Digital Transformation in the Agriculture and Food sector

Naomi Mostert n.e.mostert@tilburguniversity.edu

Vedran Presečan v.presecan@tilburguniversity.edu

Bart Scheffers b.c.scheffers@tilburguniversity.edu

Esmée Tijsterman e.g.a.i.tijsterman@tilburguniversity.edu

Rick Tijsterman r.q.v.tijsterman@tilburguniversity.edu

ABSTRACT

The outbreak of COVID-19 and the subsequent lockdown had a great impact on the food supply chain. Organizations were forced to adapt to their environment in which the digital transformation was of significant importance. One of the challenges was to overcome a food crisis, due to closed borders organizations had to come up with new ways to find supplies. Organizational changes forced new ways of thinking and innovation. A shift to a more decentralized IT-Governance model was visible since local innovation became more important. However after COVID-19 a combination of centralized and decentralized IT-Governance is expected. This way organizations can benefit from local innovation while enjoying economies of scale and data integration. Acquiring digital technologies like Big Data would help to increase the food safety monitoring, big data also helped by tracing the COVID-19 outbreak. Organizations are forced to look at the cybersecurity aspects like confidentiality, integrity and availability threats.

Keywords

Agriculture and food sector, COVID-19, Digital Transformation, Big data

INTRODUCTION

COVID-19 and the lockdown have placed the global economy under tremendous strain but are also increasing the threat of longer term food insecurity (Pollard CM., et al, 2019). This food insecurity was mainly because of two reasons. The first reason is food shortage, which triggers higher prices. The second reason is distribution problems. Due to several lockdowns around the world, food production is being slowed down due to seasonal workers coming from abroad and closed borders (The European Food Banks Federation (FEBA), 2019). Many Western economies, as well as the Dutch economy, rely on Eastern Europe labor force. The Agricultural Association Secretary for Veneto said 'If we do not collect today, ...,the entire food-supply will come to a standstill'. Which is a potential problem for countries that mainly import food.

This raises the question for digital technologies that can optimize production processes (Kosior, 2018). Collected data can be used to extract new insights and could benefit all actors in the agri-food chain (Kosior, 2018). Modern agriculture and food sector is increasingly information-driven, technological innovations are needed to reduce costs and facilitate a consistent supply of top quality food (Opara, 2003).

Supply chain management (SCM) presents the management of production, manufacturing, distribution and marketing activity in which a consumer is supplied with a desired product (Opara, 2003). The food supply chain is characterized by traceability, which refers to the collection, documentation, maintenance and application of information related to all processes in the supply chain. Which should guarantee food quality (Opara, 2003). Digitization may fundamentally change the relations between technology, input suppliers, farms, traders, processing units, retailers and consumers (Kosior, 2018). The COVID-19 pandemic has led to sharp increases in online food trade (Nielsen, 2020). Barriers for customers to do 'e-grocery' - see and feel the product - were large before, as well as data and payment security (Dannenberg & Dederichs, 2019).

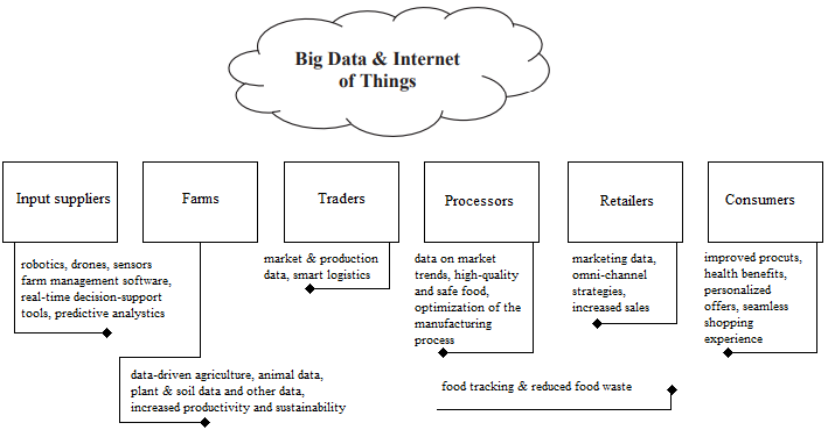

Figure 1. Food Supply Chain and Industry 4.0 (Kosior, 2018)

RESEARCH DESIGN

In this chapter the objective and research approach will be explained. This will result in a research question that will be answered at the end of this paper in the conclusion section, using the analyses of chapter 3 and chapter 4.

Objective

The growth of new digital technologies is reshaping entire sectors and economies. Digital technologies could help reversing some of the most negative effects of the ‘’green revolution’’, it could also help to overcome global issues such as climate change and biodiversity loss (Kosior, 2018). Digital technologies as AI can support businesses struggling with the COVID-19 pandemic, especially in the agri-food sector (Naude, 2020)(Rivas, 2020).

Organisations within the food industry are struggling with all kinds of problems due to COVID-19. First, the quality control of food and shortening the supply chains, which is vulnerable to disruption in a crisis. Second, the agricultural workforce. The pandemic forces employees to rethink their strategy about using low cost labor. The COVID-19 pandemic is an opportunity to rethink and optimize the agri & food supply chain, making use of digital technologies (Toffolutti, 2020).

These digital technologies could have a tremendous impact on the agricultural and food sector. It could help farmers to work more precisely, efficiently and sustainably. Which could result in more transparency to customers but also to renew business models in value chains by connecting producers and consumers in innovative ways. However, further research is vital to accelerate digital transformation in this area (European Commission (2020). The objective of this research is to find out how digital technologies with a focus on big data played a role in the adaption to the consequences of a global pandemic. Based on the research objective we have come up with the following research question:

How did digital transformation play a role in the adaptation to the consequences of a global pandemic?

Approach

The aim of this paper is to analyse the digital transformation that is happening in the agricultural and food sector through different information management perspectives. This paper will include three types of information management perspectives in the analysis: IT governance & strategic sourcing, business process integration and cyber security.

Materials used in the analysis come from a literature review in the field of agriculture and food. AThe literature review includes conference papers and industry reports that are related to digital transformation and digitalization in the agriculture and food industry, more specifically in the food supply chain during a crisis. Google Scholar and WebCat are the two search engines used to find the relevant literature.

AGRICULTURE & FOOD SECTOR

The agriculture sector is undergoing a digital transformation with an explicit interest in data value. This includes farmers from all sizes who are gathering information passively by using precision agricultural equipment. Next to collecting a large amount of data they also use large datasets and precision analytics to make on-farm decisions (Bronson, K., & Knezevic, I. 2016).

Next to the input suppliers and farmers, other players in the agricultural supply chain actively use technology to improve their business. The farmers deliver their products to traders who use market & production data and smart logistics to sell the products in the most valuable way. Next up, the processors who use data on market trends to produce the right amount of products. Processors also need to be able to ensure high quality and safe food, especially during a pandemic. After processing, retailers will use omnichannel strategies and marketing data to sell their products. Both processors and retailers use food tracking & traceability systems to reduce food waste (Kosior, K., 2018)

This emerging interest in big data value returns at multiple players in the supply chain of the agriculture sector. This resulted in strategic partnerships among corporations active in the machinery, fertilizer, seed and chemicals input

markets have been increasingly used in recent years to capitalize on Big Data generated in the sector (Kosior, K., 2018).

Trends & Challenges

An agricultural revolution called Agriculture 4.0 will have to look at innovations as well as the need to improve and address the real needs of consumers (De Clercq, Vats and Biel, 2018). The value chain and the demand side needs to be considered. Some future trends that can arise when the industry is ready are desert agriculture and seawater farming. New ways of farming need to be developed with the help of new technologies. K. Koisor (2016) addresses a summarization of the smart agri-food system based on several digital technologies that have to do with Big Data and IoT. Besides the use of Big Data and IoT, IT systems can generate information that can result in competitive advantages to the entire supply chain considering information sharing needs to occur (Victoria Salin, 1998). This includes Dynamic planning methods, Internet of Services (IoS), RFID and Blockchain for example to make the whole supply chain more transparent and visible. Time-to-market, efficiency and planning will be optimized and waste will be mitigated in all forms (Feng Tian, 2016).

Accelerated adoption of these trends has become more important due to COVID-19. The significance of COVID-19 for food supply chains comes less from its impact on primary production or overall food demand than from its disruptive effects on the complex web of actors connecting farm to fork, and the sudden change in the demand mix (OECD, 2020). There are 4 main challenges in the supply chain caused by COVID-19. Firstly, farm production has been affected by bottlenecks mostly due to labor shortages caused by limited mobility of people. This presents a serious challenge to farm sectors that are more dependent on (seasonal) labor than others (e.g. fruits and vegetables are more labor intensive). Secondly, the food processing industry has been similarly disrupted by labor shortages and shutdowns, mostly due to rules on social distancing, sickness and lockdown measures to contain the spread of the virus. Thirdly, bottlenecks in transport and logistics have disrupted the movement of products along supply chains, specifically air freight. Finally, COVID-19 led to a shift in consumer demand away from restaurants, food service and other types of “food away from home” towards food consumed at home, requiring important changes in the way food supply chains operate (OECD, 2020).

ANALYSIS

In this chapter an analysis of the disruptions caused by the pandemic COVID-19 will be analysed from three different perspectives: Business Process Integration, IT Governance and Cybersecurity. In each of these three perspectives will be discussed what the situation was before and during COVID-19, and what the expected situation will be after the COVID-19 pandemic.

Business Process Integration

COVID-19 has imposed disruptions on every segment of the food supply chain, simultaneously affecting farm, production, food processing, transport/logistics and demand. This in turn has forced companies in the food sector to rapidly change their business processes in order to address these disruptions (FutureBridge, 2020). This part of the analysis will aim to identify and analyze some of the key changes in business processes that occurred due to regulation changes or implementation of new technologies during COVID-19. Also, suggest which part of the sub-processes should be changed and represent one of the analyzed examples through an UML activity diagram.

Changes in business processes due to regulation

COVID-19 has forced governments to enact multiple regulations for safety purposes that have severely affected the food supply chain and business processes. Firstly, large Food & Beverage companies source the raw materials for their products from all around the world so as to optimise its cost. This kind of sourcing model has proven to be extremely vulnerable during COVID-19 as governments around the world restricted global movement of people and enacted lockdowns. For example, Nutella uses the hazelnuts from Turkey, cocoa from Nigeria, palm oil from Malaysia, sugar from Brazil and Europe and the vanilla flavor from China, which are brought together to some 9 production facilities around the world to make the final product. COVID-19 forced Nutella and similar large F&B companies to rapidly make changes in their supply chain either by sourcing locally or developing an alternative global source free of COVID-19. In the future, global F&B companies such as Nutella will look to implement different sourcing models that are not dependent exclusively on global sourcing so as to mitigate risks to its supply chain (Bhandari, 2020).

Secondly, the virus has created issues for labor-intense segments of the food supply chain such as food-processing by limiting access to migrant labor as well as limiting the number of workers that are able to work simultaneously (OECD, 2020). As a response, labor interactions in the value chain had to be reorganized to reduce shortfalls of access to labor, while guaranteeing worker safety. For instance, ensuring increased flexibility of labor

sourcing and timing, including facilitating the movement and safety of workers. For example, in Nigeria large chicken processors are busing workers to plants and increasing the number of shifts so there are fewer workers in the plant at one time (Reardon and Swinnen, 2020).

Changes in business processes due to the adoption of new technologies

On the other hand, the virus accelerated adoption of new technologies in the sector which in turn significantly changed usual business processes of companies. One of the most notable adoptions for new technology is the introduction of e-commerce platforms and online shopping capabilities. Due to lockdown and restricted movement measures there was an unprecedented shift to online shopping, especially for online grocery shopping (McIntyre, 2020). In most developing countries the adoption of e-commerce for grocery retailers was crucial as most of them did not have the capabilities to address the shift in demand for online grocery shopping (Reardon and Swinnen, 2020). Therefore, the majority of large grocery retailers adopted e-commerce and had to completely change their business processes and create new ones. For example, grocery retailers had to create a completely new business process for distributing food to customers who order online, which was previously not a part of their business model since the customers just picked up the groceries in supermarkets. Additionally, retailers had to implement systems that track stock of goods and are connected directly to the online shopping platform to ensure successful management of orders. Successful implementation and adoption of e-commerce among grocery retailers significantly affected their market position and their business processes (Reardon and Swinnen, 2020).

Another new technology that emerged due to COVID-19 was the introduction of automation in farming via robots and AI technology. Accelerated adoption of this technology was mostly caused due to shortage of migrant labor workers. Adoption of robots and AI technology in farming can result in lower labor costs, lower cost per unit and mitigating risks associated with migrant labor shortages. This example of technology adoption results in simplifying the business processes for farmers by removing the need for hiring migrant labor force (Gonzalez, 2020).

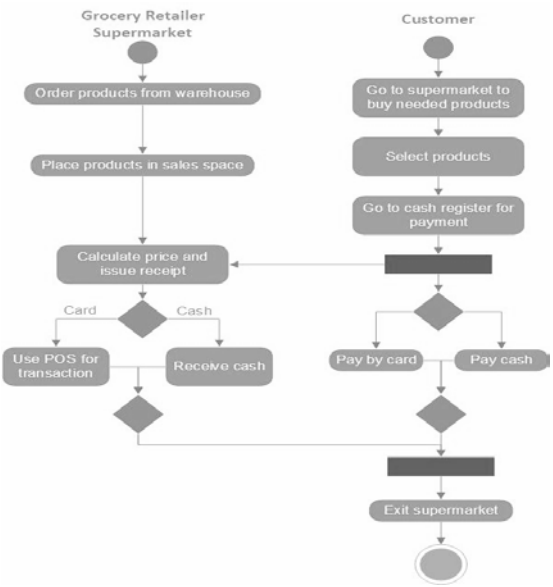

Figure 2: Grocery retailer business process without e-commerce (before COVID-19)

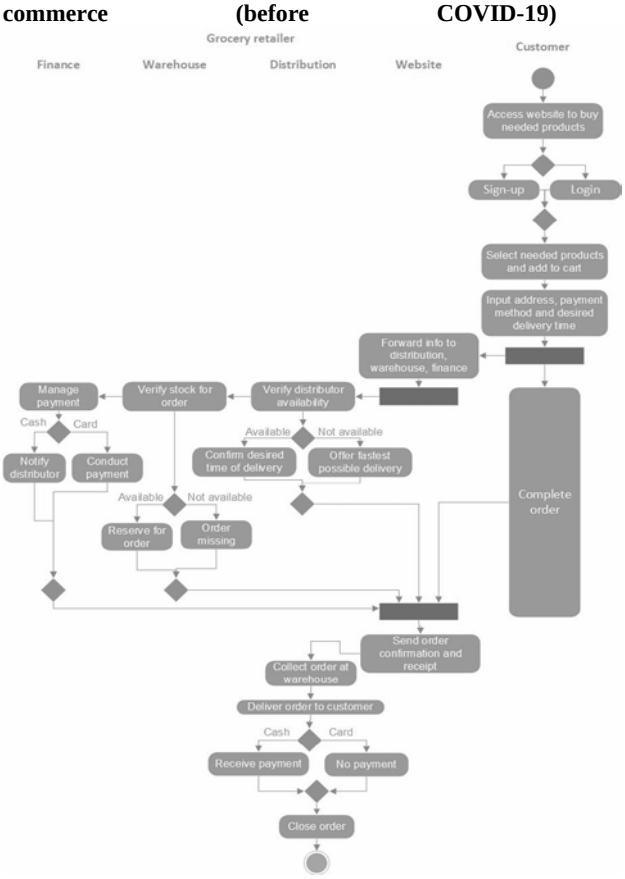

Figure 3. Grocery retailer business process with adopted e-commerce (after-COVID19)

IT Governance & Strategic Sourcing

Every organization should pursue a formal IT governance approach to define accountability and to communicate decision-making processes. Without a formal IT governance approach, it remains unclear which role is responsible for certain decisions. Weill, P., & Ross, J. (2005) distinguish the decision areas from the archetypes within IT governance. The

five major decision areas are: IT Principles, IT Architecture, IT Infrastructure Strategies, Business Application Needs and IT Investment and Prioritization. Six different archetypes can be distinguished that approach these decision areas: Business Monarchy, IT Monarchy, Federal, IT Duopoly, Feudal and Anarchy (Weill, P., & Ross, J., 2005).

Situation before COVID-19

IT Governance differs for every enterprise and every sector. However, there are some general IT government related trends that are applicable to the agriculture sector. In this sector there was a shift in the strategic drivers of IT governance. Lopez-Morales, J. A., Skarmeta, A. F., & Martinez, J. A. (2020) state that the use of new technologies allows for more precise management and the ability to combine multiple data sets to be more efficient on an enterprise-wide level, therefore before COVID-19 the focus was on enterprise-wide integration of technologies. Especially in the agriculture sector this is of great importance since this strategic driver focuses on low cost through standardized business processes. All important decisions are taken by the board of directors (Weill, P., & Ross, J., 2005). The board of directors used steering committees and communication policies to force their enterprise-wide IT governance policy (Huang et al., 2010).

Situation during COVID-19

During COVID-19 there was a shift of the governance model in the agricultural sector. Organizations had to be creative by themselves and therefore couldn't wait for company-wide innovation. The effects of the virus are tremendous and resulted in many city lockdowns which led to increased awareness of the importance of food availability locally and globally (Pulighe, G.; Lupia, F., 2020). Organizations needed local innovation to address global challenges since the scalability of innovations was made very difficult (Tittonell, 2016). A shift towards local innovation entered the world where the need for new technologies was high. In particular Big Data is one of the major new technologies that plays a huge role in the efficiency of management (Lopez-Morales, et al., 2020). Not only local innovation became a need, also local production of greens and vegetables. With the lockdowns an inevitable consequence was border closures and therefore movement restrictions which lead to increased food losses (Pulighe, G. & Lupia, F., 2020; R. Ramakumar, 2020). This changed the IT governance model into a more decentralized governance model with local accountability and and budget approval and risk assessment from the board of directors (Weill, P., & Ross, J., 2005).

Situation after COVID-19

Standardized business processes are an important factor when looking at cost reduction. Besides that, economies of scale can be achieved when handling a more centralized IT governance policy. Pedersen (2006) found that decision-analysis factors based on the input of a commercial farmer can have significant benefits. Therefore it's likely that organizations will move back to their old IT governance model where decisions are made on a more centralized level. However, since local innovation has been stimulated during covid-19 it's also likely that a more blended IT governance approach will be used after the pandemic. In this blended approach there's shared services which are centrally coordinated, but there's still room for local innovation. Local experiences that foster co-learning and support co-evolution require local innovation with global support (Tittonell, 2016). This global support also includes the use of Big Data which can barely be done locally. A centralized approach is needed to benefit from this new technology in the agricultural sector and move towards smart farming and exploit other major opportunities (A. Kamilaris, A. Kartakoullis, F. Prenafeta-Boldú, 2017).

Cyber Security

According to Feye et al (2020) the food industry is not different from any other sector when it comes to the acquisition of high-tech, computer science skills. Especially big data is an important trend within the agrifood sector, by having the potential to revolutionize food safety and traceability as well as to improve product on-demand quality and shelf-life (Taboada et al., 2017; Thompson, Rainwater, Di, & Ricke, 2017) However, to fully benefit from the implementation of automated and high-throughput and quality checks in this sector, safety monitoring will require change (Thompson et al., 2017). To improve food safety monitoring, product quality and consumer demand, big data management becomes a keystone in the vertical integration of food systems.

Situation before COVID-19

Before COVID-19 the trend of improving food safety, food traceability, improved product on-demand quality and shelf-life with big data was already ongoing. This trend was enforced due to political regulations for the environment and the need of consumers to consume more sustainable foods. This emergence of big data has caused significant advances in cybersecurity to ensure that potentially sensitive information is isolated from the public domain (Denning & Denning, 2016; Tariq et al., 2019). Furthermore, hackers have become contributors to the coevolution of cybersecurity and

data science, since they expose vulnerabilities with potentially devastating effects (Hemberg, Zipkin, Skowyra, Wagoner, & O'Reilly, 2018; Hutson, 2018; Feye et al, 2020).

Situation during COVID-19

Big data has assisted with tracing the COVID-19 virus like it has already assisted in improving epidemiological tracing of foodborne outbreaks of disease and microbial communities throughout processing plants (Kim, Park, Lee, Owens, & Ricke, 2017; Mayo et al., 2014; Schurch, Arredondo-Alonso, Willems, & Goering, 2018). The unrestrained power of analysis and traceability allows for the potential of real-time management decisions that can both reduce the cost to producers and safeguard the public food supply (Taboada et al., 2017; Thompson et al., 2017).

Most sectors are experiencing that getting the heterogeneity of data in real-time is expensive. As is the case with the food production lines in the agriculture and food sector. The technology in the sector is advancing rapidly and shows a lot of potential. An example related to COVID-19 is the real-time pathogen monitoring and whole genome sequencing for epidemiological tracking of foodborne disease (Danezis, Tsagkaris, Camin, Brusic, & Georgiou, 2016; Deurenberg et al., 2017; Granato et al., 2018; Mayo et al., 2014; Thompson et al., 2017). The importance of big data management increased during the COVID-19 crisis, as well as the need for new technologies to fully benefit from big data management. It will be more likely that, during this phase, agri food companies focus their investments in big data management systems rather than in cybersecurity.

Situation after COVID-19

Data gathered can be processed with integrated systems that utilize artificial intelligence and integrated networks will both improve the economics of food production and reduce food spoilage and waste (Ji, Hu, & Tan, 2017; Thompson et al., 2017). The integrated systems will improve overtime as more technological advancements, like blockchain, will be added to the system (Kamanth, 2018; Lin, Shen, Zhang, & Chai, 2018; Mayo et al., 2014; Tariq et al., 2019). And as AI will decipher the complexity of these data, the robustness of the structures will increase (Hutson, 2018). (Feye et al., 2020).

The adoption of new technologies, growth of data usage and increasing number of systems and integrations are causing new challenges for the cybersecurity measures of the agrifood sector. Considering the emerging trends for the agrifood sector, it is important to consider the impact of confidentiality, integrity and availability threats that concern the new trends. Visualizing on how threats will impact the new technologies within the sector on certain aspects, helps to identify where to improve cybersecurity.

Based on the findings in this analysis a risk analysis is made to assess the different scenarios.

Table 1. Impact diagram

	Confidentiality	Integrity	Availability
Traceability systems	L	M	H
Food quality data	H	H	H
IoT System integrations	M	M	M
Big Data Management	H	H	H
Real-time epidemiological tracking	L	H	L

DISCUSSION

COVID-19 brought some changes to the Business Process Integration of companies. The new regulations by governments forced companies to make a few considerable changes within the supply chain. Instead of buying raw materials internationally, companies needed to find alternatives locally. In order to obey the rules set by governments, companies need to reschedule shifts in order to guarantee the safety of their employees. Nevertheless, COVID-19 also brought some positive points in this sector. The virus has enabled the acceleration and adoption of new technologies. For example, farmers are introduced to the automation of farming via robots and AI technologies and the precision of demand through Big Data techniques.

In the analysis of IT Governance & Strategic Sourcing, it states that the use of new technologies allows for more precise management and the ability to combine multiple datasets to be more efficient (Lopez-Morales, j. et al, 2020). Before COVID-19 most important decisions were made by the board of directors (Weill, P., & Ross, J., 2005), who used steering committees and communication policies. However, during COVID-19 the IT governance model shifted into a more decentralized governance model with local accountability, budget approval and risk assessment from the board of directors.

After COVID-19 the situation is expected to return to a more centralized structure, to benefit more from the new technologies in the agrifood sector and the use of big data (A. Kamilaris, A. Kartakoullis, F. Prenafeta-Boldú, 2017).

Since the emergence of big data management in the agriculture sector, there is more sensitive information that should be isolated from the public domain (Denning & Denning, 2016; Tariq et al., 2019). Big data has proven useful with tracing the COVID-19 virus like it has already assisted in improving epidemiological tracing of foodborne outbreaks of disease and microbial communities throughout processing plants (Kim et al. 2017; Mayo et al., 2014; Schurch et al., 2018). During COVID-19 the usage of big data expanded due to the need for more information on food safety. The big data management systems will improve overtime and utilize A.I., blockchain and more technological advancement (Kamanth, 2018; Lin et al., 2018; Mayo et al., 2014; Tariq et al., 2019) to decipher the complexity of the data and ensure that the systems are secure.

During the business process integration analysis, it was noticed that companies needed to focus more on local alternatives for buying raw materials during COVID-19. This is in accordance with the findings of the IT Governance analysis, where it became visible that the IT governance shifted from a centralized model to a more decentralized IT governance with local accountability (A. Kamilaris, A. Kartakoullis, F. Prenafeta-Boldú, 2017). The Business Process Integration analysis also stated that the virus enabled the acceleration and adoption of robots and AI technologies within farming. This advancement creates more data which in turn will be deciphered by artificial intelligence. Companies must make sure that all the sensitive information will be isolated from the public domain in order to ensure resilience (Denning & Denning, 2016; Tariq et al., 2019). Lastly, in the IT governance analysis it states that risk assessments will be executed locally during the COVID-19 crisis. Considering the cybersecurity aspect, this implies that cyber security risk assessments will be done at a decentralized level as well.

CONCLUSION

The research conducted helped learn more about the impact of a pandemic - COVID-19 - on the daily processes of organizations in the entire food supply chain. More importantly, the major challenges organizations faced and how they overcame them with use of digital technologies. While looking at this question from different angles (BPI, ITG & Cybersecurity) this research provides a very comprehensive overview of how digital transformation helped the entire food sector to mitigate consequences of a global pandemic. The research tried to focus not only on the change visible now due to COVID-19, but also on what this will mean for the future of the food supply chain. Should organizations go back to normal once the COVID-19 pandemic is entirely over? What have organizations learned through the COVID-19 pandemic that could help them improve daily processes after the pandemic? In this way this research is not only adding value to the scientific knowledge base but is also of great value to organizations in the food supply chain struggling with the consequences of COVID-19. However, this research is of an exploratory nature and could be extended by a more generalizable research that will test hypotheses, based on some of the important preliminary findings discussed in this paper. Similar research could be performed more in depth about the possibilities for other digital technologies like Blockchain or Internet of Things, which are just briefly discussed in this paper. Further research could also cover the question to what extent IT governance should be decentralized in order to be able to innovate locally.

REFERENCES

Andreas Kamilaris, Andreas Kartakoullis, Francesc X. Prenafeta-Boldú (2017). A review on the practice of big data analysis in agriculture, *Computers and Electronics in Agriculture*, Volume 143, Pages 23-37, ISSN 0168-1699, https://doi.org/10.1016/j.compag.2017.09.037.

Bhandari, S. (2020), COVID-19: What's Next for Food Supply Chains?, retrieved from: https://www.publicissapient.com/insights/covid19_perspectives_on_the_coronavirus/covid_19_whats_next_for_food_supply_chain

Bronson, K., & Knezevic, I. (2016). Big Data in food and agriculture. *Big Data & Society*. https://doi.org/10.1177/2053951716648174

Danezis, G. P., Tsagkaris, A. S., Camin, F., Brusic, V., & Georgiou, C. A. (2016). Food authentication; Techniques, trends, and emerging approaches. *Trends in Analytical Chemistry*, 85, 123–132

De Clercq, Vats & Biel (2018). Agriculture 4.0: The Future of Farming Technology. *The World Government Summit.*

Denning, P. J., & Denning, D. E. (2016). Cybersecurity is harder than building bridges. American Scientist: *Computing Science*, 104, 154– 157.

Feng Tian. (2016). An agri-food supply chain traceability system for China based on RFID & blockchain technology. *2016 13th International Conference on Service Systems and Service*

Management (ICSSSM). doi:10.1109/icsssm.2016.7538424

Feye KM, Lekkala H, Lee-Bartlett J, Thompson D, Ricke SC. Survey analysis of computer science, food science, and cybersecurity skills and coursework of undergraduate and graduate students interested in food safety. (2020) *J Food Sci Educ.* 2020;1–10. https://doi.org/10.1111/1541-4329.12200

FutureBridge (2020). *Impact of COVID-19 on food supply chain*, retrieved from: https://www.futurebridge.com/industry/perspectives-food-nutrition/impact-of-covid-19-on-food-supply-chain/

Gonzalez, M. C. (2020). *Automating the Risk Out of Farming*, retrieved from: https://www.asme.org/topics-resources/content/automating-the-risk-out-of-farming

Granato, D., Putnik, P., Bursac-Kovacevic, D., Sousa-Santos, J., Calado, V., Rocha, R. S., ... Pomerantsev, A. (2018). Trends in chemometrics: Food authentication, microbiology, and effects of processing. *Comprehensive Reviews in Food Science and Food Safety*, 17, 663–677.

Hemberg, E., Zipkin, J. R., Skowyra, R. W., Wagoner, N., & O'Reilly, U. (2018). Adversarial co-evolution of attack and defense in a segmented computer network environment. *SIGEVO*, 1648–1655. https://doi.org/10.1145/3205661

Huang, R., Zmud, R. W., & Price, R. L. (2010). Influencing the effectiveness of IT governance practices through steering committees and communication policies. *European Journal of Information Systems*, 19(3), 288-302.

Hutson, M. (2018). Hackers easily fool artificial intelligence. *Science*, 361, 215.

Kamanth, R. (2018). Food traceability on blockchain: Walmart's pork and mango pilots with IBM. *JBBA*, 1, 1–12.

Kim, S. A., Park, S. H., Lee, S. I., Owens, C. M., & Ricke, S. C. (2017). Assessment of chicken carcass microbiome responses during processing in the presence of commercial antimicrobials using a next generation sequencing approach. *Scientific Reports*, 7, 43354. https://doi.org/10.1038/srep43354

Kosior, Katarzyna. (2018). DIGITAL TRANSFORMATION IN THE AGRI-FOOD SECTOR – OPPORTUNITIES AND CHALLENGES. Roczniki Naukowe Stowarzyszenia Ekonomistów Rolnictwa i Agrobiznesu. *XX*. 100-106. 10.5604/01.3001.0011.8122.

Lopez-Morales, J. A., Skarmeta, A. F., & Martinez, J. A. (2020). Agri-food Research Centres as Drivers of Digital Transformation for Smart Agriculture. In 2020 *Global Internet of Things Summit (GIoTS)* (pp. 1-5). IEEE.

Mayo, B., Rachid, C. T. C. C., Álegría, Á., Leite, A. M. O., Peixoto, R. S., & Delgado, S. (2014). Impact of next generation sequencing techniques in food microbiology. *Current Genomics*, 15, 293–309.

McIntyre, P. (2020). *Nestle: E-commerce a permanent post-COVID consumer shift but "patience" needed as supply chain, communications adapt*, retrieved from: https://www.mi-3.com.au/10-05-2020/progress-nestle-martin-brown

OECD (2020), *Food Supply Chains and COVID-19: Impacts and Policy Lessons*, retrieved from: https://read.oecd-ilibrary.org/view/?ref=134_134305-ybqvdf0kg9&title=Food-Supply-Chains-and-COVID-19-Impacts-and-policy-lessons

Pulighe, G.; Lupia, F. (2020). Food First: COVID-19 Outbreak and Cities Lockdown a Booster for a Wider Vision on Urban Agriculture. *Sustainability 2020*, 12, 5012.

R. Ramakumar, (2020). "Agriculture and the Covid-19 Pandemic: An Analysis with Special Reference to India," *Journal, Review of Agrarian Studies*, vol. 10(1), pages 72-110, January-J.

Reardon, T., Swinnen, J. (2020), *COVID-19 and resilience in food supply chains*, retrieved from: https://www.ifpri.org/blog/covid-19-and-resilience-innovations-food-supply-chains

Salin, V. (1998). Information technology in agri-food supply chains. *The International Food and Agribusiness Management Review*, 1(3), 329–334. doi:10.1016/s1096-7508(99)80003-2

Schurch, A. S., Arredondo-Alonso, S., Willems, R. J. L., & Goering, R. V. (2018). Whole genome sequencing options for bacterial strain typing and epidemiologic analysis based on single nucleotide polymorphisms verses gene-by-gene-based approaches. *Clinical Microbiology and Infection*, 24, 350–354

S. Fountas, D. Wulfsohn, B.S. Blackmore, H.L. Jacobsen and S.M. Pedersen (2006). A model of decision-making and information flows for information-intensive agriculture. *Agricultural Systems*, Volume 87, Issue 2 February 2006, Pages 192-210. https://doi.org/10.1016/j.agsy.2004.12.003

Taboada, E. N., Graham, M. R., Carrico, J. A., & Domselaar, G. V. (2017). Food safety in the age of next generation sequencing, bioinformatics, and open data access. *Frontiers in*

Microbiology, https://doi.org/10.3389/fmicb.2017.00909

Tariq, N., Muhummad, A., Al-Obeidat, F., Muhammand, Z., Baker, T., Hammoudeh, M., & Ghafir, I. (2019). The security of big data in fog-enabled IoT applications including blockchain: a survey. *Sensors*, 19(8), https://doi.org/10.3390/s19081788

Thompson, D. R., Rainwater, C. E., Di, J., & Ricke, S. C. (2017). Student cross-training of opportunities for combining food, transportation, and critical infrastructure cyber security into an academic food systems education program. Food and feed safety systems and analytics. *Elsevier.*

Tittonell, P., Klerkx, L., Baudron, F., Félix, G. F., Ruggia, A., van Apeldoorn, D., ... & Rossing, W. A. (2016). Ecological intensification: local innovation to address global challenges. In Sustainable agriculture reviews (pp. 1-34). *Springer, Cham.*

Weill, P., & Ross, J. (2005). A matrixed approach to designing IT governance. *MIT Sloan management review*, 46(2), 26.