

# Technological advances in supply chain of processed foods during COVID-19: a review

Zainab Bintay Anis, Rashid Iqbal, Wahab Nazir and Nauman Khalid  
*School of Food and Agricultural Sciences, University of Management and Technology,  
Lahore, Pakistan*

## Abstract

**Purpose** – The novel coronavirus (SARS-CoV-2) variant of 2019 has taken more than 3.8 million lives according to the World Health Organization. To stop the spread of such a deadly and contagious disease, lockdown of varying nature was imposed worldwide. Lockdown, preventive techniques and observation of standard operating procedures (SOPs) have effectively decreased the spread of contagious diseases but have affected various businesses and industries economically. The food industry has been hit hard by different restriction parameters, due to which a disruption in food supply and demand was observed. Therefore, this study aims to study this disruption in the supply chain of processed food.

**Design/methodology/approach** – A comprehensive review was conducted on PubMed, Google Scholar, and Scopus to locate articles on processed foods, food delivery and supply chain. The selected articles were evaluated using the context analysis method.

**Findings** – The pandemic situation has increased the consumption and demand for processed food products from retail stores, and decreased the demand for food service products. These circumstances called for technological advancement in the field of food supply from farm to fork. This study reviews research articles, policies and secondary literature. Several advances have been made to deliver safe, nutritious and wholesome food to consumers. Block chain-based food supply chains, value stream mapping, sustainable supply chain domain and online ordering systems via mobile apps have been discussed in correspondence with information and communication technology (ICT) during COVID-19.

**Research limitations/implications** – This study concludes that the use of advanced software and its adequate knowledge by suppliers, logistics companies and consumers have assisted in handling shocks to the global food system and provided in-time food delivery, traceability, database information and securely processed food to consumers.

**Originality/value** – This study shows the effects of COVID-19 pandemic on global food systems; disruption in food demand and supply chain is overlooked and changed; use of technological advances in food supply chain to tackle pandemic; online food ordering system gained popularity and improved technically.

## Highlights

- (1) The review highlights the effects of the COVID-19 pandemic on global food systems.
- (2) The disruption in food demand and supply chain is overlooked and changed.
- (3) The use of technological advances in the food supply chain to tackle the pandemic.
- (4) The online food ordering system gained popularity and improved technically.

**Keywords** Global food systems, COVID-19, Online services, Processed foods, ICT, Food supply chain

**Paper type** Literature review

## 1. Introduction

Coronavirus disease 2019 (COVID-19) is an infectious disease caused by SARS-CoV-2, mainly affecting the human respiratory system, causing pneumonia and acute respiratory distress



syndrome (ARDS) (Landi *et al.*, 2020). The World Health Organization (WHO) declared COVID-19 as a world pandemic on 11th March 2020 (Cucinotta & Vanelli, 2020). Countries across the world have taken strict measures to stop the transmission of the SARS-CoV-2, preventive measures along with restrictions on daily lives such as social distancing, and temporary closing of markets, offices, schools and universities was exercised in different countries around the world (Maliszewska, Mattoo, & Van Der Mensbrughe, 2020). These government restrictions have drastically changed the food supply chain, although there is no indication that SARS-CoV-2 is a foodborne virus; however, the disruptions to everyday life have caused serious repercussions on what and how people eat and have brought to light important questions on how we can keep food and food handlers safe in the whole supply chain (Cable, Jaykus, Hoelzer, Newton, & Torero, 2021). Among the other impacts, COVID-19 has also revealed the vulnerabilities of global food systems to shocks and crises (Gemelli Against, 2020).

The Global Food System (GFS) is the delivery of food from farms to our tables that interferes with the subjective sustainability of the environment. This is a chain of networks that combines the processes of food production with food consumption including manufacturing, processing, storage, packaging, trade, and delivery of food items along with related business and markets (Frazão, Meade, & Regmi, 2008). With time, such a global food system has been revolutionized by industrialization which has resulted in higher market productivity. However, this revolutionization has also encountered human history with an irregular supply and availability of food in the market (Reardon & Timmer, 2012). The smooth process of supply chain and eradication of hunger in the mass population has become an influential factor in the development of human civilization (Godfray *et al.*, 2010). The GFS has been linked with United Nations' Sustainable Development Goals (SDGs) 2030 for high-value food performance. SDGs are a set of programs that are directed to solve ongoing mankind challenges to ensure economic development, social prosperity and environmental protection. SDGs are global on the horizon, however, they require a constant commitment on a regional and national level to meet the synergies for food security, zero hunger and food supply (Bebbington & Unerman, 2018). The recent trends and research in GFS gives a significant impact on the food supply chain and its management (Alexander *et al.*, 2017). Some many challenges and problems might affect the quality of food products. During food transportation, there is an increased risk of breach of quality, flexibility and safety of food products. From production areas to trade and logistics, the quality of food might decline given the environmental, social and economic conditions, which results in food insecurity (McClements *et al.*, 2021). The major problem in food products is perishable products during the delivery from farmers to processors or retailers, which results in huge economic losses (Minten, Tamru, & Reardon, 2021).

Processed foods are defined as products of food-derived substances (oils, fats, sugars, starch and protein) that contain whole food or a part of whole food, or a combination of such food substances as its ingredients that are not primarily used in culinary preparations, such as coloring agents, flavoring and emulsifiers. These modified products are good in taste, attractive in texture and good in smell along with convenient packaging, and are highly marketed (Monteiro *et al.*, 2019). The importance of processed food in the market is that it is consumed in more than half of the total dietary energy requirement in developed countries (Rauber *et al.*, 2020). The unique characteristics of processed foods are high energy dense (high caloric food) as well as high macronutrient count, especially high in fats and sugars but low essential macronutrient constituents such as protein, dietary fiber, vitamins and minerals. This unequal distribution of food components in ingredients of processed food is due to high profit margin that gives them a low-cost ingredient list, long shelf-life and branded products (Werneck *et al.*, 2021).

With the emergence of processed foods, the food industry has played an important role to support various activities that help to promote businesses and increase market supply (McClements *et al.*, 2021). These simple activities of food products from harvesting, production, storage and delivery to the consumers are governed by legislation and ethics. This legislation requires food industrialists to minimize food loss and maximize their food production efficiency. Although it has been reported that about one-third of the food that is produced is wasted yearly (Corrado & Sala, 2018), another report states that around two third of the wasted food occurs in the food supply chain during harvesting, delivery and storage (Corrado & Sala, 2018). The sustainability of such GFS has been influenced by increased globalization and a growing world. It is important to achieve maximum sustainability throughout the food supply chain, through revolutionized science and technology trends in the food industry (Oliver *et al.*, 2018).

The food supply chain is majorly concerned with the flow of trade associated with economic growth. This association creates a positive and promising relationship with the producer and consumer on food safety and health grounds (Govindan, 2018). The global food transport system regulates smooth food transport along with administrative and infrastructure advancement. Not only this, but the global transport system of food has introduced and implemented a geopolitical transport for a world-class transport solution (Avidiyskiy, Toropova, Fedunin, & Leontyeva, 2019).

To identify the latest trends and technological advancements in the processed food delivery system during a pandemic, a legal approach for study requiring a systematic analysis of research articles, policies and secondary literature has been applied. Current details and data on new technical tools, advancements in already developed models, and mergers of such programs or software systems are discussed and critically reviewed based on the data collected. By searching databases including PubMed, Google Scholar and Scopus, the current review takes into account the body of knowledge about technological advancements in the supply chain of processed foods during COVID-19. A total of 150 articles were chosen because they were pertinent to the current theme, and 60 were eventually chosen and examined. 15 of the 60 articles were on processed foods, while 25 of them dealt with supply chains.

## **2. Food consumption and transport system before the pandemic**

### ***2.1 Food transport system***

The food transport system includes many interconnecting systems that regulate the transfer of raw food materials to processing units and processed food products to markets for consumption. One of these systems include the delivery of the food through courier services from restaurants, store or street food outlets to end consumers within due time (James, 2019). This courier service works on an order system where a customer makes an order through telephone or online (website or apps) or a food ordering company. Orders can be made for any sort of food items such as drinks, main meals, side snacks, desserts or even daily grocery items. The food delivery system requires advancements in technology and is largely dependent on the online system, especially in developed and developing countries. Utmost care is mandatory while dealing with such services for prepacked and cooked food as they are perishable, and could be damaged upon physical or biological contamination (Hailu, 2021).

The food transport system requires continuous food quality monitoring throughout the supply chain till it reaches the consumer (Reardon & Timmer, 2012). For continuous food monitoring, an effective traceability system was the need of the hour. Traceability and determination of ownership are integral parts of the food delivery network to ensure the safety and integrity of food quality and prevent contamination issues (Tian, 2017). Efficient traceability along the food logistics system includes multiple stakeholders' perspectives.

They assuredly for the valuable perspective and relationship among various stakeholders down the supply chain is the basis of various theories (Prajogo & Olhager, 2012). The critical success factor (CSF) theory corroborates (Figure 1) the distinctive features of food, including food quality and safety. CSF theory highlights the factors that are vital for the successful implementation of traceability in logistics systems in the processed food industry (Rosas, Pimenta, Leal, & Schwarzer, 2020). Implementation of a traceability system has diverged in these categories: organizational, environmental and technological.

Globally, food markets are transformed based on the impact of globalization and consumer demand. Globalization in the food industry has resulted in the expansion of food product varieties and retail markets in developed countries. To combat the high pace of global expansion of food varieties and their retail services, the standardization of how the food is produced, packaged, stored and delivered is mandated around the world (Godfray *et al.*, 2010). The food service delivery system has largely impacted the fast-food chains that majorly deal with processed foods, becoming the reason for their rapid growth, popularity and high customer demand. Along with high precautionary measures required for a successful food delivery, energy maintenance is essential (refrigeration, fossil fuels). Energy-efficient methods such as optimum temperature and minimum fossil fuel use are required to ensure food safety and high-quality shelf life (Alexander *et al.*, 2017).

The food supply chain has several segments: (1) upstream, from farms to the food industry; (2) midstream segment, from the food industry to processing and wholesale; and (3) the downstream segment is from wholesale or retailer to consumer. Food transport system modernization has indicated convergence as a valuable component in the food expenditure category. Modernization along the supermarket chains, fast-food services and retailers has transformed the technology involved in these services. The transformation includes extensive connections among stakeholders, infrastructure retrofitting, accountable management roles and a progressive procurement approach (Reardon & Timmer, 2012).

## 2.2 Processed food consumption pattern

In the past few decades, the consumption of processed foods has increased tremendously. A survey has concluded that processed food products account for 25–60% of the total daily energy intake around the world especially in European countries and the US, when supermarkets' income, food intake and household expenses were assessed (Werneck *et al.*, 2021). Processed food products have a variety of food groups on the supermarket shelf that are easily accessible such as breads and buns, desserts, sweet and savory snacks, drinks and beverages, frozen or shelf-stable ready meals and protein-based snacks. Many different processes are used for the production of such products, including extrusion, hydrogenation and hydrolysis (Lin, Teymourian, & Tursini, 2018). Other than some specialized processes,



**Figure 1.**  
CSF theory in food  
logistics system

some additives namely flavoring agents, coloring agents, emulsifiers and stabilizers are used for the production of the final product to develop desired characteristics.

Reports suggest that the huge expansion of food retailers, food service providers and food product varieties around the globe has tremendously increased consumption patterns of processed food, determined by the amount of money spent on these types of processed foods (Tefft, Jonasova, Adjao, & Morgan, 2017). These consumption patterns have been influenced by consumer food preferences and food delivery services along with the development in the perception of taste and diet. Hence, it can be proved that international globalization, ease in transport services and better mechanisms for food safety have affected the food consumption patterns across the world (King *et al.*, 2017).

Table 1 shows the comparison of different food processed groups' consumption at three different economy level countries in Asia i.e. high income, upper middle income and lower-middle income countries by the data collected in 2017. High-income generating countries include Japan, Singapore, Taiwan and South Korea, whereas upper-middle income countries are China, Malaysia and Thailand. Lower-middle income countries include Pakistan, India, Philippines, Indonesia and Vietnam (Baker & Friel, 2014).

**3. Effect of COVID-19 on food consumption patterns, transport system and logistics**

*3.1 COVID-19 and food consumption*

COVID-19 has disrupted many businesses, the food industry is one of them. Food security has been threatened for billions of people by the interference of the virus. Initially, it was reported that the virus has not greatly affected global food security in the first few months of the pandemic situation and that the world has available stocks for a mass population to combat difficult times (Laborde, Martin, Swinnen, & Vos, 2020). However, with the increase in the infection rate of COVID-19, it has been noted that statistics have changed. There are several predictions and ongoing problems associated with global food security suggesting hunger could double in response to a short food supply chain (Gray, 2020).

**Table 1.**  
Comparison of  
processed food groups  
consumption in high  
income, upper-middle  
income and lower-  
middle income  
countries

Processed food groups	Consumption (kg per capita)		
	Developed countries (high income)	Developing countries (upper middle income)	Underdeveloped countries (lower -middle income)
Baked goods	20	15	5
Carbonated soft drinks	25	19	22
Chilled processed food	35	7	10
Ready meals	4	3	3
Confectionary	3	4	2
Dairy	34	17	12
Dried processed food	25	10	6
Frozen processed food	6	5	3
Sweet and savory snacks	4	10	3
Oils and fats	7	6	11
Other processed foods	10	7	5
Total	173	103	82

With the declaration of the outbreak of the infectious disease COVID-19 as a pandemic by WHO (Cucinotta & Vanelli, 2020), several preventive measures were taken, including a worldwide lockdown. This resulted in unhealthy food and diet patterns, such as a sedentary lifestyle, poor diet meal consumption, elevated levels of processed food consumption, and decreased consumption of fruits and vegetables (Werneck *et al.*, 2021). Lockdown on schools, colleges, universities and offices might have affected the economy of the country but the lockdown on food industries and markets has extended its disruption to the basic necessity of life i.e. food. According to a report, about 25% of the reduction in the labor force in food industries has indicated a shortage of food across the globe (Gray, 2020). Mitigation measures are under consideration by research communities and authorities to identify the length of damage caused by lockdown effects during a pandemic. People have shifted to more convenient and affordable food products which are usually low in quality, as the stability of food and its availability is threatened by market insecurity. Some of these threats to the food market have aroused due to the belief that COVID-19 has originated from a meat market, compromising the stands of animal products (Hailu, 2021). A multi-dimensional crisis has been found in the food markets of the world that has affected the financial, health and behavioral characteristics of the food industry and consumers. Revised policies regarding monetary, food and health are in progress with global collaboration (Henry, 2020).

During the COVID-19 pandemic crisis, the food industry has to deal with four significant problems that arise in the food supply chain and logistics system. First, the health risks and concerns among consumers have increased due to the link between a healthier diet with strong immunity, necessary to fight coronavirus in the body. This health concern has urged consumers to adopt a healthier diet with bioactive compounds and functional foods that can lead to increased demand. Second, actors in a food supply chain from producers to consumers are aware of the importance of the safety of food, as it avoids the spread of coronavirus infection. Third, there is a threat to food security that has emerged from the effects of the worldwide lockdown. Fourth, the sustainability of the food system is vulnerable as the environmental, social and economic grounds that surround food are affected by the consequences of the pandemic situation (Chenarides, Manfredo, & Richards, 2021).

### *3.2 Lockdown effect*

As a result of the COVID-19 outbreak, governments across the world imposed a complete and smart lockdown to minimize the spread of coronavirus, which resulted in the disruption in every sector of life including the food supply chain. The global food supply chain has been hit by severe outturn of the pandemic situation. The supply chain is largely affected by the routes of transportation, such as land and air routes which were banned during peak times of coronavirus infection spread. These restrictions on transport and roads have affected other fields of the processed food industry from agriculture i.e. production of food, seed planting and harvesting, all of which can collectively delay the production of enough food. Another report has indicated that there was the deposition of unsold crops and plants i.e. grains, fruits and vegetables because the ban on transport generated a huge loss of income among small farmers and low salary wagers (Gray, 2020; Henry, 2020).

### *3.3 Processed food demand in the market*

Recent studies have demonstrated that COVID-19 has social, economic and environmental developments in the processed food industry. These changes have increased the demand for processed food in retail and wholesale stores in the first half of the year 2020 but have drastically decreased its demand from food service establishments. This study shows that the demand for processed foods by the consumer is dependent on the source from which it is coming (Shafi, Liu, & Ren, 2020). During the lockdown, retail shops were in frequent use, while

the food service establishments were closed. This change in the use of a specific service by consumers has hit the food industry differently. It has been cleared that COVID-19 has not just imposed its impairment on public health, but also on the food supply chain that deals with food demand and supply. However, the food processing industry has been defended by the harsh consequences of the pandemic due to many reasons. First, food is a basic necessity of life, and every individual needs survival food. Second, certain policies during COVID-19 exempted the food industry from complete lockdown, likely, essential things prioritization, proper packaging and strict adherence to safety policies. Third, industries with huge capital and knowledge-intensive i.e. food industries were entitled to fewer outbreaks (Chenarides *et al.*, 2021).

The pandemic has badly hit labor-intensive businesses, which are led by human force. The food industry is one of them, where there are large recruits, laborers and a huge mass in the advantage of it. On the other hand, the food industry has shown resilience to global shocks. Recent studies showed that there was a steady smooth supply of processed food products along with stable prices (Gray, 2020). Other factors that might have been a hand to smooth the supply chain are relatively solid exports and imports of processed food products, limited inflation in the food industry and stronger impacts to improve stock market performance. The pandemic situation has given a new way to understand the importance of food products. The importance of food products is better understood by the application of new strategies, policies and advanced technologies that supports trade practices and resource utilization for underdeveloped areas and underprivileged people (Gunawan, Permatasari, & Tilt, 2020).

Recent studies conclude that the effect of the pandemic and lockdown situation has resulted in an increase in the consumption and demand of processed food from retailers, and a decrease in the demand for food service processed foods (Hailu, 2020, 2021). Studies also confirm that there is a decrease in labor practices and shortage of resources i.e. raw materials and import and export restrictions that have led to the slowdown of processed food production. The consequences of COVID-19 on food industries and the economy showed that the lockdown, SOPs and restrictions have caused fecklessness in the gross domestic product (GDP), especially in food processing units (Shafi *et al.*, 2020).

#### *3.4 Demand and supply disruption*

The demand and supply business of goods has been disrupted to the extent that the pandemic has affected death. It depends on the disruption in the routes, loss of shipments, and uncertainty in the restrictions and policies regarding international border trades. Supply disruptions have been identified in loss of resources during production, disruptions in the labor market, disruption in raw materials and final products supply, economic instability caused by strong restrictive health and safety practices and equipment and cost of rearranging production areas, expanding businesses (Galanakis, Rizou, Aldawoud, Ucak, & Rowan, 2021; McClements *et al.*, 2021). Two of the most vulnerable dimensions which are hit hard by the economic instability caused by the pandemic are production and distribution lines. The restrictive control on public transport, agricultural goods transport and mobility of any equipment has resulted in a shortage of production along with a shortage of labor. Further noticed, all the steps of processed food production and distribution were badly affected, from the production of raw materials to distributing it into processing areas, from local buying of retailers to wholesale and from cross-region supply to cross-border distribution. Food processors supply food products to retailers, wholesale dealers, suppliers and food service enterprises (Aday & Aday, 2020; Pu & Zhong, 2020). The demand for the food products in the market decreased on one hand as the lockdown imposed the shutdown of restaurants, canteens and caterers that resulted in the reduced sale of fruits and vegetables either from the market or being left out at farms because of disrupted routes (Regmi, Takeshima, & Unnevehr, 2008).

According to a study, food has been classified as a basic necessity that is inelastic demand. This inelastic demand property showed that it is not greatly affected by economic instability and exaggerated food demands. This study concludes that food prices are not as much affected by economic conditions amid the pandemic as other goods and services (Hailu, 2020; Obayelu, Obayelu, Bolarinwa, & Oyeyinka, 2021). Multiple shocks have hit the food industry during the pandemic, a few of which are the thickening of borders, persistent pandemic and shortage of labor workforce. First, the thickening of the border means more strict policies for trade and hold on the movement of goods in cross-region and international borders. This thickening of the border has caused irregularity in raw material supply. Second, the increased length of time of the pandemic and persistent lockdown in various regions of the world has caused many problems including travel restrictions, closure of borders and spoilage of unsold food. These disruptions have impaired the supply of labor for transportation and logistics of processed food. Industries have invested to solve such problems that might hinder their food supply by increasing labor shift hours, more incentives and bonuses, and proper usage of operating hours (Lacombe, Quintela, Liao, & Wu, 2021). These discussions showed that, although social distancing and lockdown measures might help to control the number of cases of coronavirus infection these activities have also reduced the labor work, shortage of produced food and reduction in working at the maximum capacity of firms. During crises, demand and supply of processed food, prices and range can be adjusted by firms in response to consumer demand, frequency of delivered items and production setup (Shafi *et al.*, 2020). Annual food production revenue is generated from the sale of processed foods to retailers, wholesale dealers, exports and imports, and related actors in the supply chain. The response to overall stock markets has raised concerns of investors, businessmen and industrialists regarding food distribution.

### *3.5 Supplier relationship, logistic efficiency in the food supply chain*

During COVID-19, practitioners and researchers play a vital role to contribute in the supply chain management and performance. This relationship has two key factors around which the supply chain of processed food is dependent i.e. material and information (King *et al.*, 2017). Earlier studies showed that information and material and how they flow in the supply chain determine logistics efficiency. It has been investigated that for the operational performance of the supply chain and strong bonding among suppliers, producers and partners, both information and material flow is integrated (Prajogo & Olhager, 2012). A study on 232 Australian firms has shown the role of supplier relationships as a driver of integration and efficient logistics. Performance and operational supply chain can be both positively and negatively impacted by information, technology and material flow (Prajogo & Olhager, 2012).

### *3.6 Effect of COVID-19 on the economy, infrastructure and politics*

COVID-19 has imposed some serious and devastating effects on the socio-economic, regional and socio-political aspects across the globe. The COVID-19 crisis has been an after-effect of disruptive time of the length of uncertain decisions and activities. Economic impacts of coronavirus include unemployment, loss of value of pensions or individual savings accounts, huge sale of industries due to bankruptcy, and huge debts for health insurance that has led individuals to work in over-crowded and closed places to earn bread for their family (Amekudzi-Kennedy, Labi, Woodall, Chester, & Singh, 2020). Political impacts which include the bold actions taken by the government to stop the spread of coronavirus have raised questions among different sectors of a population as those actions were strict and might have negatively impacted the lives of people (Avdiyskiy *et al.*, 2019). Some of the decisions were a ban on official work in government and private sectors, a ban on traveling, ban on religious activities in crowded places, all of which have affected the psychological, social and cultural

values of people. These activities have oppressed government protection measures and might play a role in negative political consequences during elections.

The lighter aspect of these crises is the initiative of various digital technologies, accelerated micro-level programs, a globalized supply chain and refined forms of communication (Karabag, 2020). COVID-19 has taught different means to develop a sustainable approach to combat these crises, following are some of the means. First, planning and developmental frameworks should be analytical and comprehensive for long-term and shock-resistant sustainability. Second, the use of a multi-modal transportation system that serves both physical and online modes. Third, the formation of a productive infrastructure strategy that includes tele-activities for better performance. Fourth, sustainable development has a crucial parameter of economic capital that is essential even if it is a non-existential threat. Fifth, global disaster resistance and recovery require the implementation of an effective and leveraged social capital infrastructure. Sustainable resilient infrastructure has developed a relationship between infrastructure and its economic, social, and environmental elements. This relationship has highlighted their importance between them as it minimizes the adverse impacts and provides beneficial impacts on each other (Amekudzi-Kennedy *et al.*, 2020).

### *3.7 Problem of transport in the case of urban, rural and hilly areas*

During COVID-19, not only the inter-region and international border restriction and ban on transport have affected the delivery of food products to the population but the various types of regions/areas, namely, rural, urban and hilly areas have also impacted their influence. For rural transport, the provision of roads that connect villages to markets is essential (Starkey, 2016). Rural households have easy access to markets and stores for buying necessities to grow on their lands that serve as raw materials for the production of processed food and similarly they need quick, steady transport facilities to take their products to the market for sale. Urban areas have more access to processed foods comparatively, but this supply can be disrupted by the restrictions on the transport of raw materials from farms to industries (Tefft *et al.*, 2017). Likely, the hilly areas have an issue while delivering the processed foods but with the advancement in technology and increased construction of roads, the pavement has made this delivery system smooth. During COVID-19, it has been suggested by recent studies that further investigations and mitigation is required for urban management and governance, and transportation in urban design, but the study does not undermine the capacity of rural areas to deal with adverse events (Sharifi & Khavarian-Garmsir, 2020). The short food supply chain (SFSC), a newly developed sustainable supply chain approach, emerged during COVID-19. It enables a direct connection between farmers and consumers by omitting many intermediaries found in complex supply chains. The COVID-19 pandemic's effects on the agri-food supply chain have made it more important than ever to develop strategies that will make the food supply chain more environmentally friendly while also assisting local populations (Cappelli, Cini, & Technology, 2020). Food supply in mountainous and rural areas was aided by the provision of individualized and customized services to customers, organic production via supporting home gardens, and direct interactions between farmers and consumers.

To encourage these kinds of food chains, numerous European Union (EU) member states have created legislative frameworks and incentives. In the framework of the 2009 Action Plan to promote them, France, for instance, specifically defined the idea of a short chain (or "circuit court," as it is known in Italy), and legislative decrees for the regulation of farmers' markets have also been formed there (Kneafsey *et al.*, 2013). Short supply chains may be covered by thematic sub-programs inside rural development programs, according to a proposal made by the European Commission in the "CAP toward 2020" proposals. At the EU level, funding for

this kind of effort comes from rural development initiatives. The European Commission has been asked to prepare a report on a potential new agricultural product quality scheme as part of the recently passed “Agricultural Product Quality Schemes Regulation” (Regulation (EU) No 1151/92) by the European Parliament and the Council.

#### 4. Advantages and disadvantages of food delivery systems

Table 2 shows the advantages and disadvantages of different food delivery/transport systems that are used by retailers, industrialists as well as consumers. The transport system includes platform logistics, a short supply chain and an online delivery system that works on different grounds to deliver finalized products to consumers (Govindan, 2018; Prabhash, 2020). Various types of supply chain systems were analyzed concerning COVID-19. It has been observed that those countries which have less population involved in agriculture like the USA (1%) (NASS, 2017) have suffered a lot during pandemics due to long supply chains and an integrated approach. Similarly, countries like Spain and Italy which rely on the integrated food processing approach also experienced significant harm, and their food supply system was severely compromised (Cappelli *et al.*, 2020; Hobbs, 2020). While on the other hand, countries like Pakistan and India whose very high populations involved in agriculture were less affected due to supply chain issues due to a very high percentage of the short or local supply chain. Similarly, in times of disaster, the European Commission mandated that local food supplies can greatly save the cost of transportation and the time it takes for processed meals to arrive (Clark, 2018).

##### 4.1 Technological advances in the food supply chain

After the declaration of coronavirus as a pandemic around the globe, various countries have decided to develop programs and policies that neither precipitate nor foster the circumstances ahead of such adverse effects in the future as well. Human history is filled with scientific discoveries and innovations in the field of medicine, technology, ethics, and socio-environmental and socio-political system in response to the damages caused by natural or anthropogenic events. One of these innovations has also targeted the food industry and has tremendously changed the way we perceive food (Wright, Kelly, & Chester, 2017). For sustainable development, multiple models reflect the technological advancement in the field. Triple bottom line (TBL) is the most cited, evident and applied model that defines sustainable development. This model refers to indicate the social, environmental and economic dynamics

Food delivery system	Advantages	Disadvantages
Platform logistics system (offline)	Trust worthy Need minimum knowledge to use by consumers Transparent system	Communication problems High transaction cost
Short supply chain	Expanded sources Less fuel consumption Fast processes Make-to-order (less pilling inventory)	Fuel consumption relatively high Unpredictability of supplies Decentralized control High impact of collision
Online delivery system	On time delivery Convenience Ease of payment Offers/Discounts	Needs knowledge to operate Prevalent online fraud Distrust on companies Fake websites

**Table 2.**  
Advantages and  
disadvantages of  
various food delivery  
systems

that aimed to plan and implement programs to advance sustainable development. This model has no universal standard method for calculation. TBL is viewed as a solidity that provides a user manual for the formation of a framework specific to their organization, program, policy and geographic boundary (Slaper & Hall, 2011).

Multiple operations research technologies have found their way to achieving economic, social and environmental sustainability in the food industry. These operational technologies include information and communication technologies (ICTs), apps, Internet of things (IoT) platforms, big data and artificial technology (Liu, Long, Song, & He, 2020). Their function is the collection of data and redistribution of food products to provide better communication between suppliers and consumers. During shock or alterations, the implementation of artificial intelligence could assist farmers and suppliers to connect with markets digitally. Similarly, the execution of ICTs can minimize the delay in transport of processed food at inter-region or of imported products at international borders resulting in an extension of the shelf life of products when implemented during on-farm handling, postharvest, storage and food transportation (Galanakis *et al.*, 2021). For the advancement in the delivery of processed food, many emerging technologies have been identified, a few of which are also assisting the industrialists during the pandemic situation.

#### *4.2 Blockchain-based agriculture and food (agri-food) supply chain*

Blockchain is a method for safe and secure distribution and handling of information about the product, and digital authentication to protect intellectual property rights and to bring transparency to the traceability system in the supply chain (Shahid *et al.*, 2020). Blockchain technology represents an innovative technological approach that encourages a trustless system. This decentralized trustless system involves participants who do not necessarily know each other or other organizations for the system to launch. This digital technology has presented a future for fault-tolerance, transparent, immutable and completely traceable transactions of record among the stakeholders, partners and consumers. Transactions are provided along with a coherent representation of physical assets and transaction executions (Caro, Ali, Vecchio, & Giaffreda, 2018; Pal & Kant, 2019; Shahid *et al.*, 2020). A study has been investigated that suggests the link between agriculture and the food supply chain with blockchain technology. It showed the fusion of a Chinese agriculture plant with the environmental application of big data and blockchain. A green agri-food supply chain has been selected with one producer and one retailer in the research. Demand functions were revised and the model of both producer and retailer was built and revised with the use of International Standard Bibliographic Description (ISBD). A revenue and cost-sharing contract had been forwarded to coordinate the food supply chain. The results showed that ISBD in combination with blockchain can give more financial benefits as the traceability in the system has encouraged to optimization of valuable information and a more transparent approach assists in better delivery of processed food (Liu *et al.*, 2020). Blockchain technology can assist in times of restrictions and ban on physical transport as it provides a pathway to maximize profit economically and transport effectively with its digital system.

#### *4.3 Sustainable food supply chain (SFSC) domain*

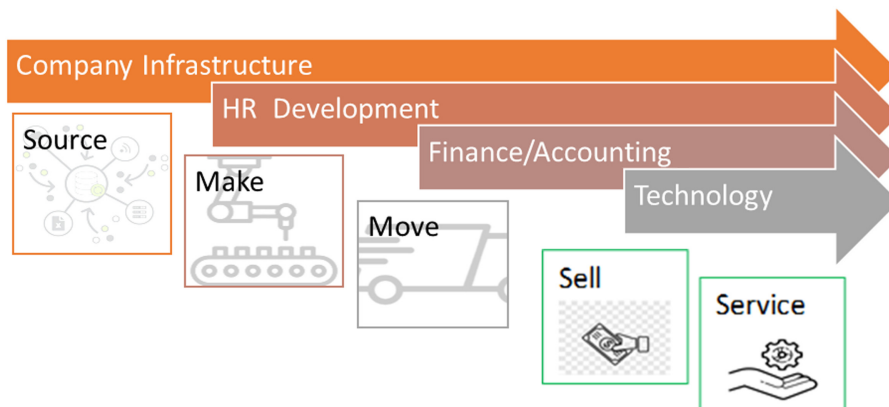
The food supply chain is concerned with the flow of trade associated with economic growth. This association creates a positive and promising relationship with the producer and consumer on food safety and health grounds (James, 2019). A sustainable food supply chain is dependent on primary as well as secondary activities. Primary activities include source, make, move, sell and service. These primary activities are linked with supporting activities i.e. company infrastructure, human resources development, finance and technology. There are different functional areas in a typical manufacturing firm, and the primary activities are

classified into five categories (Figure 2) that are the main source, make, move, sell and service. Source refers to purchasing and procurement, “Make” is about production and packaging. Whereas “Move” refers to transportation and logistics, and “Sell” is about pricing promotion and retailing; and “Services” refers to customer services such as maintenance and support. Domain, in an international supply chain, is essential from source to inbound logistics to make and how they are related from outbound logistics to sell and customer services. For all these primary activities, certain supporting activities are linked i.e. technology. The advancement in technology has assisted in the supply chain domain (Anitha & Patil, 2018).

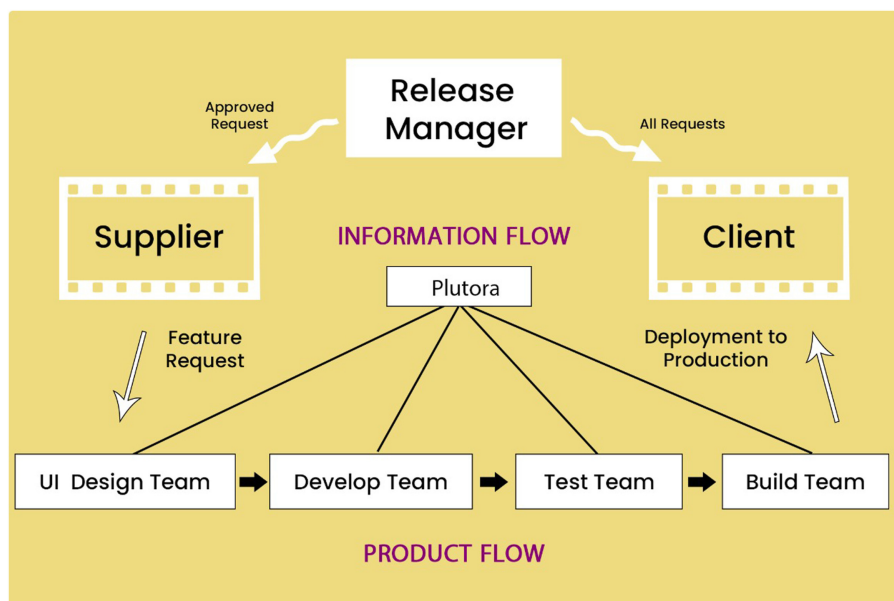
#### 4.4 Value stream mapping

The value stream is a series of steps that assisted the suppliers to provide products or services that the customer wants. Value stream mapping (VSM) is a new technique that includes lean thinking and implementation. Previously, this technique is used only on an individual level, but a recent study has suggested its process implementation in product development, health care, manufacturing and service sectors (Shou, Wang, Wu, Wang, & Chong, 2017). This stream mapping includes the supply chain from farm to fork and is useful for the identification of different food resources. There are different companies (for example, inTech Open Limited) that have developed the software to introduce the visualization that how the material and information flows within the supply chain. VSM introduces the monitoring of different processes from production to distribution of processed food within the market a new version of value stream mapping 4.0 has been introduced that enables the mapping and analysis of different process chains. Digitalization of VSM has opened new gates for the development of new and efficient production lines. This has been accompanied by methods of In Line production that have helped us systematically to drive measures for improvement (Meudt, Metternich, & Abele, 2017).

The basic functionality of VSM works (Figure 3) on new software development that has enabled industrialists, suppliers and retailers to connect in one place. This software advancement enables the mapping to add actual value in the process, and it is being verified by the team and leadership management, which overall affects the efficiency that is associated with the delivery of the product. For the completion of this value stream mapping, a software program has been introduced named Plutora, which has helped many industries, suppliers, retailers and consumers to connect better during the pandemic situation (Salvador *et al.*, 2021).



**Figure 2.** The supply chain domain concept, it is one of the best models in sustainable food supply chain and will be an interesting model for future studies during pandemic



**Figure 3.**  
Future state VSM for  
software development

#### 4.5 Mobile phones, apps and ICT

Multiple advanced technologies have been around the world, assisting to transport products, travel, and communication better and faster. One of these technologies includes app services in the modern day. An e-sourcebook has been provided by the World Bank that provides insights and connections between institutions and retailers in the agriculture business. Information and communication have always been a part of the transport. ICT is a well-timed technology that has comparatively lowered prices for consumers, provided ways to improve supply chain management and has contributed to “smart” transportation (Chaudhary, Gustafson, & Mathys, 2018; Galanakis *et al.*, 2021). With the escalated introduction of mobile phones, the Internet and wireless system in the world, ICT has been more focused during the pandemic situation. The use of mobile phones have a tremendous effect on the livelihood of individuals and communities especially in service delivery system as it has increased income, reduced transaction costs, improved efficiency, and offered a great opportunity for innovative programs and software (Gunden, Morosan, & DeFranco, 2020). Mobile phones as a networked technology exhibit supply-side improvements which have met strong demand from customers around the globe. Delivery apps have also placed their position in different countries of the world during a pandemic. Easy to use, safe and convenient shopping through mobile phones and apps has gained popularity and has eased customer demands. There are different delivery apps around the world; Uber Eats, Food Panda, etc. These apps have helped consumers to shop, eat and drink conveniently at any time. These technologies have developed traceability as a regulatory or voluntary intervention along with capacity strengthening. Easy to use, quick response, transparency and more control over services have enabled consumers to benefit from online delivering systems (Kaur, Dhir, Talwar, & Ghuman, 2021; Selvan & Andrew, 2021).

#### 5. Future prospects

COVID-19 has drastically affected the supply chain worldwide. As a result, traditional supply chains like local supply chains or short supply chains emerged as successful delivery systems

during a pandemic. Despite the benefits of a global supply chain, short and local supply chains should be promoted in developing countries. This will not only reduce food security issues in conditions like the pandemic, but it will also strengthen the livelihood of local farmers. A systematic review is required on this topic which will improve the shortcomings of this review and provide a concrete framework on formulation of policies and trainings on food supply chains.

## 6. Conclusion

The coronavirus pandemic situation had arisen many problems that the world had never experienced before. Emergencies in hospitals, complete lockdown, restrictions on air and land travel, and closed markets, offices and schools are some of the never-experienced circumstances. These situations held the economy and necessities at a corner. One of them was the supply of food to the consumer. It was also concluded that consumption and demand for processed food from retailers increased, whereas a decrease in the demand for food service products was observed. Keeping in mind the increased demand for processed food, it became necessary to provide enough food to consumers during the lockdown. For such purposes, many technologies were redefined and used with information and communication system. For sustainable delivery, multiple models reflect the technological advancement in the field. TBL is the most cited, evident and applied model that provides a user manual for the formation of a framework specific to their organization, program, policy and geographic boundary. Another system was “Block chain” specific to the processed food supply chain that digitalized the authentication to protect the intellectual property rights and transparency in the traceability system. ISBD and blockchain gave more financial benefits by more traceability options to optimize valuable information. The supply chain domain has been linked with one of its supporting activities, technology. Technology in communication and transaction has enabled the primary activities of the domain. SFSC domain linkages have provided better insight into the supply chain from farm to fork. Value stream mapping also works on the same principle as SFSC, but it has linked a software program that has introduced a new course of line that links every step of the supply chain. This new version has provided a more efficient production according to demand by directing all requests from consumers to suppliers. One of the most noticeable technologies during a pandemic is the advancement in food delivery app features and their popularity among mass. These technologies have developed traceability as a regulatory or voluntary intervention along with capacity strengthening.

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### Corresponding author

Nauman Khalid can be contacted at: [nauman.khalid@umt.edu.pk](mailto:nauman.khalid@umt.edu.pk)

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