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

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Abstract

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 perishable food supply chain (PFSC) during the pandemics by applying context, interventions, mechanism and outcomes (CIMO-logic).

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

Findings: The findings of this study reveal that blockchain capabilities such as immutability & transparency, visibility, traceability, integration & interoperability, disintermediation & 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 generalization 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: 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

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) describes the impact of the COVID-19 on 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). 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 (Sterman & Dogan 2015; Hobbs 2020; Naeem 2020a, Naeem 2020b). 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 (Thundertech.com 2020).

The grocery store 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 & 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 & 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 food supply chains and supply chains 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 such as 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. Supply chain coordination, supply chain responsiveness, information and resource sharing and digitisation of the process are key to a resilient FSC amid the COVID-19 pandemic (Kumar & Singh, 2021). Mishra *et al.* (2021) emphasized 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; Kayikci 2020; Liu *et al.* 2020; Köhler & Pizzol 2020; Saurabh & Dey 2021). There is growing interest in applying blockchain technology to SC operations (Lim *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 stimulating perspectives for decision-makers throughout the SC.

Blockchain Technology (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 below 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, generalizing 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 contextualize 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 is 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.

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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 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 & 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"}

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 10853, and string 2 returned 9497 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 2348 and 1449. 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.

>INSERT FIGURE 2 HERE<

We categorized 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 optimizing the quality and freshness of the food delivered (Musavi & Bozorgi-Amiri 2017; George *et al.* 2019; Bumblauska *et al.* 2020; Behnke & Janssen 2020). In the COVID-19 era, food safety and hygiene have gained importance. Thus, the ability to supply transparency for hygiene factors (Bastian & Zentes 2013) has become key operational excellence. Zhang & 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 & Arshinder (2016) provide practical insights for improved profitability. A strategic pricing strategy facilitates the maximization 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 & 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.* (2020) proposed a model for location-allocation and 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 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 & Atalan-Helicke 2020; Hamilton *et al.* 2020). Food security, defined as the constant availability of food (Chin 2020; Deaton & Deaton 2020; Heck *et al.* 2020), become an important worldwide concern facing developed and developing countries.

The social aspects of PFSCs can be categorized predominantly into human capital management, corporate social responsibility, collaboration, fair-trade, and ethical practice. Khan *et al.* (2020) 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.* (2020) pointed out that collaborative interorganizational relationships facilitate SC risk mitigation. Hernandez-Martinez *et al.* (2020) 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 marginalization effect and resulting in equitable outcomes for all participants. The optimal markdown model was developed for perishable food pricing to optimize 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.* (2020) 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 & 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 & Accorsi 2017; Govindan *et al.* 2014; Haass *et al.* 2015; Musavi & Bozorgi-Amiri 2017; Rahimi *et al.* 2017; S. 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 & 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) emphasized the importance of understanding consumer behaviour to encourage food waste reduction. Makhal *et al.* (2020) 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 verticalized operations and partnerships between buyers and suppliers facilitate circular economy practices. Lombardi & Costantino (2020) emphasized the importance of building a sense of community for better food redistribution. Mallidis *et al.* (2020) proposed a quantitative decision-making tool that optimizes a retailer's replenishment policy to minimize discarded perishables. Ciulli *et al.* (2020) revealed the importance of digital platform organizations 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 optimize 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 & Atalan-Helicke 2020; Chin 2020; Deaton & 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 & 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.* 2020). 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 minimization of total customers waiting time (Esmaili & Sahraeian 2017) particularly important. Zanoni & 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 minimize the idle time during transportation, distribution, storage, and delivery (Bastian & 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 minimization of the total cost (Saif & Elhedhli 2016; Accorsi *et al.* 2017), operating cost (Bortolini *et al.* 2015), logistics costs (Govindan *et al.* 2014), total travel cost (Esmaili & Sahraeian 2017) transportation cost (Musavi & 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 minimizing emissions versus minimizing cost. Rahimi *et al.* (2017) aim to optimize 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 supply chain capabilities during the COVID-19 pandemic and utilizing partial least square regression and a fuzzy-set qualitative comparative analysis conclude, that organizational flexibility is a driver of higher agility in agri-food supply chains, which positively affects supply chain 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 specialized job roles, further complicates the matter (Gray, 2020). Due to lock downs and travel restrictions, supply-demand mismatch and the risk of product expiry have increased. In order to preserve the shelf life of products (Gallo & 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 & Zhao (2014) advocated that collaboration drives the commercial value accumulation of information technologies in downstream processes. If companies within the SC try to maximize 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 supply chain integration directly impacts the responsiveness of agri-food supply chains 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, supply chain 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 life cycle management and provide historical information to understand patterns for redesigning the FSC. Yu *et al.* (2018) emphasized 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 & Zentes, 2013) gained importance. Companies jeopardize 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, facilitate 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). 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.* 2020). A layered architecture model was proposed for the Internet of Perishable Logistics (Pal & Kant 2019). Kappelman & Sinha (2021) proposed to use big data mining techniques to determine optimal supplier selection, which reduces the rate of rejected products and maximizes 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 2020). In Table 1 we summarize the excellence enabler constructs, variables, and main references.

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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 standardization and reduction in complexity of the job, facilitates improved data safety and decentralization, 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 & Sing 2020).

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 & Shong 2017). Similarly, other research papers (Ahmed & 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; Wang *et al.* 2019b; Wang *et al.* 2019c). Shoaib *et al.* (2020) prioritize accessibility, overall efficiency, trackability, and traceability as the most important success factors of a blockchain-based supply chain.

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 & Janssen 2020; George *et al.* 2019) provenance/authenticity (Bumblauska *et al.* 2020), implementation of food safety pre-warning systems (Wang & Yue 2017). Food quality management can be improved after blockchain adoption (Chen *et al.* 2020).

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 supply chains. (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 *et al.* 2020) and improving recall efficiency (Duan *et al.* 2020). Blockchain applications enable transparency in labelling, presentation, and advertising of foodstuffs, GMO labelling (Bastian & Zentes 2013), minimize consumers' concerns about the authenticity of their intended purchase (Hughes *et al.*2019), and enhance and sustain consumer-based brand equity (Boukis 2019).

2.3.2. Immutability & Transparency

Food security can benefit from BT transparency, relatively low transaction costs, and instant implementation (Ahmed & 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 & Parry 2020). Furthermore, as blockchain networks exist in different formats using different terminologies, coding languages, consensus algorithms, and privacy measures, there is 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 & Mejuto 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.* 2020) 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 & 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 organize 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 *et al.* 2020). 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 centralized 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.* 2020).

2.3.7. Disintermediation/Decentralisation

The appeal and primary feature of blockchain is its decentralization and disintermediation. Decentralisation refers to removing control and decision-making power from a central authority (individual, organization, or group) and transferring it to a distributed network (Kayikci 2020). Therefore, blockchain requires a decentralized 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 (Tönnissen *et al.* 2020). Saurabh & 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 & Janssen 2020). The more data is shared, the higher 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).

The 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.

>INSERT FIGURE 3 HERE<

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 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 subject 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 generalized 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 & 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 & Liedong 2015; Holmström *et al.* 2017; Pilbeam *et al.* 2019; Bin Makhashen *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 & Jonsson 2014; Santti *et al.* 2017; Brusset & 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 summarizes the various application areas of CIMO-logic.

>INSERT TABLE 2 HERE<

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 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 synthesizing previously published research. Figure 4 depicts the rudimentary solution design based on our systematic literature review.

>INSERT FIGURE 4 HERE<

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 food supply chains 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 digitizing the trusted journey of the food product to verify transactions and share, record, and exchange data securely, transparently, decentralized, and efficiently in a distributed ledger system provide it to the stakeholders. This is necessary for the food supply chain 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 food supply chains 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, invited them for an interview. The food supply chain is a global cocoa supply chain, 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, 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 finalized 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.

>INSERT FIGURE 5 HERE<

4.CIMO Analysis of the Selected Use-Case

4.1. Food Loss and Waste

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-consumers' 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 the information holds true on the 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 organizations 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, 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 life cycle management.

4.2. Food Quality & 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 fertilizer 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 digitization 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 utilize 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 a 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, optimizing 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 enables farmers and producers to identify inefficiencies, and allows decreased input and labour cost. Blockchain utilizes 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.

>INSERT TABLE 3 HERE<

5. Results

5.1. Sustainable Operational Excellence Outcomes

Blockchain-driven PFSC offers greater potential to achieve operational excellence for ecosystem participants in performance and life-cycle 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 supply chain 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 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 optimize their operating costs with higher crops, lower livestock losses, less water usage, and utilize their capacities through smart contracts which facilitate the collaboration of cross-organizational 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.

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 & 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:

>INSERT TABLE 4 HERE<

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 & 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 & 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 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 summarizes the analysis of the whole PFSC with three operational stages of PFSC for the aforementioned five propositions and the details are depicted in the Appendix.

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 & 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 life cycle 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 enact 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.

>INSERT TABLE 5 HERE<

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, Lee & Gharehgozli (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 & 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 supply chain resilience during outbreaks. Kumar & 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-food supply chains as supply chain correlation, supply chain responsiveness, coordination between stakeholders, information, and resource sharing, digitisation of the process, which are in turn all interlinked. Mishra *et al.* (2021) emphasize 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 supply chain 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 & Singh *et al.* (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 utilizing 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 supply chain 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 organizational 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 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 supply chain), as its implementation can help improve supply chain performance such as reducing crop losses, improving yields, decreasing transaction time and cost, optimizing product storage, avoiding food contamination & spoilage, improve recall efficiency, manage operational risks and maximize profits and provide sustainability benefits such as promote fair trade, track carbon emissions, minimize food loss & waste. Blockchain capabilities, such as traceability/visibility, immutability & 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 generalization 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 supply chain and within the organization. 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 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 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 supply chain compared to the backward supply chain. Second, the packaging of cocoa products is not recyclable & reclaimable, and the investigated cocoa supply chain does not engage in circular economy activities. COP 26 has emphasized 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.

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APPENDIX – Details on Sensitivity Analysis

Downstream	**Context 1**	**Interventions**	**Mechanisms**	**Outcomes**
	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
	Context 2	**Interventions**	**Mechanisms**	**Outcomes**
	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
	Context 3	**Interventions**	**Mechanisms**	**Outcomes**
	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	**Context 1**	**Interventions**	**Mechanisms**	**Outcomes**
	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
	Context 2	**Interventions**	**Mechanisms**	**Outcomes**
	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	**Context 1**	**Interventions**	**Mechanisms**	**Outcomes**
	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
	Context 2	**Interventions**	**Mechanisms**	**Outcomes**
	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
	Context 3	**Interventions**	**Mechanisms**	**Outcomes**
	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 1: Operational Excellence Enablers

Construct	Variables	Main References
Responsiveness	Product availability	Abiral & Atalan-Helicke 2020, Chin 2020; Deaton & Deaton 2020
	Customer response time	Gholami-Zanjani *et al.* 2020, Stranieri *et al.* 2021, Esmaili & Sahraeian 2017, Bumblauska *et al.* 2020
	Food & Loss Waste	Tian 2016, Astill 2019, Astarita *et al.* 2020
	Food Recall	Bumblauska *et al.* 2020, Qian *et al.* 2020, Duan *et al.*2020
Efficiency	Cost efficiency	Zanoni & Zavanella 2012, Govindan *et al.* 2014, Bozorgi *et al.* 2014, Bortolini *et al.* 2015, Saif & Elhedhli 2015, Camanzi *et al.* 2017, Accorsi *et al.* 2017, Rahimi *et al.* 2017, Esmaili & Sahraeian 2017, Wang *et al.* 2017, Musavi & Bozorgi-Amiri 2017, Patidar & Agrawal 2020
	Elimination of intermediaries and auditors	Zhu 2017, Bumblauska *et al.* 2020
	Energy consumption & GHG emission	Zanoni & Zavanella 2012, Haass *et al.* 2014, Bozorgi *et al.* 2014, Govindan *et al.* 2014, Bortolini *et al.* 2015, Saif & Elhedhli 2015, Liljestrand *et al.* 2015; Adekomaya *et al.* 2016, Accorsi *et al.* 2017, Camanzi *et al.* 2017, Rahimi *et al.* 2017, Ghadge *et al.* 2017, Wang *et al.* 2017, Gallo & Accorsi 2017, Musavi & Bozorgi-Amiri 2017, Cannas *et al.* 2020, Jouzdani & Govindan 2020, Melkonyan *et al.* 2020
	Resource Recovery & Efficiency	Hrabec *et al.* 2020, Kandemir *et al.* 2020, Krishnan *et al.* 2020, Mallidis *et al.* 2020
Flexibility	Life Cycle Management	Gallo & Accorsi 2017, Yang, Xiao, & Kuo 2017, Chowdhury *et al.* 2020, Hendalianpour 2020
	Shelf Space Management	Gallo & Accorsi 2017, Gholami-Zanjani *et al.* 2020
	Personel Scheduling	Siddh *et al.* 2018, Chowdhury *et al.* 2020; Heck *et al.* 2020, Gray 2020, Moon *et al.* 2020, Zucchi *et al.* 2020
Collaboration	Coordination	Zhang & Su 2020
	Collaboration (Vertical/Horizontal)	Borrero 2019, Juma *et al.*2019, Bumblauska *et al.* 2020, Dania *et al.* 2020, Daghar *et al.* 2020, Dossa *et al.* 2020, Kumar *et al.* 2021, Lu *et al.* 2021, Ramos *et al.* 2021, Wang & Zhao 2021
	Public Private Partnership	Narrod *et al.* 2009, Pant *et al.* 2015, Rais & Jain 2019
	Fairness/ Fair Trade	Wang *et al.* 2016, Tao *et al.* 2019, Katsikouli *et al.* 2019, Bumblauska *et al.* 2020, Hernandez-Martinez *et al.* 2020
Technology	Food Safety & Fraud Threat	Wang & Yue 2017, Juma *et al.* 2019, Katsikouli *et al.* 2019, Bumblauska *et al.* 2020, Behnke & Janssen 2020, George *et al.* 2020
	Food Quality	Musavi & Bozorgi-Amiri 2017, George *et al.* 2019, Bumblauska *et al.* 2020, Behnke & Janssen 2020

	Plant Safety & Hygiene	Bastian & Zentes 2013, Bumblauska *et al.* 2020
Information	Accuracy, accessibility and actuality of SC data	Bastian & Zentes 2013, Xiao *et al.* 2017, Galvez *et al.* 2018, Borrero 2019, Katsikouli *et al.* 2019, Bumblauska *et al.* 2020, Behnke & Janssen 2020, Mangla *et al*. 2021
	Data Security	Richey *et al.* 2016, Fernando *et al.* 2018, Fitzgerald *et al.* 2018
	Digital Continuity	Fazili *et al.* 2017; Liao *et al.* 2017; Minner *et al.* 2017; Qu *et al.* 2017; Strozzi *et al.* 2017; Tran-Dang *et al.* 2017; Yang *et al.* 2017

Table 2: Studies using application areas of CIMO-logic

Authors	Application Area
Rajwani & Liedong (2015)	To present evidence of the impact of Corporate political activity on firm value through a literature review using CIMO-logic
Holmström et al. (2017)	To evaluate the potential of direct digital manufacturing-based practices through a literature review using CIMO-logic
Pilbeam et al. (2019)	To design safer working interventions through a literature review using CIMO-logic
Bin Makhashen et al. (2020)	To explore the role of ambidexterity and coopetition in designing resilient fashion supply chains through a literature review using CIMO-logic
Ivert & 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 et al. (2017)	to explore the effects of business model development project activities on organizational culture through multi-case study using CIMO-logic
Brusset & 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 et al. (2020)	To design an collaborative networks between industrial business associations and SME mediated by digital platforms through case study using CIMO-logic
Konietzko et al. (2020)	To identify principles for circular ecosystem innovation through case study using CIMO-logic
Tanila et al. (2020)	To explain the value formulation of digital health interventions through multi-case study using CIMO-logic
Reich et al. (2021)	To develop a solution framework for global supply chain network design problem through case study using CIMO-logic

Table 3: CIMO Analysis of the Single Use Case for the Supply Chain Participants

Context narrated by PFSC participant	**PFSC participant**	**Intervention** narrated by PFSC participant	**Intervention** **Blockchain Capabilities** synthesized from previously published research	**Mechanism** **Operational Excellence Enablers** synthesized from previously published research	**Outcome** **Sustainable Operational Excellence Outcomes** narrated by PFSC participant
Food Loss	Farmer, Cooperative, Food Processor, Retailer	Additional yields can be announced on the blockchain	Immutability & Transparency	Information, Technology	Supply and demand are matched. Consumers access quality produce, while farmers increase their profits
Food Loss & Waste	Food Processor, Retailer, logistics provider	Digital twin of the PFSC can be created	Immutability & 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 & 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 & 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.

Context narrated by PFSC participant	**PFSC participant**	**Intervention** narrated by PFSC participant	**Intervention**	**Mechanism**	**Outcome**
Fairness & 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
Food Safety & 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 & 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 & Transparency, Integration/ Interoperability, Data Standardisation/ Security/Sharing	Collaboration, Efficiency, Information, Technology	It offers interoperability for all participants.

Context narrated by PFSC participant	**PFSC participant**	**Intervention** narrated by PFSC participant	**Intervention**	**Mechanism**	**Outcome**
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 & 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 & 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	Collaboration	Improves livelihoods of small farmers and producers

Table 4: The Formation of Design Propositions

Context 1	Interventions	Mechanisms	Outcomes
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
Context 2	**Interventions**	**Mechanisms**	**Outcomes**
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
Context 3	**Interventions**	**Mechanisms**	**Outcomes**
Financing Operating Costs Liquidity	Primary Capabilities: Immutability & Transparency 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 5: Sensitivity Analysis

Propositions #	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

Figure 1: Research Design

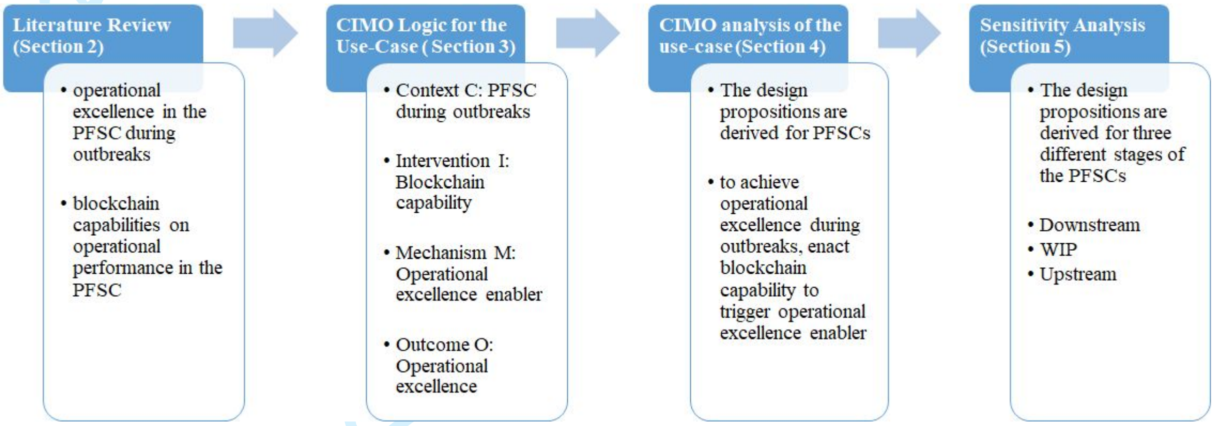


Figure 2: Flowchart for Article Selection

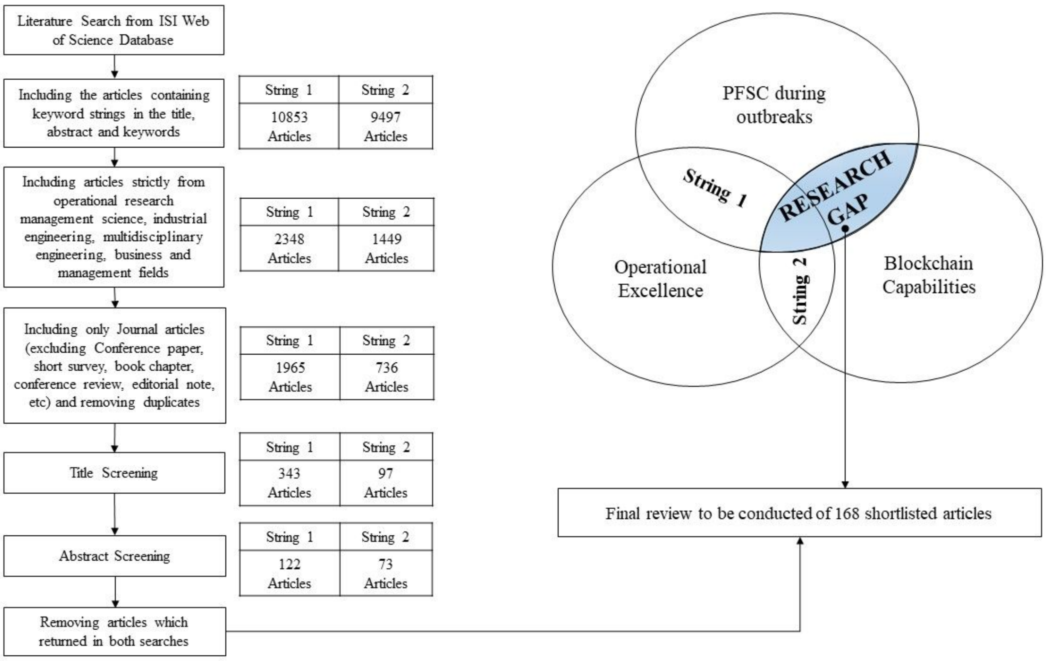


Figure 3: System Dynamics of PFSC during Outbreaks

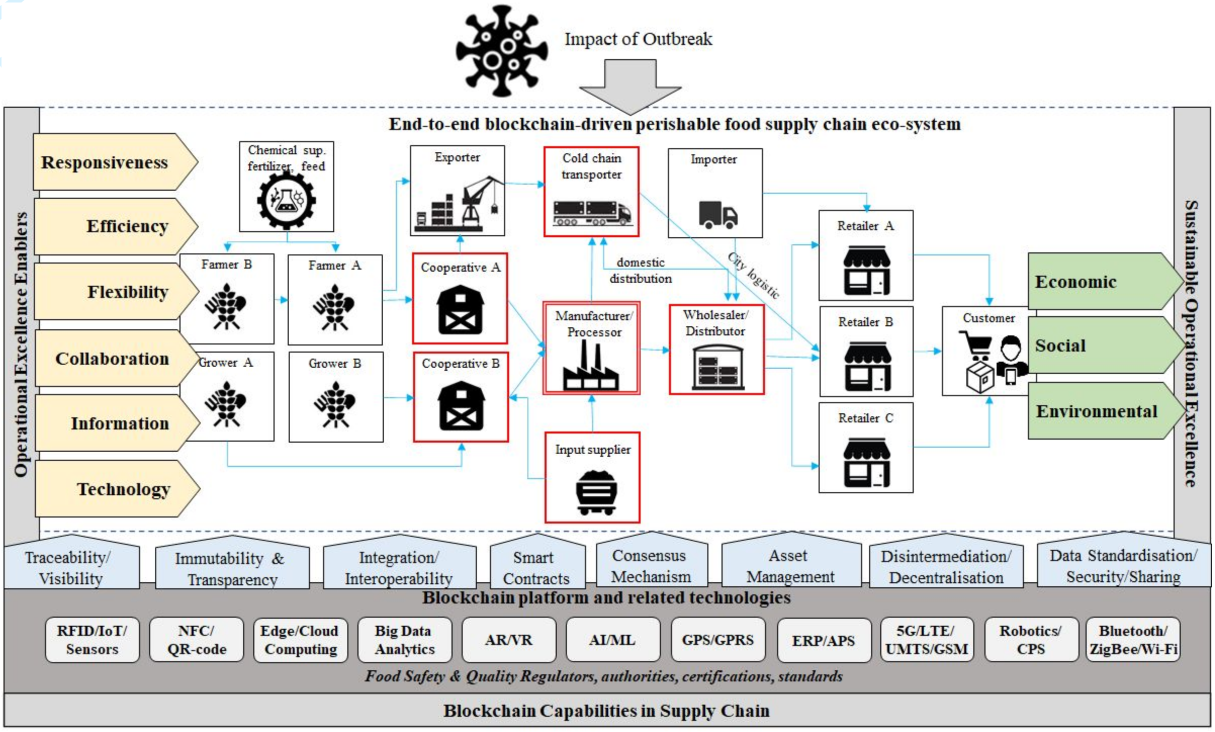
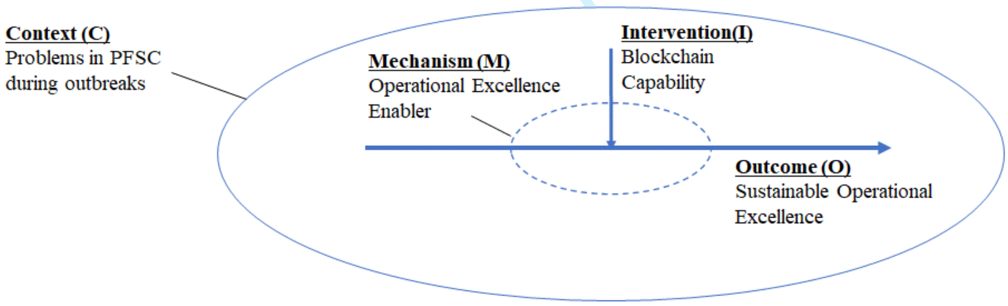


Figure 4: CIMO-Configuration for Use-Case (based on Denyer *et al.* 2008)



Context	Interventions	Mechanisms	Outcomes
• PFSC during COVID-19 outbreak	• Visibility • Immutability • Transparency • Traceability • Asset Management • Integration/Interoperability • Disintermediation/Decentralisation • Consensus mechanism • Smart Contracts	• Efficiency • Responsiveness • Flexibility • Collaboration • Information • Technology	• Economic • Social • Environmental

Figure 5: Flowchart for Use Case Analysis