of Enterprise Information Management*, Vol. 33 No. 6, pp. 1599-1625.
- Borrello, M., Caracciolo, F., Lombardi, A., Pascucci, S. and Cembalo, L. (2017), "Consumers' perspective on circular economy strategy for reducing food waste", *Sustainability*, Vol. 9 No. 1, doi: [10.3390/su9010141](https://doi.org/10.3390/su9010141).
- Borrero, J.D. (2019), "Agri-food supply chain traceability for fruit and vegetable cooperatives using blockchain technology", *CIRIEC-España, revista de economía pública, social y cooperativa*, Vol. 95, pp. 71-94.
- Bortolini, M., Faccio, M., Ferrari, E., Gamberi, M. and Pilati, F. (2015), "Fresh food sustainable distribution: cost, delivery time and carbon footprint three-objective optimization", *Journal of Food Engineering*, Vol. 174, pp. 56-67.
- Boukis, A. (2019), "Exploring the implications of blockchain technology for brand-consumer relationships: a future research agenda", *Journal of Product and Brand Management*, Vol. 29 No. 3, pp. 307-320.
- Bozorgi, A., Pazour, J. and Nazzal, D. (2014), "A new inventory model for cold items that considers costs and emissions", *International Journal of Production Economics*, Vol. 155, pp. 114-125.
- Brusset, X. and Bertrand, J. (2018), "Hedging weather risk and coordinating supply chains", *Journal of Operations Management*, Vol. 64, pp. 41-52.
- Bumblauskas, D., Mann, A., Dugan, B. and Rittmer, J. (2020), "A blockchain use case in food distribution: do you know where your food has been?", *International Journal of Information Management*, Vol. 52, doi: [10.1016/j.ijinfomgt.2019.09.004](https://doi.org/10.1016/j.ijinfomgt.2019.09.004).
- Camanzi, L., Alikadic, A., Compagnoni, L. and Merloni, E. (2017), "The impact of greenhouse gas emissions in the EU food chain: a quantitative and economic assessment using an environmentally extended input-output approach", *Journal of Cleaner Production*, Vol. 157, pp. 168-176.
- Cannas, V.G., Ciccullo, F., Pero, M. and Cigolini, R. (2020), "Sustainable innovation in the dairy supply chain: enabling factors for intermodal transportation", *International Journal of Production Research*, Vol. 58 No. 24, pp. 7314-7333.
- Casino, F., Kanakaris, V., Dasaklis, T.K., Moschuris, S. and Rachaniotis, N.P. (2019), "Modeling food supply chain traceability based on blockchain technology", *IFAC PapersOnLine*, Vol. 52 No. 13, pp. 2728-2733.
- Casino, F., Kanakaris, V., Dasaklis, T.K., Moschuris, S., Stachtariis, 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*, Vol. 59 No. 19, pp. 5758-5770, doi: [10.1080/00207543.2020.1789238](https://doi.org/10.1080/00207543.2020.1789238).
- Chaudhuri, A., Bhatia, M.S., Kayikci, Y., Fernandes, K. and Fosso Wamba, S. (2021), "Improving social sustainability and reducing supply chain risks through blockchain Implementation: role of outcome and behavioural mechanisms", *Annals of Operations Research*. doi: [10.1007/s10479-021-04307-6](https://doi.org/10.1007/s10479-021-04307-6).
- Chaudhuri, A., Dukovska-Popovska, I., Subramanian, N., Chan, H.K. and Bai, R. (2018), "Decision-making in cold chain logistics using data analytics: a literature review", *International Journal of Logistics Management*, Vol. 29 No. 3, pp. 839-861.
- Chen, S., Liu, X., Yan, J., Hu, G. and Shi, Y. (2021), "Processes, benefits, and challenges for adoption of blockchain technologies in food supply chains: a thematic analysis", *Information Systems and E-Business Management*, Vol. 19, pp. 909-935, doi: [10.1007/s10257-020-00467-3](https://doi.org/10.1007/s10257-020-00467-3).

- Chen, X., Wu, S., Wang, X. and Li, D. (2019), "Optimal pricing strategy for the perishable food supply chain", *International Journal of Production Research*, Vol. 57 No. 9, pp. 2755-2768.
- Chin, C.F. (2020), "The impact of food supply chain disruptions amidst COVID-19 in Malaysia", *Journal of Agriculture, Food Systems, and Community Development*, Vol. 9 No. 4, pp. 161-163.
- Cholewa, J.B. and Shanmugam, A.P. (2017), "Trading real-world assets on blockchain-an application of trust-free transaction systems in the market for lemons", *Business and Information Systems Engineering*, Vol. 59 No. 6, pp. 425-440.
- Chowdhury, T., Sarkar, A., Paul, S.K. and Moktadir, A. (2020), "A case study on strategies to deal with the impacts of COVID-19 pandemic in the food and beverage industry", *Operations Management Research*. doi: [10.1007/s12063-020-00166-9](https://doi.org/10.1007/s12063-020-00166-9).
- Ciulli, F., Kolk, A. and Boe-Lillegraven, S. (2020), "Circularity brokers: digital platform organizations and waste recovery in food supply chains", *Journal of Business Ethics*, Vol. 167 No. 2, pp. 299-231.
- Cole, R., Stevenson, M. and Aitken, J. (2019), "Blockchain technology: implications for operations and supply chain management", *Supply Chain Management*, Vol. 24 No. 4, pp. 469-483.
- Costa, E., Soares, A.L. and de Sousa, J.P. (2020), "Industrial business associations improving the internationalisation of SMEs with digital platforms: a design science research approach", *International Journal of Information Management*, Vol. 53, doi: [10.1016/j.ijinfomgt.2020.102070](https://doi.org/10.1016/j.ijinfomgt.2020.102070).
- Daghar, A., Alinaghian, L. and Turner, N. (2021), "The role of collaborative interorganizational relationships in supply chain risks: a systematic review using a social capital perspective", *Supply Chain Management: An International Journal*, Vol. 26 No. 2, pp. 279-296, doi: [10.1108/SCM-04-2020-0177](https://doi.org/10.1108/SCM-04-2020-0177).
- Dania, W.A.P., Xing, K. and Amer, Y. (2020), "The assessment of collaboration quality: a case of sugar supply chain in Indonesia", *International Journal of Productivity and Performance Management*. doi: [10.1108/IJPPM-11-2019-0527](https://doi.org/10.1108/IJPPM-11-2019-0527).
- Deaton, B.J. and Deaton, B.J. (2020), "Food security and Canada's agricultural system challenged by COVID-19", *Canadian Journal of Agricultural Economics*, Vol. 68 No. 2, pp. 143-149, doi: [10.1111/cjag.12227](https://doi.org/10.1111/cjag.12227).
- Denyer, D., Tranfield, D. and Van Aken, J.E. (2008), "Developing design propositions through research synthesis", *Organization Studies*, Vol. 29 No. 3, pp. 393-413.
- Ding, M.J., Jie, F. and Parton, K.A. (2014), "Relationships between quality of information sharing and supply chain food quality in the Australian beef processing industry", *International Journal of Logistics Management*, Vol. 25 No. 1, pp. 85-108.
- Dolgui, A., Ivanov, D. and Sokolov, B. (2018), "Ripple effect in the supply chain: an analysis and recent literature", *International Journal of Production Research*, Vol. 56 Nos 1-2, pp. 414-430, doi: [10.1080/00207543.2017.1387680](https://doi.org/10.1080/00207543.2017.1387680).
- Dora, M., Kumar, A., Mangla, S.M., Pant, A. and Kamal, M.M. (2021), "Critical success factors influencing artificial intelligence adoption in food supply chains", *International Journal of Production Research*. doi: [10.1080/00207543.2021.1959665](https://doi.org/10.1080/00207543.2021.1959665).
- Dossa, A.A., Gough, A., Batista, L. and Mortimer, K. (2020), "Diffusion of circular economy practices in the UK wheat food supply chain", *International Journal of Logistics Research and Applications*. doi: [10.1080/13675567.2020.1837759](https://doi.org/10.1080/13675567.2020.1837759).
- Duan, J., Chen, Z., Yu, G., Steve, B. and Zhi, L. (2020), "A content-analysis based literature review in blockchain adoption within food supply chain", *International Journal of Environmental Research and Public Health*, Vol. 17 No. 5, doi: [10.3390/ijerph17051784](https://doi.org/10.3390/ijerph17051784).
- Dutta, P., Choi, T.M., Somani, S. and Butala, R. (2020), "Blockchain technology in supply chain operations: applications, challenges and research opportunities", *Transportation Research Part E: Logistics and Transportation Review*, Vol. 142, doi: [10.1016/j.tre.2020.102067](https://doi.org/10.1016/j.tre.2020.102067).
- Eberhardt, T., Hubert, M., Lischka, H.M., Hubert, M. and Lin, Z.B. (2021), "The role of subjective knowledge and perceived trustworthiness in fair trade consumption for fashion and food products", *Journal of Consumer Marketing*, Vol. 38 No. 1, pp. 58-68, doi: [10.1108/JCM-08-2019-3356](https://doi.org/10.1108/JCM-08-2019-3356).

-
- Esmaili, M. and Sahraeian, R. (2017), "A new Bi-objective model for a two-echelon capacitated vehicle routing problem for perishable products with the environmental factor", *International Journal of Engineering*, Vol. 30 No. 4, pp. 523-531.
- Fazili, M., Venkatadri, U., Cyrus, P. and Tajbakhsh, M. (2017), "Physical Internet, conventional and hybrid logistic systems: a routing optimisation-based comparison using the Eastern Canada road network case study", *International Journal of Production Research*, Vol. 55 No. 9, pp. 2703-2730.
- Feng, X.J., Rong, Y., Shen, Z.J.M. and Snyder, L.V. (2020), "Pricing during disruptions: order variability versus profit", *Decision Sciences*. doi: [10.1111/dec.12494](https://doi.org/10.1111/dec.12494).
- Fernando, Y., Chidambaram, R.R.M. and Wahyuni-TD, I.S. (2018), "The impact of Big Data analytics and data security practices on service supply chain performance", *Benchmarking*, Vol. 25 No. 9, pp. 4009-4034.
- Fitzgerald, J., Mussomeli, A., Daecher, A. and Chandramouli, M. (2018), "Using smart sensors to drive supply chain innovation", available at: <https://www2.deloitte.com/content/dam/Deloitte/us/Documents/process-and-operations/us-cons-smart-sensors.pdf> (accessed 15 January 2021).
- Fountsop, A.N., Fendji, J.L.E.K. and Atemkeng, M. (2020), "Deep learning models compression for agricultural plants", *Applied Sciences*, Vol. 10 No. 19, p. 6866.
- Gallo, A., Accorsi, R., Baruffaldi, G. and Manzini, R. (2017), "Designing sustainable cold chains for long-range food distribution: energy-effective corridors on the Silk Road Belt", *Sustainability*, Vol. 9 No. 11, p. 2044.
- Galvez, J.F., Mejuto, J.C. and Simal-Gandara, J. (2018), "Future challenges on the use of blockchain for food traceability analysis", *TrAC Trends in Analytical Chemistry*, Vol. 107, pp. 222-232.
- Gammelgaard, B. (2017), "Editorial: the qualitative case study", *The International Journal of Logistics Management*, Vol. 28 No. 4, pp. 910-913.
- Gao, Z., Xu, L., Chen, L., Zhao, X., Lu, Y. and Shi, W. (2018), "Coc: a unified distributed ledger based supply chain management system", *Journal of Computer Science and Technology*, Vol. 33 No. 2, pp. 237-248.
- George, R.V., Harsh, H.O., Ray, P. and Babu, A.K. (2019), "Food quality traceability prototype for restaurants using blockchain and food quality data index", *Journal of Cleaner Production*, Vol. 240, doi: [10.1016/j.jclepro.2019.118021](https://doi.org/10.1016/j.jclepro.2019.118021).
- Ghadge, A., Kaklamanou, M., Choudhary, S. and Bourlakis, M. (2017), "Implementing environmental practices within the Greek dairy supply chain: drivers and barriers for SMEs", *Industrial Management and Data Systems*, Vol. 117 No. 9, pp. 1995-2014, doi: [10.1108/IMDS-07-2016-0270](https://doi.org/10.1108/IMDS-07-2016-0270).
- Gholami-Zanjani, S.M., Jabalameli, M.S., Klibi, W. and Pishvae, M.S. (2021), "A robust location-inventory model for food supply chains operating under disruptions with ripple effects", *International Journal of Production Research*, Vol. 59 No. 1, pp. 301-324, doi: [10.1080/00207543.2020.1834159](https://doi.org/10.1080/00207543.2020.1834159).
- Göbel, C., Langen, N., Blumenthal, A., Teitscheid, P. and Ritter, G. (2015), "Cutting food waste through cooperation along the food supply chain", *Sustainability*, Vol. 7 No. 2, pp. 1429-1445.
- Gonçalves, P., Hines, J. and Serman, J. (2005), "The impact of endogenous demand on push-pull production system", *System Dynamics Review*, Vol. 21 No. 3, pp. 187-216.
- 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.
- Gray, R. (2020), "Agriculture, transportation, and the COVID-19 crisis", *Canadian Journal of Agricultural Economics*, Vol. 68 No. 2, pp. 239-243, doi: [10.1111/cjag.12235](https://doi.org/10.1111/cjag.12235).
- Griffin, M., Sobal, J. and Lyson, T.A. (2009), "An analysis of a community food waste stream", *Agriculture and Human Values*, Vol. 26 Nos 1-2, pp. 67-81.
- Haass, R., Dittmer, P., Veigt, M. and Lütjen, M. (2015), "Reducing food losses and carbon emission by using autonomous control—a simulation study of the intelligent container", *International Journal of Production Economics*, Vol. 164, pp. 400-408.

- Hamilton, H., Henry, R., Rounsevell, M., Moran, D., Cossar, F., Allen, K. and Alexander, P. (2020), "Exploring global food system shocks, scenarios and outcomes", *Futures*, Vol. 123, doi: [10.1016/j.futures.2020.102601](https://doi.org/10.1016/j.futures.2020.102601).
- Hanukov, G., Avinadav, T., Chernonog, T. and Yechiali, U. (2021), "A service system with perishable products where customers are either fastidious or strategic", *International Journal of Production Economics*, Vol. 228, doi: [10.1016/j.ijpe.2020.107696](https://doi.org/10.1016/j.ijpe.2020.107696).
- Heard, B.R., Taiebat, M., Xu, M. and Miller, S.A. (2018), "Sustainability implications of connected and autonomous vehicles for the food supply chain", *Resources, Conservation and Recycling*, Vol. 128, pp. 22-24.
- Heck, S., Campos, H., Barker, I., Okello, J.J., Baral, A., Boy, E. and Birol, E. (2020), "Resilient agri-food systems for nutrition amidst COVID-19: evidence and lessons from food-based approaches to overcome micronutrient deficiency and rebuild livelihoods after crises", *Food Security*, Vol. 12 No. 4, pp. 823-830.
- Heinrich, M., Scotti, F., Booker, A., Fitzgerald, M., Kum, K.Y. and Löbel, K. (2019), "Unlocking high-value botanical value chains: is there a role for blockchain systems?", *Frontiers in Pharmacology*, Vol. 10, doi: [10.3389/fphar.2019.00396](https://doi.org/10.3389/fphar.2019.00396).
- Hendalianpour, A. (2020), "Optimal lot-size and Price of Perishable Goods: a novel game-theoretic model using double interval grey numbers", *Computers and Industrial Engineering*, Vol. 149, doi: [10.1016/j.cie.2020.106780](https://doi.org/10.1016/j.cie.2020.106780).
- Hernandez-Martinez, N., Mutlu, N. and Fransoo, J.C. (2021), "Social equity in supplier-buyer relationships in smallholder agri-food supply chains", *Flexible Services and Manufacturing Journal*, Vol. 33, pp. 1027-1089, doi: [10.1007/s10696-020-09397-1](https://doi.org/10.1007/s10696-020-09397-1).
- Hobbs, J. (2020), "Food supply chains during the COVID-19 pandemic", *Canadian Journal of Agricultural Economics*, Vol. 68, pp. 171-176.
- Holmström, J., Ketokivi, M. and Hameri, A. (2009), "Bridging practice and theory: a design science approach", *Decision Sciences*, Vol. 40 No. 1, pp. 65-87.
- Holmström, J., Liotta, G. and Chaudhuri, A. (2017), "Sustainability outcomes through direct digital manufacturing-based operational practices: a design theory approach", *Journal of Cleaner Production*, Vol. 167, pp. 951-961.
- Holotiuk, F., Pisani, F. and Moormann, J. (2019), "Radicalness of blockchain: an assessment based on its impact on the payments industry", *Technology Analysis and Strategic Management*, Vol. 31 No. 8, pp. 915-928.
- Hrabec, D., Kudela, J., Somplak, R., Nevrlý, V. and Popela, P. (2020), "Circular economy implementation in waste management network design problem: a case study", *Central European Journal of Operations Research*, Vol. 28 No. 4, pp. 1441-1458.
- Hughes, A., Park, A., Kietzmann, J. and Archer-Brown, C. (2019), "Beyond Bitcoin: what blockchain and distributed ledger technologies mean for firms", *Business Horizons*, Vol. 62 No. 3, pp. 273-281.
- Ivanov, D., Sokolov, B., Solovyeva, I., Dolgui, A. and Jie, F. (2015), "Ripple effect in the time-critical food supply chains and recovery policies", *Proceedings of the 15th IFAC Symposium on Information Control Problems in Manufacturing*, Ottawa, May 11-13, 2015.
- Ivert, K.L. and Jonsson, P. (2014), "When should advanced planning and scheduling systems be used in sales and operations planning?", *International Journal of Operations and Production Management*, Vol. 34 No. 10, pp. 1338-1362.
- Jiang, Y. and Zhao, J. (2014), "Co-creating business value of information technology", *Industrial Management and Data Systems*, Vol. 114 No. 1, pp. 53-69.
- Jouzani, J. and Govindan, K. (2021), "On the sustainable perishable food supply chain network design: a dairy products case to achieve sustainable development goals", *Journal of Cleaner Production*, Vol. 278, doi: [10.1016/j.jclepro.2020.123060](https://doi.org/10.1016/j.jclepro.2020.123060).
- Juma, H., Shaalan, K. and Kamel, I. (2019), "A survey on using blockchain in trade supply chain solutions", *IEEE Access*, Vol. 7, pp. 184115-184132.

-
- Kamble, S.S., Gunasekaran, A. and Sharma, R. (2020), "Modeling the blockchain enabled traceability in agriculture supply chain", *International Journal of Information Management*, Vol. 52, p. 101967.
- Kamilaris, A., Fonts, A. and Prenafeta-Boldú, F.X. (2019), "The rise of blockchain technology in agriculture and food supply chains", *Trends in Food Science and Technology*, Vol. 91, pp. 640-652.
- Kandemir, C., Reynolds, C., Tom, Q., Fisher, K., Devine, R., Herszenhorn, E. and Evans, D. (2020), "Using discrete event simulation to explore food wasted in the home", *Journal of Simulation*. doi: [10.1080/17477778.2020.1829515](https://doi.org/10.1080/17477778.2020.1829515).
- Kang, P. and Indra-Payoong, N. (2019), "A framework of blockchain smart contract in fair trade agriculture", *Paper Published at the 9th Panyapiwat National and 2nd International Conference*, Nonthaburi, 5 July, available at: <https://conference.pim.ac.th/thai/wp-content/uploads/2017/09/A-Logistic.pdf> (accessed 15 January 2021).
- Kappelman, A.C. and Sinha, A.K. (2021), "Optimal control in dynamic food supply chains using big data", *Computers and Operations Research*, Vol. 126, doi: [10.1016/j.cor.2020.105117](https://doi.org/10.1016/j.cor.2020.105117).
- Katsikouli, P., Wilde, A.S., Dragoni, N. and Høgh-Jensen, H. (2020), "On the benefits and challenges of blockchains for managing food supply chains", *Journal of the Science of Food and Agriculture*, Vol. 101 No. 6, pp. 2175-2181, doi: [10.1002/jsfa.10883](https://doi.org/10.1002/jsfa.10883).
- Kayikci, Y. (2018), "Sustainability impact of digitization in logistics", *Procedia Manufacturing*, Vol. 21, pp. 782-789.
- Kayikci, Y. (2020), "Blockchain driven supply chain management: the application potential of blockchain technology in supply chain and logistics", in Paksoy, T., Kochan, C.G. and Ali, S.S. (Eds), *Logistics 4.0: Digital Transformation of Supply Chain Management*, CRC Press, Boca Rotan, FL, pp. 146-155.
- Kayikci, Y., Subramanian, N., Dora, M. and Bhatia, M.S. (2020), "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 and Control*. doi: [10.1080/09537287.2020.1810757](https://doi.org/10.1080/09537287.2020.1810757).
- Keogh, J.G., Rejeb, A., Khan, N., Dean, K. and Hand, K.J. (2020), "Optimizing global food supply chains: the case for blockchain and GSI standards", *Building the Future of Food Safety Technology*, pp. 171-204, doi: [10.1016/B978-0-12-818956-6.00017-8](https://doi.org/10.1016/B978-0-12-818956-6.00017-8).
- Khan, S.A., Mubarik, M.S., Kusi-Sarpong, S., Zaman, S.I. and Kazmi, S.H.A. (2021), "Social sustainable supply chains in the food industry: a perspective of an emerging economy", *Corporate Social Responsibility and Environmental Management*, Vol. 28 No. 1, pp. 404-418, doi: [10.1002/csr.2057](https://doi.org/10.1002/csr.2057).
- Kim, H.M. and Laskowski, M. (2018), "Toward an ontology-driven blockchain design for supply-chain provenance", *Intelligent Systems in Accounting, Finance and Management*, Vol. 25 No. 1, pp. 18-27.
- Köhler, S. and Pizzol, M. (2020), "Technology assessment of blockchain-based technologies in the food supply chain", *Journal of Cleaner Production*, Vol. 269, doi: [10.1016/j.jclepro.2020.122193](https://doi.org/10.1016/j.jclepro.2020.122193).
- Konietzko, J., Bocken, N. and Hultink, E.J. (2020), "Circular ecosystem innovation: an initial set of principles", *Journal of Cleaner Production*, Vol. 253, doi: [10.1016/j.jclepro.2019.119942](https://doi.org/10.1016/j.jclepro.2019.119942).
- Kopyto, M., Lechler, S., von der Gracht, H.A. and Hartmann, E. (2020), "Potentials of blockchain technology in supply chain management: long-term judgments of an international expert panel", *Technological Forecasting and Social Change*, Vol. 161, doi: [10.1016/j.techfore.2020.120330](https://doi.org/10.1016/j.techfore.2020.120330).
- 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, doi: [10.1016/j.jclepro.2019.118374](https://doi.org/10.1016/j.jclepro.2019.118374).
- Kshetri, N. (2017), "Blockchain's roles in strengthening cybersecurity and protecting privacy", *Telecommunications Policy*, Vol. 41 No. 10, pp. 1027-1038.
- Kumar, P. and Singh, R.K. (2021), "Strategic framework for developing resilience in Agri-Food Supply Chains during COVID 19 pandemic", *International Journal of Logistics Research and Applications*, pp. 1-24.

- Kumar, A., Mangla, S.K., Kumar, P. and Karamperidis, S. (2019), "Challenges in perishable food supply chains for sustainability management: a developing economy perspective", *Business Strategy and the Environment*, Vol. 29, pp. 809-1831, doi: [10.1002/bse.2470](https://doi.org/10.1002/bse.2470).
- Kumar, A., Mangla, S.K., Kumar, P. and Song, M. (2021), "Mitigate risks in perishable food supply chains: learning from COVID-19", *Technological Forecasting and Social Change*, Vol. 166, doi: [10.1016/j.techfore.2021.120643](https://doi.org/10.1016/j.techfore.2021.120643).
- Li, K., Lee, J. and Gharehgozli, A. (2021), "Blockchain in food supply chains: a literature review and synthesis analysis of platforms, benefits and challenges", *International Journal of Production Research*. doi: [10.1080/00207543.2021.1970849](https://doi.org/10.1080/00207543.2021.1970849).
- Liao, Y., Deschamps, F., Loures, E.D.F.R. and Ramos, L.F.P. (2017), "Past, present and future of Industry 4.0-a systematic literature review and research agenda proposal", *International Journal of Production Research*, Vol. 55 No. 12, pp. 3609-3629.
- Liljestrand, K., Christopher, M. and Andersson, D. (2015), "Using a transport portfolio framework to reduce carbon footprint", *The International Journal of Logistics Management*, Vol. 26 No. 2, pp. 296-312.
- Lim, M.K., Li, Y., Wang, C. and Tseng, M. (2021), "A literature review of blockchain technology applications in supply chains: a comprehensive analysis of themes, methodologies and industries", *Computers and Industrial Engineering*, Vol. 154, doi: [10.1016/j.cie.2021.107133](https://doi.org/10.1016/j.cie.2021.107133).
- Liu, P., Long, Y., Song, H.C. and He, Y.D. (2020), "Investment decision and coordination of green agri-food supply chain considering information service based on blockchain and big data", *Journal of Cleaner Production*, Vol. 277, doi: [10.1016/j.jclepro.2020.123646](https://doi.org/10.1016/j.jclepro.2020.123646).
- Lombardi, M. and Costantino, M. (2020), "A social innovation model for reducing food waste: the case study of an Italian non-profit organization", *Administrative Sciences*, Vol. 10, p. 3, doi: [10.3390/admsci10030045](https://doi.org/10.3390/admsci10030045).
- Lu, H., Mangla, S.K., Hernandez, J.E., Elgueta, S., Zhao, G., Liu, S. and Hunter, L. (2021), "Key operational and institutional factors for improving food safety: a case study from Chile", *Production Planning and Control*, Vol. 32 No. 14, pp. 1248-1264, doi: [10.1080/09537287.2020.1796137](https://doi.org/10.1080/09537287.2020.1796137).
- Lu, Q., Tran, A.B., Weber, I., O'Connor, H., Rimba, P., Xu, X., Staples, M., Zhu, L. and Jeffery, R. (2021), "Integrated model-driven engineering of blockchain applications for business processes and asset management", *Journal of Software: Practice and Experience*, Vol. 51 No. 5, pp. 1059-1079, doi: [10.1002/spe.2931](https://doi.org/10.1002/spe.2931).
- Makhal, A., Robertson, K., Thyne, M. and Miroso, M. (2021), "Normalising the ugly to reduce food waste: exploring the socialisations that form appearance preferences for fresh fruits and vegetables", *Journal of Consumer Behaviour*, Vol. 20 No. 5, pp. 1025-1039, doi: [10.1002/cb.1908](https://doi.org/10.1002/cb.1908).
- Mallidis, I., Vlachos, D., Yakavenka, V. and Eleni, Z. (2020), "Development of a single period inventory planning model for perishable product redistribution", *Annals of Operations Research*, Vol. 294, pp. 697-713.
- Mangla, S.K., Börühan, G., Ersoy, P., Kazancoglu, Y. and Song, M. (2021a), "Impact of information hiding on circular food supply chains in business-to-business context", *Journal of Business Research*, Vol. 135, pp. 1-18, doi: [10.1016/j.jbusres.2021.06.013](https://doi.org/10.1016/j.jbusres.2021.06.013).
- Mangla, S.K., Kazancoglu, Y., Ekinci, E., Liu, M., Ozbiltekin, M. and Sezer, M.D. (2021b), "Using system dynamics to analyze the societal impacts of blockchain technology in milk supply chainsrefer", *Transportation Research Part E: Logistics and Transportation Review*, Vol. 149, doi: [10.1016/j.tre.2021.102289](https://doi.org/10.1016/j.tre.2021.102289).
- Manning, L. (2007), "Food safety and brand equity", *British Food Journal*, Vol. 109 No. 7, pp. 496-510.
- Mao, D., Wang, F., Hao, Z. and Li, H. (2018), "Credit evaluation system based on blockchain for multiple stakeholders in the food supply chain", *International Journal Of Environmental Research and Public Health*, Vol. 15 No. 8, p. 1627.
- Martinez, V., Zhao, M., Blujdea, C., Han, X., Neely, A. and Albores, P. (2019), "Blockchain-driven customer order management", *International Journal of Operations and Production Management*, Vol. 39 Nos 6/7/8, pp. 993-1022.

-
- Melkonyan, A., Gruchmann, T., Lohmar, F., Kamath, V. and Spinler, S. (2020), "Sustainability assessment of last-mile logistics and distribution strategies: the case of local food networks", *International Journal of Production Economics*, Vol. 228, doi: [10.1016/j.ijpe.2020.107746](https://doi.org/10.1016/j.ijpe.2020.107746).
- Minner, S., Battini, D. and Çelebi, D. (2017), "Innovations in production economics", *International Journal of Production Economics*, Vol. 194, pp. 1-2.
- Mishra, R., Singh, R.K. and Subramanian, N. (2021), "Impact of disruptions in agri-food supply chain due to COVID-19 pandemic: contextualised resilience framework to achieve operational excellence", *International Journal of Logistics Management*. doi: [10.1108/IJLM-01-2021-0043](https://doi.org/10.1108/IJLM-01-2021-0043).
- Moon, I., Jeong, Y.J. and Saha, S. (2020), "Investment and coordination decisions in a supply chain of fresh agricultural products", *Operational Research*, Vol. 20 No. 4, pp. 2307-2331.
- Mukherjee, A., Singh, R.K. and Mishra, R. (2021), "Application of blockchain technology for sustainability development in agricultural supply chain: justification framework", *Operations Management Research*. doi: [10.1007/s12063-021-00180-5](https://doi.org/10.1007/s12063-021-00180-5).
- Musavi, M.M. and Bozorgi-Amiri, A. (2017), "A multi-objective sustainable hub location-scheduling problem for perishable food supply chain", *Computers and Industrial Engineering*, Vol. 113, pp. 766-778.
- Naeem, M. (2021a), "Understanding the customer psychology of impulse buying during COVID-19 pandemic: implications for retailers", *International Journal of Retail & Distribution Management*, Vol. 49 No. 3, pp. 377-393, doi: [10.1108/IJRDM-08-2020-0317](https://doi.org/10.1108/IJRDM-08-2020-0317).
- Naeem, M. (2021b), "The role of social media to generate social proof as engaged society for stockpiling behaviour of customers during Covid-19 pandemic", *Qualitative Market Research*, Vol. 24 No. 3, pp. 281-301, doi: [10.1108/QMR-04-2020-0050](https://doi.org/10.1108/QMR-04-2020-0050).
- Narro, C., Roy, D., Okello, J., Avendaño, B., Rich, K. and Thorat, A. (2009), "Public-private partnerships and collective action in high value fruit and vegetable supply chains", *Food Policy*, Vol. 34 No. 1, pp. 8-15.
- O'Leary, D.E. (2017), "Configuring blockchain architectures for transaction information in blockchain consortiums: the case of accounting and supply chain systems", *Intelligent Systems in Accounting, Finance and Management*, Vol. 24 No. 4, pp. 138-147.
- OECD (2020), "Food supply chains and COVID-19: impacts and policy lessons", OECD Policy Responses to Coronavirus (COVID-19), 2 June, available at: <https://www.oecd.org/coronavirus/policy-responses/food-supply-chains-and-covid-19-impacts-and-policy-lessons-71b57aea/> (accessed 2 January 2021).
- Oh, J. and Shong, I. (2017), "A case study on business model innovations using Blockchain: focusing on financial institutions", *Asia Pacific Journal of Innovation and Entrepreneurship*, Vol. 11 No. 3, pp. 335-344.
- Osmanoglu, M., Tugrul, B., Dogantuna, T. and Bostanci, E. (2020), "An effective yield estimation system based on blockchain technology", *IEEE Transactions on Engineering Management*, Vol. 67 No. 4, pp. 1157-1168, doi: [10.1109/TEM.2020.2978829](https://doi.org/10.1109/TEM.2020.2978829).
- Pal, A. and Kant, K. (2019), "Internet of perishable logistics: building smart fresh food supply chain networks", *IEEE Access*, Vol. 7, pp. 17675-17695.
- Pant, R.R., Prakash, G. and Farooque, J.A. (2015), "A framework for traceability and transparency in the dairy supply chain networks", *Procedia - Social and Behavioral Sciences*, Vol. 189, pp. 385-394, doi: [10.1016/j.sbspro.2015.03.235](https://doi.org/10.1016/j.sbspro.2015.03.235).
- Patidar, R. and Agrawal, S. (2020), "A mathematical model formulation to design a traditional Indian agri-fresh food supply chain: a case study problem", *Benchmarking: An International Journal*, Vol. 27 No. 8, pp. 2341-2363, doi: [10.1108/BIJ-01-2020-0013](https://doi.org/10.1108/BIJ-01-2020-0013).
- Pawson, R.N.S. and Tilley, N. (1997), *Realistic Evaluation*, Sage Publications, London.
- Pilbeam, C., Denyer, D., Doherty, N. and Davidson, R. (2019), "Designing safer working interventions through a literature review using a mechanisms-based approach", *Safety Science*, Vol. 120, pp. 352-361.

- Qian, X. and Papadonikolaki, E. (2021), "Shifting trust in construction supply chains through blockchain technology", *Engineering, Construction and Architectural Management*, Vol. 28 No. 2, pp. 584-602, doi: [10.1108/ECAM-12-2019-0676](https://doi.org/10.1108/ECAM-12-2019-0676).
- Qu, T., Thüerer, M., Wang, J., Wang, Z., Fu, H., Li, C. and Huang, G.Q. (2017), "System dynamics analysis for an Internet-of-Things-enabled production logistics system", *International Journal of Production Research*, Vol. 55 No. 9, pp. 2622-2649, doi: [10.1080/00207543.2016.1173738](https://doi.org/10.1080/00207543.2016.1173738).
- Rahimi, M., Baboli, A. and Rezik, Y. (2017), "Multi-objective inventory routing problem: a stochastic model to consider profit, service level and green criteria", *Transportation Research Part E*, Vol. 101, pp. 59-83.
- Rais, M., Kaul, A. and Jain, A. (2019), "Evaluation of public private partnerships in perishable food supply chain in India", *Journal of Supply Chain Management Systems*, Vol. 8 No. 2, pp. 52-63.
- Rajwani, T. and Liedong, T.H. (2015), "Political activity and firm performance within nonmarket research: a review and international comparative assessment", *Journal of World Business*, Vol. 50 No. 2, pp. 273-283.
- Ramos, E., Patrucco, A.S. and Chavez, M. (2021), "Dynamic capabilities in the "new normal": a study of organizational flexibility, integration and agility in the Peruvian coffee supply chain", *Supply Chain Management*. doi: [10.1108/SCM-12-2020-0620](https://doi.org/10.1108/SCM-12-2020-0620).
- Reich, J., Kinra, A., Kotzab, H. and Brusset, X. (2021), "Strategic global supply chain network design – how decision analysis combining MILP and AHP on a Pareto front can improve decision-making", *International Journal of Production Research*, Vol. 59 No. 5, pp. 1557-1572.
- Richey, R.G., Morgan, T.R., Lindsey-Hall, K. and Adams, F.G. (2016), "A global exploration of Big Data in the supply chain: global exploration of Big Data", *International Journal of Physical Distribution and Logistics Management*, Vol. 46 No. 8, pp. 710-739.
- Rijanto, A. (2021), "Business financing and blockchain technology adoption in agroindustry", *Journal of Science and Technology Policy Management*, Vol. 12 No. 2, pp. 215-235, doi: [10.1108/JSTPM-03-2020-0065](https://doi.org/10.1108/JSTPM-03-2020-0065).
- Rogerson, M. and Parry, G.C. (2020), "Blockchain: case studies in food supply chain visibility", *Supply Chain Management*, Vol. 25 No. 5, pp. 601-614, doi: [10.1108/SCM-08-2019-0300](https://doi.org/10.1108/SCM-08-2019-0300).
- Rohm, H., Oostindjer, M., Aschemann-Witzel, J., Symmank, C.L., Almli, V., De Hooge, I.E. and Karantininis, K. (2017), "Consumers in a sustainable food supply chain (COSUS): understanding consumer behavior to encourage food waste reduction", *Foods*, Vol. 6 No. 12, p. 104.
- Rume, T. and Islam, S.D.U. (2020), "Environmental effects of COVID-19 pandemic and potential strategies of sustainability", *Heliyon*, Vol. 6 No. 9, doi: [10.1016/j.heliyon.2020.e04965](https://doi.org/10.1016/j.heliyon.2020.e04965).
- Saif, A. and Elhedhli, S. (2016), "Cold supply chain design with environmental considerations: a simulation-optimization approach", *European Journal of Operational Research*, Vol. 251 No. 1, pp. 274-287.
- Sander, F., Semeijn, J. and Mahr, D. (2018), "The acceptance of blockchain technology in meat traceability and transparency", *British Food Journal*, Vol. 120 No. 9, pp. 2066-2079.
- Santti, U., Eskelinen, T., Rajahonka, M., Villman, K. and Happonen, A. (2017), "Effects of business model development projects on organizational culture: a multiple case study of SMEs", *Technology Innovation Management Review*, Vol. 7 No. 8, pp. 15-26.
- Saurabh, S. and Dey, K. (2021), "Blockchain technology adoption, architecture, and sustainable agri-food supply chains", *Journal of Cleaner Production*, Vol. 284, p. 124731, doi: [10.1016/j.jclepro.2020.124731](https://doi.org/10.1016/j.jclepro.2020.124731).
- Sehnm, S., Jabbour, C.J.C., Pereira, S.C.F. and de Sousa Jabbour, A.B.L. (2019), "Improving sustainable supply chains performance through operational excellence: circular economy approach", *Resources, Conservation and Recycling*, Vol. 149, pp. 236-248.
- Seth, J. (2020), "Impact of Covid-19 on consumer behavior: will the old habits return or die?", *Journal of Business Research*, Vol. 117, pp. 280-283.

-
- Shanker, S., Barve, A., Muduli, K., Kumar, A., Garza-Reyes, J.A. and Joshi, S. (2021), "Enhancing resiliency of perishable product supply chains in the context of the COVID-19 outbreak", *International Journal of Logistics Research and Applications*. doi: [10.1080/13675567.2021.1893671](https://doi.org/10.1080/13675567.2021.1893671).
- Shoab, M., Lim, M.K. and Wang, C. (2020), "An integrated framework to prioritize blockchain-based supply chain success factors", *Industrial Management and Data Systems*, Vol. 120 No. 11, pp. 2103-2131.
- Siddh, M.M., Soni, G., Jain, R. and Sharma, M.K. (2018), "Structural model of perishable food supply chain quality (PFSCQ) to improve sustainable organizational performance", *Benchmarking: An International Journal*, Vol. 25 No. 7, pp. 2272-2317.
- Singh, A., Thakkar, J. and Jenamani, M. (2019), "An integrated Grey-DEMATEL approach for evaluating ICT adoption barriers in manufacturing SMEs: analysing Indian MSMEs", *Journal of Enterprise Information Management*. doi: [10.1108/JEIM-09-2018-0211](https://doi.org/10.1108/JEIM-09-2018-0211).
- Spain, C.V., Freund, D., Mohan-Gibbons, H., Meadow, R.G. and Beacham, L. (2018), "Are they buying it? United States consumers' changing attitudes toward more humanely raised meat, eggs, and dairy", *Animals*, Vol. 8, p. 8, doi: [10.3390/ani8080128](https://doi.org/10.3390/ani8080128).
- Sterman, J.D. and Dogan, G. (2015), "I'm not hoarding, I'm just stocking up before the hoarders get here: behavioral causes of phantom ordering in supply chains", *Journal of Operations Management*, Vol. 39, pp. 6-22.
- Stranieri, S., Riccardi, F., Meuwissen, M.P. and Soregaroli, C. (2021), "Exploring the impact of blockchain on the performance of agri-food supply chains", *Food Control*, Vol. 119, doi: [10.1016/j.foodcont.2020.107495](https://doi.org/10.1016/j.foodcont.2020.107495).
- Strozzi, F., Colicchia, C., Creazza, A. and Noè, C. (2017), "Literature review on the 'smart factory' concept using bibliometric tools", *International Journal of Production Research*, Vol. 55 No. 22, pp. 1-20.
- Subramanian, N., Chaudhuri, A. and Kayikci, Y. (2020), *Blockchain and Supply Chain Logistics: Evolutionary Case Studies*, Springer Nature, Cham.
- Sumrin, S., Gupta, S., Asaad, Y., Wang, Y.C., Bhattacharya, S. and Foroudi, P. (2021), "Eco-innovation for environment and waste prevention", *Journal of Business Research*, Vol. 122, pp. 627-639.
- Sundgren, C. (2020), "Supply chain structures for distributing surplus food", *The International Journal of Logistics Management*, Vol. 31 No. 4, pp. 865-883.
- Tanila, T., Tenhunen, H. and Hirvonen, P. (2020), "Value mechanisms in the implementation of intelligent patient flow management system - a multiple case study", *Studies in Health Technology and Informatics*, Vol. 270, pp. 708-712.
- Tao, Q., Cui, X., Huang, X., Leigh, A.M. and Gu, H. (2019), "Food safety supervision system based on hierarchical multi-domain blockchain network", *IEEE Access*, Vol. 7, pp. 51817-51826, doi: [10.1109/ACCESS.2019.2911265](https://doi.org/10.1109/ACCESS.2019.2911265).
- Tian, F. (2016), "An agri-food supply chain traceability system for China based on RFID & blockchain technology", *2016 13th International Conference on Service Systems and Service Management (ICSSSM)*, pp. 1-6, doi: [10.1109/ICSSSM.2016.7538424](https://doi.org/10.1109/ICSSSM.2016.7538424).
- Tönmissen, S. and Teuteberg, F. (2020), "Analysing the impact of blockchain-technology for operations and supply chain management: an explanatory model drawn from multiple case studies", *International Journal of Information Management*, Vol. 52, doi: [10.1016/j.ijinfomgt.2019.05.009](https://doi.org/10.1016/j.ijinfomgt.2019.05.009).
- Toussaint, M., Cabanelas, P. and Blanco-González, A. (2020), "Social sustainability in the food value chain: an integrative approach beyond corporate social responsibility", *Corporate Social Responsibility and Environmental Management*, Vol. 28, pp. 103-115, doi: [10.1002/csr.2035](https://doi.org/10.1002/csr.2035).
- Tran-Dang, H., Krommenacker, N. and Charpentier, P. (2017), "Containers monitoring through the Physical Internet: a spatial 3D model based on wireless sensor networks", *International Journal of Production Research*, Vol. 55 No. 9, pp. 2650-2663.
- Treiblmaier, H. (2018), "The impact of the blockchain on the supply chain: a theory-based research framework and a call for action", *Supply Chain Management: An International Journal*, Vol. 23 No. 6, pp. 545-559.

- Treiblmaier, H. (2019), "Toward more rigorous blockchain research: recommendations for writing blockchain case studies", *Frontiers in Blockchain*, Vol. 2, doi: [10.3389/fbloc.2019.00003](https://doi.org/10.3389/fbloc.2019.00003).
- Tsang, Y.P., Wu, C.H., Lam, H.Y., Choy, K.L. and Ho, G.T.S. (2021), "Integrating Internet of Things and multi-temperature delivery planning for perishable food logistics: a model and application", *International Journal of Production Research*, Vol. 59 No. 5, pp. 1534-1556, doi: [10.1080/00207543.2020.1841315](https://doi.org/10.1080/00207543.2020.1841315).
- Tse, D., Zhang, B., Yang, Y., Cheng, C. and Mu, H. (2017), "Blockchain application in food supply information security", *2017 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)*, Singapore, pp. 1357-1361.
- U4SSC (2020), "Blockchain for smart sustainable cities", ISBN: 978-92-61-32121-5, available at: https://www.itu.int/dms_pub/itu-t/opb/tut/T-TUT-SMARTCITY-2020-54-PDF-E.pdf (accessed 15 March 2021).
- Upadhyay, N. (2020), "Demystifying blockchain: a critical analysis of challenges, applications and opportunities", *International Journal of Information Management*, Vol. 54, doi: [10.1016/j.ijinfomgt.2020.102120](https://doi.org/10.1016/j.ijinfomgt.2020.102120).
- Van Aken, J.E. (2007), "Design science and organization development interventions: aligning business and humanistic values", *The Journal of Applied Behavioral Science*, Vol. 43 No. 1, pp. 67-88.
- Van Aken, J., Chandrasekaran, A. and Halman, J. (2016), "Conducting and publishing design science research", *Journal of Operations Management*, Vols 47-48, pp. 1-8.
- Varriale, V., Cammarano, A., Michelino, F. and Caputo, M. (2021), "New organizational changes with blockchain: a focus on the supply chain", *Journal of Organizational Change Management*, Vol. 34 No. 2, pp. 420-438.
- Vivaldini, M. (2021), "Blockchain in operations for food service distribution: steps before implementation", *International Journal of Logistics Management*, Vol. 32 No. 3, pp. 995-1029.
- Wang, Y. and Yang, Y. (2020), "Research on agricultural food safety based on blockchain technology", *Journal of Physics: Conference Series*, Vol. 1606, p. 012013, The 2020 International Conference on 5G Mobile Communication and Information Science (MCIS-5G), 26-28 June 2020, Guangzhou, China.
- Wang, J. and Yue, H. (2017), "Food safety pre-warning system based on data mining for a sustainable food supply chain", *Food Control*, Vol. 73, Part B, pp. 223-229.
- Wang, M. and Zhao, L.D. (2021), "Cold chain investment and pricing decisions in a fresh food supply chain", *International Transactions in Operational Research*, Vol. 28 No. 2, pp. 1074-1097.
- Wang, X., Fan, Z.P. and Liu, Z. (2016), "Optimal markdown policy of perishable food under the consumer price fairness perception", *International Journal of Production Research*, Vol. 54 No. 19, pp. 5811-5828.
- Wang, S., Tao, F., Shi, Y. and Wen, H. (2017), "Optimization of vehicle routing problem with time windows for cold chain logistics based on carbon tax", *Sustainability*, Vol. 9 No. 5, p. 694.
- Wang, Y., Han, J.H. and Beynon-Davies, P. (2019a), "Understanding blockchain technology for future supply chains: a systematic literature review and research agenda", *Supply Chain Management*, Vol. 24 No. 1, pp. 62-84.
- Wang, L., Luo, X.R. and Lee, F. (2019b), "Unveiling the interplay between blockchain and loyalty program participation: a qualitative approach based on Bubichain", *International Journal of Information Management*, Vol. 49, pp. 397-410.
- Wang, Y., Singgih, M., Wang, J. and Rit, M. (2019c), "Making sense of blockchain technology: how will it transform supply chains?", *International Journal of Production Economics*, Vol. 211, pp. 221-236.
- Xiao, Y. and Yang, S. (2017), "The retail chain design for perishable food: the case of price strategy and shelf space allocation", *Sustainability*, Vol. 9 No. 1, doi: [10.3390/su9010012](https://doi.org/10.3390/su9010012).

-
- Xue, X., Dou, J. and Shang, Y. (2021), "Blockchain-driven supply chain decentralized operations – information sharing perspective", *Business Process Management Journal*, Vol. 27 No. 1, pp. 184-203, doi: [10.1108/BPMJ-12-2019-0518](https://doi.org/10.1108/BPMJ-12-2019-0518).
- Yadav, G. and Desai, T.N. (2016), "Lean Six Sigma: a categorized review of the literature", *International Journal of Lean Six Sigma*, Vol. 7 No. 1, pp. 2-24.
- Yadav, S. and Singh, S.P. (2020), "Blockchain critical success factors for sustainable supply chain", *Resources, Conservation and Recycling*, Vol. 152, doi: [10.1016/j.resconrec.2019.104505](https://doi.org/10.1016/j.resconrec.2019.104505).
- Yakavenka, V., Vlachos, D. and Bechtsis, D. (2018), "Blockchain impact on food supply chains: a Critical Taxonomy", *MIBES Transactions*, Vol. 12 No. 1, pp. 221-228.
- Yang, S., Xiao, Y. and Kuo, Y.H. (2017a), "The supply chain design for perishable food with stochastic demand", *Sustainability*, Vol. 9 No. 7, pp. 1-12.
- Yang, Y., Pan, S. and Ballot, E. (2017b), "Innovative vendor-managed inventory strategy exploiting interconnected logistics services in the Physical Internet", *International Journal of Production Research*, Vol. 55 No. 9, pp. 2685-2702.
- Yiannas, F. (2018), "A new era of food transparency powered by blockchain", *Innovations: Technology, Governance, Globalization*, Vol. 12 Nos 1-2, pp. 46-56.
- Yu, K., Luo, B.N., Feng, X. and Liu, J. (2018), "Supply chain information integration, flexibility, and operational performance: an archival search and content analysis", *The International Journal of Logistics Management*, Vol. 29 No. 1, pp. 340-364.
- Zanoni, S. and Zavanella, L. (2012), "Chilled or frozen? Decision strategies for sustainable food supply chains", *International Journal of Production Economics*, Vol. 140 No. 2, pp. 731-736, doi: [10.1016/j.ijpe.2011.04.028](https://doi.org/10.1016/j.ijpe.2011.04.028).
- Zhang, W.B. and Su, Q. (2020), "Quality visibility improvement with effort alignment and cost-sharing policies in a food supply chain", *Mathematical Problems in Engineering*, Vol. 2020, doi: [10.1155/2020/8918139](https://doi.org/10.1155/2020/8918139).
- Zhu, L. (2017), "Economic analysis of a traceability system for a two-level perishable food supply chain", *Sustainability*, Vol. 9 No. 5, doi: [10.3390/su9050682](https://doi.org/10.3390/su9050682).
- Zucchi, G., Iori, M. and Subramanian, A. (2020), "Personnel scheduling during Covid-19 pandemic", *Optimization Letters*, pp. 1-12, doi: [10.1007/s11590-020-01648-2](https://doi.org/10.1007/s11590-020-01648-2).

Corresponding author

Yasanur Kayikci can be contacted at: yasanur.kayikci@gmail.com; yk327@sussex.ac.uk

	Context 1	Interventions	Mechanisms	Outcomes
Downstream	Food Quality Food Provenance & Fraud Threat Food Safety & Hygiene Food Recall	Primary Capabilities: Visibility, Traceability Supporting Capabilities: Smart Contracts Disintermediation/Decentralisation	Detect=> Information, Technology React=> Responsiveness	Economic: Brand equity Social: Food Safety Environmental: Minimization of Food Waste
	Supply- Demand Mismatch Food Loss & Waste Life Cycle Management & Shelf Management Production planning & Personnel scheduling	Primary Capabilities: Immutability & Transparency, Traceability Supporting Capabilities: Integration/interoperability	Detect=> Information, Technology React=> Efficiency Responsiveness Flexibility Collaboration	Economic: No Supply- Demand Mismatch Social: Food Accessibility Environmental: Minimization of Food Waste
	Liquidity	Primary Capabilities: Consensus mechanism, Smart contracts Supporting Capabilities: Integration/interoperability, Consensus mechanism, Smart contracts	Detect=> Information, Technology React=> Collaboration	Economic: Improved Liquidity Social: Food security
WIP	Food Quality Food Provenance & Fraud Threat Food Safety & Hygiene Food Recall	Primary Capabilities: Visibility, Traceability Supporting Capabilities: Smart Contracts Disintermediation/Decentralisation	Detect=> Information, Technology React=> Responsiveness	Economic: Brand equity Social: Food Safety Environmental: Minimization of Food Waste
	Supply- Demand Mismatch Food Loss & Waste Life Cycle Management & Shelf Management Production planning & Personnel scheduling	Primary Capabilities: Immutability & Transparency, Traceability Supporting Capabilities: Integration/interoperability	Detect=> Information, Technology React=> Efficiency Responsiveness Flexibility Collaboration	Economic: No Supply- Demand Mismatch Social: Food Accessibility Environmental: Minimization of Food Waste
Upstream	Food Quality Food Safety & Hygiene	Primary Capabilities: Visibility, Traceability	Detect=> Information, Technology React=> Responsiveness	Economic: Consumer Trust Social: Food Safety Environmental: Minimization of Food Waste
	Supply- Demand Mismatch Food Loss & Waste Production planning & Personnel scheduling	Primary Capabilities: Immutability & Transparency, Traceability	Detect=> Information, Technology React=> Flexibility	Economic: No Supply- Demand Mismatch Social: Food Accessibility Environmental: Minimization of Food Waste
	Financing Operating Costs Liquidity	Primary Capabilities: Consensus mechanism, Smart contracts Supporting Capabilities: Integration/interoperability, Consensus mechanism, Smart contracts	Detect=> Information, Technology React=> Collaboration	Economic: Better Financing, Lower Operating Costs, Improved Liquidity Social: Food security

Table A1.
Details on sensitivity analysis