

# DID COVID-19 ACCELERATED SUPPLY CHAIN DIGITAL TRANSFORMATION?

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## Abstract

*Under the influence of modern technologies in Industry 4.0, supply chains are experiencing a “renaissance” in terms of digitization. Rapid transformation of functions and processes in supply chains has begun quite recently - in the middle of the last decade. Since then, key decision stakeholders within the value chain managed to implement several digital components in order to overcome the complexity in supply chain relations. Sudden disruptions in the global business environment, such as the beginning of COVID-19 pandemic, can be catalysator for or against accelerated supply chain digitization. Considering the conditions of the pandemic, decision makers are standing in front of the strategic dilemma: to preserve money or to continue to invest financial assets in supply chain optimization in order to achieve future cost savings. The analysis starts from a recent historic overview of supply chain digitization, continues with analysis of its speed and structural digitization before pandemic, followed by stakeholder response to the crisis and summarizing the affection for the acceleration of supply chain digitization. The aim of the paper is to show whether pandemic did or did not have any effect on acceleration of supply chain digital transformation. Conclusion will also provide a quick look on future actions which stakeholders need to take in order to retain and/or advance in supply chain digitization.*

**Key words:** COVID-19 pandemic, supply chain management, digital transformation

## 1. INTRODUCTION

Global economy has been “under attack” due to outbreak of ferocious Coronavirus. Its participants were already so deeply involved in a saturated business network that many of them were not even aware of the global external risk that could befall them. 2020. outbreak hit business community hard - aggregate supply and demand for commodities got a sudden drop (Seetharaman 2020), businesses are closing for work, critical stakeholders are preserving financial assets and taking care of any expense which can be avoided, etc. Nowadays, companies around the world are still trying to find a proper way to exit the crisis and to stabilize or advance in business operations.

It can be brought to attention that some of businesses are more or less resilient to disruptions like this one due to their nature of business. Supply chains are very common area for any kind of interruptions to show their first effects. Almost all members throughout one supply chain can rapidly feel negative impacts of the pandemic. One question still remains in terms of gathered knowledge and experience in terms of adaptation to crisis: did something positive happened during the pandemic to supply chains and their advancing status regarding digitization? It is of high importance to search and find answers regarding impact of COVID-19 onto supply chain digital transformation.

Most important part of this research has been addressed to acceleration of supply chain digitization. Digital transformation during the pandemic can be one of few positive outcomes

to humankind regarding the circumstances. The aim of this paper is to show whether pandemic have had any influence on digital transformation of supply chain or not. Even more, to show whether or not it had an impact on accelerating the digitization of the supply chain. After introduction, first part deals with supply chain digitization before pandemic. Second part analyses supply chain areas which are under influence of COVID-19 pandemic. Third part reflects on actual effects and acceleration of digitization. Fourth part is focused on prediction of possible long-term digitization effects within supply chain.

## **2. SUPPLY CHAIN DIGITAL TRANSFORMATION BEFORE COVID-19 PANDEMIC**

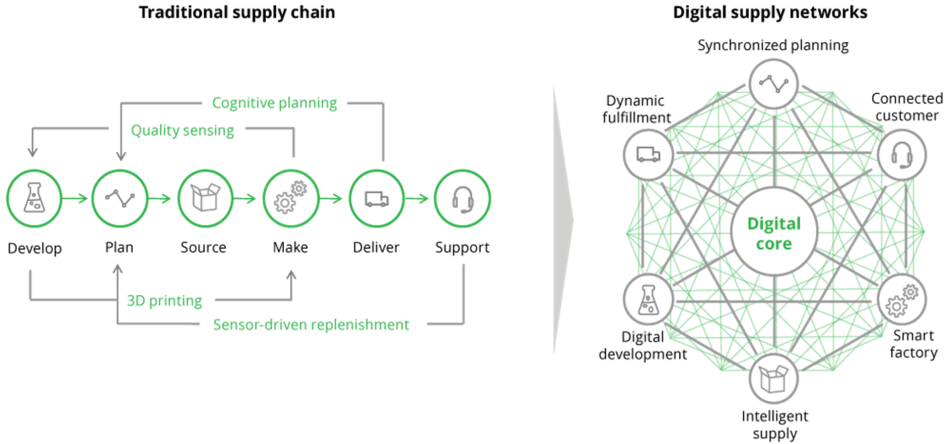
Fourth industrial revolution (Industry 4.0) has been based on innovative technology solutions which commercial implementation is resulted with evolution of doing business. Continued digitization of business functions and processes in variety of industries has been affecting decision makers in order to proactively and strategically make right and on-time decisions based on cost-benefit analysis. The pioneers of business processes technology solutions acceptance are companies which core business is situated in supply chain. Inevitably, implementation of digital business solutions is affecting transformation in functions and processes in supply chain.

Since 2011 rise of digital business solutions has been tremendous. New technological solutions such as blockchain, machine learning, big data, AI, VR, autonomous vehicles, drones etc. have been bastions of changes in business models. Digital transformation started as soon as company leaders started to implement mentioned technologies. Global transformation of primarily production followed by the implementation of digital technologies marks the beginning of digital transformation (Tjahjono et al., 2017).

Supply chains weren't resisted to changes, too. As a matter of fact, they were one of the pioneers in adaption of modern technologies which have been dominated in Industry 4.0. The amount of adopted innovative solutions within supply chain in 2010 – 2015. was so extensive that term of "digital supply chain" became usual amongst academic and commercial members. The vision of digital supply chain can be defined as an upgraded business model in everyday business activities based on intelligent technological innovations with aim on reaching highest performances (Aćimović and Stajić, 2019). The concept of digital supply chain has been researched by academia and broadly accepted by business actors all around the world (Buyukozkan et al., 2018). Transition from traditional to digital supply chain management has been complex task for all members of supply chain. Foundation for knowledge adoption regarding supply chain digitization has to be proper understanding of Industry 4.0 technologies.

Advances in digital technologies are extensive especially in quick restructuring of supply chains (Sang and Trimi, 2021). Figure 1 demonstrates digital transformation of supply chain from traditional to digital business model. The real-time communication within network with reduced time for decision making and transparent tracking of transactions are just a few of many functions represents of supply chain digitization. Regarding current business environment, convergence innovation in Industry 4.0, especially in COVID-19 pandemic crisis should be the future topic for researchers to discover.

**Figure 1.** Transition from traditional to digital supply chains



Source: retrieved from <https://www2.deloitte.com/us/en/insights/focus/industry-4-0/digital-transformation-in-supply-chain.html>, (2016).

Research conducted in previous period of time have shown that improved business process competences, faster pace of innovation, new forms of communication and engagement are factors for faster driving digitization (Amankwah-Amoah et al., 2019). Overall flow velocity of supply chain management functioning has been increasing by adoption of digital technologies in terms of product life – cycle. That business trend becomes usual in middle of 2010s especially in demand – sensitive networks (Farahani et al., 2020). In terms of business performance, digital supply chains managed to reduce standard difficulty load for several key services such as lost sale, transport and warehousing, administration and inventory, etc. Cumulative reduced effect of change in standard difficulty load for several services in digital supply chain has been represented in Table 1.

**Table 1.** Cumulative reduced effect of standard difficulty load for several services in digital supply chain network after the Industry 4.0 technologies implementation

Services and functions		Standard difficulty load before technology implementation	Reduced change in difficulty load after technology implementation	Cumulative reduced change in digital supply chain after technology implementation
Services	Agility and cost	Lost sales	100%	up to 50%
		Transport and warehousing	100%	from 10% to 50%
Capital		Administration	100%	from 5% to 10%
		Inventory	100%	from 20% to 50%

Source: Represented by author. Data retrieved from McKinsey & company. Available at: <https://www.mckinsey.com/business-functions/operations/our-insights/digital-transformation-raising-supply-chain-performance-to-new-levels#>, (accessed 26 August 2017).

The data in Table 1 demonstrates some of key services with standard difficulty load for companies in supply chain before and after technology implementation. After the digitization of key services, members of supply chain can expect reduced difficulty load in range from 5% to 50% for some of mentioned key services. Overall, cumulative reduced effect for all members within digital supply chain can vary from 15% up to 80% for some of mentioned services. So, in terms of difficulty load (cost reduction, time consumption, inventory assets

and management, etc), implementation of digital technologies is proven to be a key result of supply chain digitization in period before COVID-19 outbreak.

Multinational companies have been leaders in implementation of digital solutions in the last decade. Companies such as Walmart, Emerson, Amazon, Alibaba etc., have already been implementing technologies such as blockchain, big data, AI, robots and drones. Emerson, an electronic device producer, has been one of the pioneers in adopting blockchain technology. Their vision with blockchain implementation has been oriented on better supply chain transparency. End to end supply chain visibility and execution reached new levels of certainty by using blockchain in everyday business (Wang, 2019). Amazon has an impressive number of 45.000 different kind of robots in their everyday warehouse operations. In 2020. Amazon launched drone delivery system with goal for product delivery under the 30 minutes in less than 16 kilometres radius. Alibaba implemented smart big data platform, Cainiao merchant, which reduced human errors in more than 40% (Tham Jo Ee and Yazdanifard, 2015). All these examples of function and process digital transformation have represented a true value to the significance of supply chain digitization in the last decade.

The period before COVID-19 outbreak describes several most important barriers regarding supply chain transformation: conceptual (fear of change), societal (human interfering with technology), technical and technological (lack of knowledge) and environmental (side consequences on nature). These barriers hold the most of the reasons against supply chain rapid digitization (Jones et al., 2021). Today, during pandemic, when companies are trying to find new business models to survive, these barriers are facing a sharp contrast and key decision makers are challenging them in more bravely manner. True question still stands: did key decision makers learn to overcome current crisis by trying to digitize their cost centres?

### **3. MAIN AREAS OF SUPPLY CHAIN AFFECTED BY THE COVID-19 CRISIS – CONCERNING DIGITIZATION**

Disruption risks vary, but the epidemic outbreak scale fast and disperse over many geographic regions creating a lot of uncertainty which makes it difficult to fully determine the impact of the outbreak on the supply chain (Ivanov, 2020). The Coronavirus has global impact on economy with measures like trade and transport restriction, border closing, imposed lockdowns, shipment disorders etc. Freight forwarders and logistics face many obstacles to mitigate the impact of the virus (Aćimović et al., 2020). Supply chains in total are facing serious disruptions, but question of success regarding digital transformation opportunity still remains unknown. In order to investigate outcomes of supply chain digitization during pandemic, this research need to show the effects of COVID-19 onto supply chain digital transformation.

Communication and human resource management has been one of the first fields to feel the immediate impact of the pandemic. One of the main characteristics of COVID-19 regarding to possible human consequences has been a need for distancing and transition to remote working. Many organizations shifted to digital channels of communication almost overnight, which was a fertile ground for customers to make a change in their everyday behaviour, as well (Baig et al., 2020). Remote working has shown potential for cost reduction, faster internal communication, more flexible customer relationship management, bureaucracy and even reducing environmental footprints (Hensher et al., 2021). Remote way of communication and tracking of activities swiftly showed importance of using digital technologies in order to safely continue with everyday work assignments. Social distancing impacted on all members along the supply chain. Companies have been reducing number of

on-site employees in factories, warehouses, distribution centres, retailing facilities etc and replacing them with their “digital clones”. Reducing number of people engaged in processes of production, loading, routing, transport, forced a way in decreasing of human error. Much of the human-related labour has been replaced by robots (loading – unloading, packaging, routing etc.), drones (last mile delivery), AI and chatbots (customer support centres), autonomous vehicles (in-house transporting system), blockchain (procurement and sales). Reducing of human factor within supply chain accelerated the digitization, but showed vulnerability in terms of blue-collar workers shortage in environment without proper digitization plan.

Procurement during pandemic continued on a digitization road with big data and AI as leading technologies of digital transformation. Advanced analytics in coordination with AI and ERP systems have impacted a steady course for digitization procurement processes. Additionally, e-procurement showed its purpose and significance during COVID-19. E-procurement recently have been on a path for implementation of big data and blockchain as foundations for its future work (Khamis Alnuaimi, 2021). Some companies referred to external partners such as Deloitte on path for identification, triage, mitigation, monitor and alertness for anomalies in supply chain. Deloitte offered their Central Sight analytics tool as a solution for exact same mentioned challenges (Deloitte, 2021).

Manufacturing companies needed a shift to more flexible way of production. Rise of 3D production technology and geographical risks renewed company’s opinion on near-shoring. Several authors considered, even before pandemic, that reshoring would take place if organizations excel in 3D production of its products - in full or partial manner (Banalieva and Dhanaraj, 2019). Blockchain and other similar digitization tools helped SMEs connect with suppliers and customers to ensure resilient and sustainable manufacturing through (Bai and Sarkis, 2020). SMEs have proved to be more agile and flexible to crisis, but they lacked financial capital structure for in-depth technology implementation. COVID-19 pandemic showed that there is still a shortage of engineers with digital knowledge in order to adequately respond to demand for digitization (Milisavljević-Syed, 2020).

Inventory management managers during pandemic needed to redesign their models for understanding inventory volatility and management systems. They needed to understand demand volatility, to simulate stock management scenarios and to foresee future disruptions. Material handling is an essential variable cost that is often completely ignored by the industries. It is very inefficient in warehouses. It accounts for 55% of the factory floor, 25% of workers and up to 70% of materials overall cost. During pandemic Walmart included robots in order to overcome inventory material and product managing, and Alphabot (the name of the robot) currently assist to 20% of online ordering purchase (Ammar et al., 2021). Lack of planning capability lead producers to invisible stock in PPE equipment, which was quickly overcome by implementing of 3D technology (additive manufacturing concept) in face mask production facilities. Data on inventory levels, material capacity, materials in transit, consumption levels, and unexpected disruptions need to be available in real-time, consumed by a persistently prepared team of decision-makers in time of pandemic. Companies started to implement AI based solutions for above mentioned challenges (Finkenstadt and Handfield, 2021).

E-commerce gained significant value during lockdowns. For example, e-commerce penetration rate during 2020. increased from 16% to 27% in comparison to 11% gained during 2009-2019 (McKinsey, 2020). Online grocery sales in China increased by 26.4% compared to 20.2% in the same period of the last year (Kang, 2020). Even though e-commerce is firmly established as a known marketing channel, the upgraded system based on big data technology managed to become a powerful tool for organizations to improve their

customer relation systems. Big data and cloud computing used by Alibaba brought them rise within this revenue source up to 37% in first quarter of 2021. Early mentioned, Cainiao network logistics system, gained 4% of revenue increases in comparison to same quarter in 2020. (Businesswire, 2021).

Transport capacities and freight forwarders took a huge hit during pandemic regarding disruptions in demand, routes, groupage cargo, delivery time, cost rates increase etc. There has been a steady growth in digital transformation in field of automatization of shipping portfolio, tracking of parcels and shipments to ensure an end-to-end visibility, temperature control, as well as ensuring fragile cargo integrity and customs clearance management (DHL, 2020). COVID-19 ensured that new digital technologies are implemented so organizations could reduce costs and improve reliability. World first autonomous container ship has been expected to set sails in 2022; truck platooning in full or partial manner (with fuel savings from 3% to 7%) urged its upcoming in 2021-2022. (O'Byrne, 2020). Urge for digitization in transportation has been on site since the pandemic outbreak.

Delivery has also been under the influence of digital transformation especially during pandemic spikes. Food delivery industry redesigned their delivery software systems in terms of more adequate technologies for purchase ordering and cancellation management. Data management has been improved by integrating data analytics systems and chatbots often on website landing page (Xu et al., 2021). Delivery time has also been a challenge for companies during COVID-19. Pandemic outcomes led to Amazon to receive an approval from the FAA (Federal Aviation Administration) regarding their license for Prime air program (drone program) in 2020. Even though they have more business to cover before launching, COVID-19 excel their efforts for digitization of last mile delivery system (Chen, 2021). Modernized models of last-mile delivery services, especially in B2C terms, gained in importance. Last-mile delivery model, *crowdshipping*, especially arose as a new model for organization's cost reduction. Model includes two-side platform (sender/retailer and transporter/shipper) where shippers (often ordinary people with bikes, motorbikes, and cars as a transport vehicles) are taking sender's offer to transport any kind of good on arranged location. This model has been used mostly in part of city logistics. Nevertheless, crowdshipping model gained on attention during pandemic (Pourrahmani and Jaller, 2021). Domino's pizza delivery robot, Nuro, has been on public roads for almost 2 years now. These robots are self-driving vehicles who delivers pizzas to the customer front door. These kinds of robots are being used for last-mile delivery during pandemic (Kasper et al., 2021).

Payment systems regarding cashless payment based on smart mobile technology has been on a surge since pandemic outbreak (Xiao and Chorzempa, 2020). Fintech companies have been on an urgent task to provide solutions for mobile payment. Contactless payment considering supply chain transformation is mostly focused on consumer preferences. Delivery units such as early mentioned Amazon's Prime air program, developed an option for contactless payment. Cashless payment got even implication on country level since governments have noticed that these kind of automatic payment methods are not totally regulated. The question remains what will be governments response regarding digitized cashless model of payment (Ng, 2021).

Additionally, large affection of pandemic onto upstream and downstream supply chain is visible and represents direct cause for even more urged – process of digitization. Next chapter will show the visible effects of COVID-19 onto acceleration of supply chain digital transformation.

#### 4. POSSIBLE EFFECTS OF COVID-19 ON ACCELERATING SUPPLY CHAIN DIGITIZATION

Digitization is seen as an essential driver for further development of infrastructure and transactions within the supply chain (Rachinger et al., 2019). Some authors claim that COVID-19 pandemic has been stimulating accelerated adoption of technological advancements within value chain while digital technologies are facilitating consumer management (Willems et al., 2021). Stakeholders tried to adapt and overcome the crisis with main goal – to survive and continue with doing business. On one side, many of them, mostly ones with lower capital capacity, reached for cost reduction and cash perseverance as primary defence system. However, there has been a significant number of key decision makers whose strategy relied upon improvement of function and processes in order to secure certainty during pandemic. The outcome of that strategy has been increasing the speed of digitization.

Technologies 4.0 have been used more significantly with pandemic outbreak. Some areas of supply chain are being under higher level of digital acceleration (e.g., delivery) rather than some with lower level of acceleration (e.g., payment). The decisive factors for accelerated digital impact ranking, shown in Table 2 (Low – Medium – High) have been addressed as followed:

- transition level from traditional to digital solutions within area, function or process;
- redesign of business model for some/whole business units/products;
- change in level of human labour – to machine working hours;
- technology 4.0 adoption speed and daily usage afterwards;
- cost reduction within individual company or part of/whole supply chain;
- level of digitization/automatization of area, function or process within supply chain;
- increased level of transparency and visibility of supply chain;
- accelerated mitigation consequences of COVID-19 pandemic;
- accepted technologies 4.0 as the main tool for the future conduct of business.

Based on previous mentioned decisive factors Table 2 shows most important pandemic effects which are representing drivers for accelerated digitization within supply chain. The following analysis is based upon literature review, case study review and available data and publications regarding multinational company digitalization plans and results. This analysis can be used as a foundation for further empirical analysis regarding the subject.

**Table 2.** COVID-19 effects as drivers for supply chain accelerated digitization

Supply chain COVID-19 affected area	COVID-19 effects as drivers for supply chain digital acceleration	Digital technology/ies as a “cure” for affected area	Digital acceleration outcome level (Yes/No) Low (L) – Medium (M) – High (H)
<b>Communication and HR management</b>	<ul style="list-style-type: none"> <li>• “Overnight” shift toward remote working</li> <li>• Flexible CRM</li> <li>• Paper based – electronic based procedures and processes</li> <li>• Video conferencing instead of face-to-face meetings</li> <li>• Logistics workforce layoff</li> </ul>	<ul style="list-style-type: none"> <li>• Online communication platforms (Zoom, MS Teams, customized platforms etc)</li> <li>• AI</li> <li>• Chatbots</li> <li>• Blockchain</li> <li>• Autonomous vehicles</li> </ul>	Yes (H)
<b>Procurement</b>	<ul style="list-style-type: none"> <li>• Higher cost of procurement management</li> <li>• E-procurement disruptions</li> <li>• Unexpected anomaly alerts</li> <li>• Supply of raw materials/goods visibility</li> </ul>	<ul style="list-style-type: none"> <li>• Big data</li> <li>• Advanced analytics</li> <li>• Cloud platforms</li> <li>• Blockchain</li> </ul>	Yes (M)
<b>Manufacturing</b>	<ul style="list-style-type: none"> <li>• Higher cost of continuous production</li> <li>• Necessity for lower cost of raw material</li> </ul>	<ul style="list-style-type: none"> <li>• 3D</li> <li>• VR</li> </ul>	Yes (M-H)

	<ul style="list-style-type: none"> <li>and parts</li> <li>● Necessity for production flexibility</li> <li>● Workforce layoff</li> <li>● Automatization</li> </ul>	<ul style="list-style-type: none"> <li>● AI</li> <li>● Robots</li> <li>● Blockchain</li> </ul>	
<b>Inventory management</b>	<ul style="list-style-type: none"> <li>● Inventory management automatization</li> <li>● Redesign of inventory management strategy model</li> <li>● Uncertain stock management due to demand volatility</li> <li>● Material handling rise of cost</li> <li>● Invisible stock possibility for certain products</li> <li>● WMS more directed with suppliers ordering networks</li> <li>● Re-evaluation of stock-outs</li> <li>● Direct connection with real – time ordering purchase</li> <li>● Necessity for more real – time stock management</li> <li>● Warehouse workforce layoff</li> </ul>	<ul style="list-style-type: none"> <li>● 3D</li> <li>● Advanced analytics</li> <li>● Robots with smart sensing systems</li> <li>● Real -time ordering platforms</li> <li>● AI</li> <li>● IoT</li> <li>● RFID</li> </ul>	Yes (H)
<b>E-commerce</b>	<ul style="list-style-type: none"> <li>● High percentage of new customers at</li> <li>● High rise of online grocery sales</li> <li>● Demand for next level data analytics</li> <li>● Higher scale of e-commerce platform daily visit</li> <li>● Necessity for better distribution planning</li> <li>● Better UX models for e-commerce platforms</li> </ul>	<ul style="list-style-type: none"> <li>● Real -time network communication platforms</li> <li>● Big data analytics</li> <li>● Advanced analytics</li> <li>● VR</li> <li>● AI</li> <li>● Cloud computing</li> <li>● IoT</li> </ul>	Yes (H)
<b>Transport</b>	<ul style="list-style-type: none"> <li>● Intensive planning of routing, loading and delivering</li> <li>● Lockdowns and increased state border waiting time</li> <li>● Fall of profit rates (dollar per mile / euro per km)</li> <li>● Necessity for real-time service ordering management</li> <li>● Need to reduce the time required to collect transport documentation</li> <li>● Increase of cargo delivery costs</li> <li>● Possible delivery time disruptions</li> <li>● Last-mile vehicles model redesign</li> </ul>	<ul style="list-style-type: none"> <li>● Platooning</li> <li>● Robots</li> <li>● VR</li> <li>● Smart document collection platforms</li> <li>● Blockchain</li> <li>● Autonomous vehicles</li> </ul>	Yes (M-H)
<b>Delivery</b>	<ul style="list-style-type: none"> <li>● Higher demand for real-time connection with customer</li> <li>● Higher demand for direct communication between e-commerce platforms and delivery service providers</li> <li>● Demand for better data management</li> <li>● Demand for better tracking and monitoring of delivery</li> <li>● Contactless last-mile delivery</li> <li>● High demand for delivery cost reduction</li> <li>● Demand for business model redesign</li> <li>● Demand for more advanced automatization</li> </ul>	<ul style="list-style-type: none"> <li>● IoT</li> <li>● Drones</li> <li>● Autonomous vehicles</li> <li>● Smart monitoring platforms</li> <li>● Real – time network communication</li> <li>● Chatbots</li> </ul>	Yes (H)
<b>Payment</b>	<ul style="list-style-type: none"> <li>● Rise in demand for cashless payment</li> <li>● Rise in demand for smart mobile payment services</li> <li>● Connected device to payment technology innovations</li> <li>● Model of virtual currencies payment</li> </ul>	<ul style="list-style-type: none"> <li>● IoT</li> <li>● Advanced analytics</li> <li>● RFID</li> <li>● AI</li> <li>● Blockchain</li> <li>● Chatbots</li> </ul>	YES (L-M)

Data collected throughout literature review, case study and available company data and publications regarding acceleration of supply chain digitization suggest that businesses are facing rapid digital transformation during/post COVID-19 period. Table 2 represents

summarization of the most important aspects regarding acceleration of supply chain digitization. First, one has identified the main areas of pandemic impact on supply chain ordinary way of conducting business; second, COVID-19 effects are being resonated as a drivers for change; third, usage possibility of several Industry 4.0 technologies have risen since pandemic outbreak; fourth, there is solid unquantified conclusion regarding level of digitized acceleration outcome ranked from low to high. Ranking of acceleration drivers in specific area of supply chain is something that cannot be entirely quantified since it is still too early to collect viable data.

In this case, qualitative methods of presenting the results are more convenient considering scarce of raw numerical data. Responsible and proactive decision-makers resonated the crisis as a model for function or process innovation. They have accepted or internally developed digital solutions (mentioned in Table 2) in order to overcome disruptions caused by pandemic outbreak.

Many industries downstream supply chain accepted new trends which are currently mostly relied on digitization in times of pandemic. According to survey conducted in Q4 of 2020, by consulting company EY, the pandemic has indeed accelerated many pre-existing trends, and supply chain is no exception: 64% of surveyed supply chain executives confirmed that digital transformation has accelerated due to the pandemic. The race is on for digital enablement and automation: 52% of executives say that the autonomous supply chain (e.g., robots in warehouses and stores, driverless forklifts and trucks, delivery drones and fully automated planning) is either here or will be by 2025 (EY, 2021).

Considering decisive factors for accelerated digital transformation of supply chain during COVID-19, Table 2 can show following conclusions:

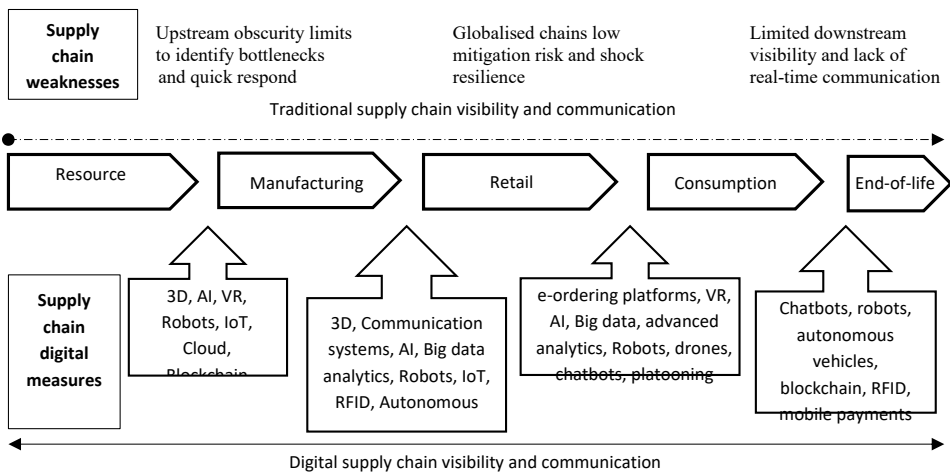
- almost every area of supply chain „suffered“ with some form of digitization;
- almost every area of supply chain gained acceleration of digital transformation;
- COVID-19 effects are being used as a drivers for accelerated digitization;
- digital transformation of supply chain in the times of COVID-19 pandemic is mostly focused on distancing, automatization, risk mitigation and big data analysis;
- majority of forced lay off labour has been replaced by technology 4.0 solution;
- production flexibility using 3D technology rather than production outsource (Shokrani et al., 2020);
- accelerated usage of online tools for communication and administrative ordering with aim to stay reluctant to change (Wilson & Chen, 2020);
- accelerated usage of drones, autonomous vehicles, robots, and other technologies in order to increase contactless manipulation of materials and goods;
- creating new online shopping platforms or upgrading the existing platforms with direct connection with distributors or shippers;
- accelerated usage of robots and autonomous vehicles in transportation area;
- accelerated usage of IoT, drones and smart networking regarding last-mile delivery;
- increased demand for using of contactless payment, mostly regarding IoT, RFID and mobile device payment (Mollenkopf et al., 2021);
- increased usage of blockchain in order to maintain or upgrade transaction security;
- increased visibility and transparency of downstream supply chain (Gunessee and Subramanian, 2020);
- communication, HR management, inventory management, e-commerce and delivery are areas with highest digital acceleration outcome level (H) considering decisive factors of supply chain digitization during pandemic;

- procurement, manufacturing and transportation are areas with medium to highest digital acceleration outcome level (M-H) considering decisive factors of supply chain digitization during pandemic;
- payment is the area with lowest to medium supply chain digital acceleration outcome level (L-M) considering decisive factors of supply chain digitization during pandemic;
- digital transformation of supply chain during pandemic has been oriented on accelerated smart network organizing of communication, function and processes.

## 5. EXPECTATIONS FOR LONGTERM POST-COVID SUPPLY CHAIN DIGITIZATION

Disrupted areas of supply chain network are being digitized since pandemic outbreak. Synergetic effect of digitization in each and every mentioned area leads to higher pace of supply chain digitization in whole. Accelerated digitization of some areas, such as e-commerce, lead to digitization of delivery, and vice versa. Multinational companies, such as Walmart, Amazon, Alibaba, Emerson etc, have proven that COVID-19 affected their supply chains in terms of digitization pace. Authors are anticipating that accelerated implementation of digital technologies will be especially important for **understanding future visibility and communication in after pandemic period**. Kenco’s 2020 SC innovation survey showed that 90% of participants considers visibility for digitization’s highest priority (Kenco, 2020).

**Figure 2.** Supply chain weaknesses and possible digital measures in order to improve supply chain visibility and communication



Source: adapted by authors, Sarkis et al., 2020.

Figure 2 represents identified supply chain weaknesses and possible digital resilience measures in order to improve visibility, automatization, predictability, risk mitigation and cost effectiveness. Traditional supply chains are usually described as a one-way street in terms of visibility and communication. Therefore, disruptions such as the bottlenecks are often to see in these cases. By implementing Industry 4.0 technologies members within supply chain are gathering and sharing information in real-time, and there is a high visibility downstream of the supply chain. Mitigation of risk is often mutual, so supply chain members can always be

prepared for a possible crisis. This figure represents a model for better understanding a post pandemic supply chain digitization.

Long-term expectations regarding supply chain digitization are almost completely focused on gaining higher level of visibility downstream supply chain and achieving real-time communication between companies.

## 6. CONCLUSION

COVID-19 disrupted supply chains with significant impact. Structural distortions within supply chain areas are obviously present today. In terms of digitization, these disruptions can also be resonated as a drivers for accelerated digital supply chain transformation. Disruptions as a drivers and implementation of technologies 4.0 in common business operations can lead to gaining faster digitized society.

Authors have identified crucial areas of supply chain and technologies within Industry 4.0 which together have already made an impact on digitization during pandemic. These technologies are not just being used as a tool for healing the problems started with the pandemic, but more as a viable asset for future business conduct. Although, there is a lack of quantitative data for possible in-depth analysis, this research showed that companies have willingly, on their own, started with implementation of Industry 4.0 solutions in order to overcome COVID-19 crisis. Rapid adoption of digital technologies amongst companies lead to accelerated digitization of their supply chains.

In order to retain their positions and keep their digitization pace, supply chain stakeholders need to adjust their digital strategies with focus on:

- overall business analysis for potential areas with need for digitization;
- redesign of business models, units, products or services in terms of digitization;
- cost reduction based on technology 4.0 implementation;
- risk mitigation based on technology 4.0 implementation;
- finance plans adjustments considering investment in digital technologies;
- raising employees' awareness of the opportunities that digital technologies brings.

This analysis can serve as a foundation for further empirical research, considering a lack of quantitative data at this moment. The long-term expectations and possible post COVID-19 outcomes regarding digitization of supply chains are turned to visibility and transparency.

Post pandemic supply chains are expected to be more visible and transparent. Accelerated technology 4.0 implementation is transforming supply chains into digitized cooperation networks during COVID-19 pandemic even faster than anticipated.

## 7. LITERATURE

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