

AGRICULTURE 4.0 APPLICATIONS IN SUPPLY CHAIN MANAGEMENT FOR FOOD SAFETY– A STRUCTURED LITERATURE REVIEW

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Abstract The purpose of this paper is to is to examine how Industry 4.0 applications can be used in agricultural context in order to create more efficient food safety operations in supply chain management, leading towards the Agriculture 4.0 era. The Industry 4.0 trend is transforming the production capabilities of all industries as companies try to keep pace with the era of globalization and aiming to obtain a competitive advantage on the market as they benefit from technological advancements and this also applies to the agricultural sector. As the world's population is increasing, the importance of the food safety is more important than ever. As a result technological development is a necessity especially in light of the length and complexity of the global supply chains. This paper provides a structured literature review of related papers, examining the various applications and opportunities created by the Industry 4.0 in the agricultural sector, and aims to show how the use of technology in agricultural supply chains has evolved.

Keywords:
industry 4.0,
agriculture 4.0,
supply chain
management,
food safety,
digitalization

1 Introduction

The fourth industrial revolution which is also called Industry 4.0 and its technological advancements impacted many areas of our life during the last decade. The fourth industrial revolution became a very important topic in many domains such as production, design, sales, inventory, scheduling, quality, engineering, customer service, and many more.

There are several approaches to precisely define its concept. According to Hoffmann and Rütsch (2017) we can talk about industry 4.0 when devices and services are connected to a network and not only people but also machines communicate with each other. The driving force behind this phenomenon is the spread of the Internet and, as a result, the emergence of various cyber-physical systems (CPS), the main task of which is to satisfy the agile and dynamic requirements of production, as well as to improve the efficiency and effectiveness of the entire industry. Industry 4.0 encompasses a range of technologies and related paradigms, including for example radio frequency identification (RFID), enterprise resource planning (ERP), the Internet of Things (IoT), cloud-based manufacturing, and social product development.

According to the literature that the main pillars of Industry 4.0 are digitization, data and continuous connectivity. Regarding the extent of the fourth industrial revolution, different formulations can be read, but overall, companies must face changes that cover the entire company value chain, and even challenges that grow beyond the borders of the company, that cover the supply chain or even the entire supply network, in order to maintain their competitiveness. It requires companies and their employees to introduce state-of-the-art technological systems and procedures, learn new competencies, be open to the new and unknown, and even develop changing business models. Industry 4.0 is therefore a phenomenon that, through a set of technological tools and activities, by exploiting the opportunities provided by digitalization, raises the transparency of processes to a high level and integrates the company's value chain and the supply network, raising customer value creation to a new level.

The purpose of this paper is to examine how Industry 4.0 applications can be used in agricultural context in order to create more efficient food safety operations in supply chain management, leading towards the Agriculture 4.0 era.

The Industry 4.0 trend is transforming the production capabilities of all industries, including agriculture. The cornerstone of this transformation is connectivity, and IoT is a key technology that is increasingly part of the agricultural equipment.

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2 Industry 4.0 and Agriculture 4.0

Industry 4.0 refers to technological evolution by using automation, intelligent systems and digitalized production (Muhuri, Shukla, & Abraham, 2019). One of the critical challenges which organizations have faced is the ability to respond to demand speedily in light of the increasing volatility. Recently, the competition between companies has increased significantly and rapidly. Because of the clear similarity between products in terms of quality and price in addition to the short life cycle of the product, the companies have become required to focus on managing supply chains and speeding up their operations because of competitive pressures (Christopher, 2016).

The aim of Industry 4.0 is to raise efficiency and productivity to a higher level, as well as to achieve extensive automation of processes. The research of Roblek et al (2016) and Posada et al. (2015) clearly names the five drivers of the revolution: digitization, optimization and production customization; automation and adaptation; human-machine interaction (HMI); value-added services and businesses, as well as automatic data exchange and communication. These functions are not only closely related to Internet technologies and advanced algorithms, but also indicate

that Industry 4.0 is an industrial process of value addition and knowledge management.

According to Zezulka et al. (2016), the whole phenomenon is driven by digitization and the Internet. Its goal is to combine the value-creating activities of a company and the partners working together in the value-creating chain into a large digital system with the help of the Internet and modern tools.

According to Nagy (2019) the concept of Industry 4.0 is a phenomenon that, based on technological tools, through a set of activities, by exploiting the opportunities provided by digitalization, raises the transparency of processes to a high level, integrates the company's value chain and the supply network, raising customer value creation to a new level by making customized and smart products available. According to Nagy (2019), Industry 4.0 includes the need for change organizational changes as well, but still does not discuss the rethinking of the company-wide strategic goals or the business process. Prause and Günter (2019) writings already clearly mention that the constantly changing industry necessitates a change in management thinking, according to which, during Industry 4.0, the line between the independent operations of individual sectors becomes gray, and this makes it increasingly necessary for business transformation of models and structures, this is digital transformation itself.

The emergence of Industry 4.0 provides a number of opportunities for organizations across the world in the current rapidly changing environment as Industry 4.0 can be used to engender a transformation from machine dominant manufacturing to digital manufacturing by bridging the physical industrial assets and digital technologies in cyber-physical systems. One of the main objectives is essentially to enable autonomous decision-making processes, monitor assets and processes in real-time, and enable equally real-time connected value creation networks through early involvement of stakeholders, and vertical and horizontal integration (Wamba & Queiroz, 2022).

Today's digital supply chain networks employ a wide range of technologies to create efficient, transparent, adaptive, and resilient systems at various stages of supply chain development, such as new product development, manufacturing, procurement, planning, logistics, and marketing (Ghadgeet al., 2020).

Enterprises have realized the significance of technological advancements and regard technology as a powerful strategic tool for ensuring long-term performance (Chavarría-Barrientos et al., 2017). Companies must be prepared to adopt required technological innovations and understand their capabilities and potential benefits in business processes in order to successfully implement the Industry 4.0 perspective (Moktadir et al., 2018).

Agriculture 4.0, also known as the fourth agricultural revolution, differs from precision farming in that it applies technology to all aspects of farming processes, from the crop yield through harvesting, to logistics and transportation. Agriculture 4.0 is basically the digitization of the classic agricultural farm operations. (Maffezzoli et al., 2022)

Agriculture 4.0 offers a strong opportunity to stimulate economic growth and increase the incomes of companies working in the agricultural sector by increasing the efficiency of agricultural production. Because of these aspects Agriculture 4.0 also plays a decisive role in terms of sustainability, as it enables agricultural practices to adapt to climate change, reduce greenhouse gas emissions and use inputs such as water and fertilizers more efficiently. The agriculture of the future will use sophisticated technologies such as robots, temperature and moisture sensors, aerial photography and GPS technology. These advanced tools, along with precision farming and robotic systems, enable farms to be more profitable, efficient, safer and more environmentally friendly. (Weltzien, 2016)

Agriculture 4.0 encompasses the development of precision farming and refers to all activities carried out in agriculture based on accurate and precise analysis of data and information collected and transmitted using advanced tools and technology. It refers to the tools and strategies that enable the synergistic use of a range of digital 4.0 technologies, enabling the automatic collection, integration and analysis of data from the field, sensors or other technologies. (Beluhova-Uzunova et al., 2022)

Agriculture 4.0 refers to the use of the Internet of Things (IoT), Big Data, Artificial Intelligence and robotics to extend, accelerate and increase the efficiency of activities affecting the entire production chain. The purpose of these technologies is to provide the most comprehensive and accurate support to farmers in the decision-making processes related to their activities, as well as in maintaining contact with

other actors in the supply chain. The ultimate goal is to increase the economic, environmental and social sustainability and profitability of agricultural processes. (Aricioğlu, Yılmaz, 2020)

According to Silveira et al. (2021) the adoption of 4.0 solutions in agriculture means voiding unnecessary wastage by accurately calculating the crop's water requirement or detecting the appearance of certain plant diseases or pests in advance, having more control over costs and you can plan every stage of cultivation, sowing and harvesting with high precision, saving time and money, and improving supply chain traceability, resulting in a short supply chain that can sustainably produce high-quality food with a low margin of error.

Effective data management is also a crucial part of Agriculture 4.0 applications according to Oleiro Araújo et al. (2021), stating that the most innovative technologies have to be applied in order to be able to manage the large amount of data and information coming from the fields, and also to have the ability to interpret this information in a useful way.

According to Maffezzoli et al. (2022) there are several main technologies that can be effective in the increased digitalization and connectivity of agricultural processes. Drones for example can be used as small unmanned aircrafts to monitor crops in real time and transmit images and useful information. They are mainly used for land mapping, but the most advanced versions use infrared sensors and imaging systems to detect problems that cannot be seen otherwise. Besides that environmental sensors can record weather data and information about soil moisture requirements.

The Internet of Things (IoT) allows many devices (drones, sensors or satellites) to connect and communicate with each other to exchange useful data to monitor crop development conditions. As more and more information will be generated by the connected technologies, Big Data applications can also be useful to assist in making more efficient decisions during the production process. However, these datasets can be very different since they will usually originate from different sources. Because of that during the processing of the information applying Artificial Intelligence can also be beneficial as it has the ability to process and interpret large amounts of data is the main input for machine learning. (Silveira et al., 2021)

Nevertheless the approach and the applied set of tools the management of data and information is very important to exploit the economic value of this information

3 Food safety in supply chain management

Agriculture is the main source of raw materials for the food industry and since the importance of the food safety becomes a crucial challenge nowadays, the continuous development and digitalization of the agricultural supply chain becomes a focal point (Yadav, et al., 2022).

There are three main obstacles that have led to a decline in agricultural development in general around the world, namely the lack of water, and the shrinking of arable land, for many reasons, including desertification, high salinity and urban sprawl. And migration from the countryside towards the city, and thus a shortage of labor. These factors can be overcome by employing modern technology, which will greatly reduce the land area. It reduces the amount of water used and allows it to be recycled. Of course, robots will reduce the need for labor. Adopting modern technology primarily requires creating the appropriate environment for its use, and this will only happen with the support of governments and with huge investments (Mendes, 2022).

(Yadav, et al., 2022) in their paper described the industry 4.0 technologies as an added value features to the agricultural supply chain, which also helps in a better decision making process. The concept of smart agriculture has emerged, which allows for the fulfilment of agricultural activities with greater accuracy and efficiency, in line with the increasing demand for food products in the world. In smart farm applications, electronic sensors distributed in the field monitor different conditions. In some cases, the tools send data to a cloud server on the farm (network servers are widely used for computing and data processing). These numbers are automatically analyzed and instructions are sent to the farm's automatic irrigation system, which in some cases may add the correct dose of fertilizer as needed before dispersing the right amount of water; through the drip tape. This technology increases efficiency, periodically distributes the right amount of water, can prevent wastage and reduce the volume of fertilizer water. Farmers can access this data via a tablet or smartphone; Which gives them real-time information that would have required the slow and extensive manual soil testing process in the past (Javaid et al., 2022; Abbasi et al., 2022).

In case of The Internet of Things, the digital transformation is revolutionizing the agricultural sector. IoT technologies enable the linking of structured and unstructured data to provide insights into food production. In data-driven agriculture, farmers can make better decisions by analyzing interconnected data on climate, grain types, soil quality, disease probability, historical data, market trends and prices (Abbasi et al., 2022).

Another application is the use of drones in the agricultural sector using technology by planning sowing seeds through accurate 3D mapping of primary soil analyses, and data collection to manage irrigation and nitrogen levels. It also helps detect dry parts that need irrigation and sprays crops five times faster than conventional machines. In addition to tracking changes in plants and indicators of their health, and alerting farmers to the presence of any diseases (Maffezzoli et al., 2022).

Also one of the most important and useful tools in the agriculture sector is the blockchain technology, which secures digital transactions and keeps records. blockchain technology can reduce inefficiency and fraud, enhance food security, and pay farmers on time. Improving the ability to trace products within the supply chain will make it easier for regulators to trace contaminated food, determine the range of affected products during contamination cases, as well as reduce waste by identifying bottlenecks in the supply chain that lead to food spoilage. The transparency that blockchain provides can reduce food fraud. As consumer demand for organic and free from genetically modified products' foods has increased, the number of cases of fraud in antibiotics and antibiotics has increased, so has food ratings. The smallest of transactions in farms, warehouses or factories can be efficiently monitored and their details communicated along the supply chain when paired with IoT technology such as sensors and RFID labels. The benefits of this openness extend to all honest parties in the market. Blockchain technology can prevent price gouging, delay payments, eliminate middlemen and lower transaction costs, leading to fair pricing and helping small farmers get a greater share of the value of their crops (Yadav, et al., 2022).

Artificial intelligence and smart small robots, which can distinguish between weeds and agricultural crops, have been employed to improve resources, preserve the environment and human health, and produce healthy and high-quality agricultural crops. This can be done by performing a mechanical eradication of it, or dealing

with it with electricity or laser beams, or using precise spraying of chemical pesticides on weeds only, without agricultural crops. That is, a very large reduction in the chemicals that farmers spray in the entire field, by twenty times, which means less negative environmental impact and a significant reduction in the annual expenditure of farmers on herbicides. One of the tasks of robots in agriculture is also to help farmers choose and pack their crops, as 30 human workers can be replaced by one robot, and here the problem of labor shortage can be solved. (Krstić et al., 2022) & (Javaid et al., 2022).

Modern transportation helps in making the products in the markets available from the farm at the right time. Technologies in the field of transportation help farmers easily transport fertilizers or other agricultural products to their farms, and also speeds up the process of providing agricultural products from farms to markets where consumers get them daily (Krstić et al., 2022).

In terms of cooling in logistics applications, the farmer buys modern refrigeration to ensure that tomatoes and other perishable crops are delivered and kept fresh while they are transported to the market. Coolers are installed in food transport trucks, which keeps perishable crops like tomatoes fresh on delivery (Chandran et al., 2022).

In terms of modern greenhouses, it has become high-tech, using LED lights and automated control systems to adapt the agricultural environment. An important contribution to technological development, indoor vertical farming is the practice of cultivating products stacked one on top of the other in a closed environment. This type of growth is often associated with urban and urban agriculture due to its ability to thrive in a limited space, and is unique in that the plants do not require soil, mostly aquatic plants, where the roots of plants are regularly sprayed with water and nutrients. Humans cannot create this type of farm without relying heavily on technology in terms of observing plants, determining the amount of light, moisture, and other conditions that are difficult for humans to accurately determine (Kobayashi et al., 2022).

4 Conclusion

There is consensus in the literature on the great effects and benefits of the application of industry 4.0 technologies in the agricultural sector, in addition to some challenges such as the cost of employing these technologies and the need to train the farmers to accept and use the equipment in an appropriate manner.

However, there is still a lot of reluctance towards a new way of understanding agriculture and the new technologies associated with it. Nonetheless, there is no doubt that Agriculture 4.0 has many advantages.

First, it can provide economic advantages, through greater control over the agricultural processes leading to better optimization of resources, thus resulting in less waste in terms of materials. Second, the environmental benefits are another great addition as technological advancements in agriculture can result in more sustainable processes and operations while reducing the environmental impact of the entire food chain. Third, constant and precise monitoring of each stage of the production chain translates into a higher quality end product, which is undoubtedly beneficial for food safety and human health conditions. Last, these new applications can be also beneficial for the workers as they can improve the working conditions and decrease the burdens of everyday processes.

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