INCREASING THE EFFECTIVENESS OF FOOD SUPPLY CHAIN LOGISTICS THROUGH DIGITAL TRANSFORMATION

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Abstract *During the COVID-19 crisis, there were many restrictions placed on transportation. Due to this, a significant disruption in the food supply chain emerged. The transportation of fresh food and maintaining its quality from farm to the table, or distributing and then collecting from warehouses and delivering to the consumer, has become crucial. Technologies, and especially the IoT, have become the primary tools to fight this. The research objective is to analyze and create new knowledge about digital technologies used to improve and make more effective food supply chain processes. An exploratory case study methodology helps to investigate a large consortium based on IoT technologies, implemented in pilot cases at the farm level and measuring their performance over a period of four years. This is an interpretative study, and the method of semi-structured interviews and document review for collecting the data was used. The results show IoT-connected sensors and systems in food and beverage supply chain logistics offer real-time visibility and data-driven analytics, allowing stakeholders to improve performance, cut operating costs, conduct predictive maintenance to avoid downtime, and even decrease energy usage or reduce negative environmental impacts.*

Keywords: *agriculture, digitalization, digital technologies, IoT, logistics, supply chain, effectiveness.*

Introduction

The European Green Deal sets out how to make Europe the first climate-neutral continent by 2050. It outlines a new, sustainable and inclusive growth strategy aimed at improving people's health and quality of life, boosting the economy, caring for nature and leaving no one behind. The strategy of Farm to Fork (European Commission, 2020a) is at the heart of the Green Deal. It addresses the challenges of sustainable food systems and seeks to ensure a sustainable livelihood for primary producers who are still lagging behind in terms of income, which is essential for the success of the climate recovery and transition.

Given the complexity and the huge number of actors involved in the food value chain, crises such as COVID-19 affect the food chain in different ways. Although there has been sufficient food supply in general, this pandemic has presented many problems, such as logistical

disruption of supply chains. In today's intensely competitive global marketplace, businesses' pressure to find new ways to create value and offer it to their customers is growing ever stronger. The growing need for the industry to compete with its goods in a global economy across cost, quality, and service dimensions has contributed significantly to the need to develop a more efficient logistics system.

Technology has been completely revolutionizing the present era, and digitalization can bring new opportunities for companies by improving the whole value chain (Kilimis et al., 2019). The agricultural sector is no exception. Digital transformation can bring new opportunities for agriculture and food (agrifood) companies and open up new growth paths for development. One of the most significant contributions to future sustainability would come from a radical transformation of the agrifood value chain (Renda et al., 2019).

Literature review

The applications of digital solutions in the agrifood sector are very diverse. They can help extend shelf life, monitor freshness, display information on quality, improve safety, and improve convenience. Rotz et al. (2019) emphasize the technical and organizational challenges of digitalization in agrifood. Lack of awareness, especially among rural farmers, low level of digitalization of agrifood companies, and low incomes of rural farmers – together with high costs of ICT infrastructure, insufficient personnel to handle ICT facilities, and the absence of local language content on the Internet – are making digital transformation a challenge (Salampasis & Theodoridis, 2013). Many problems exist throughout agriculture, such as irrigation, the use of pesticides, fertilizers, the monitoring of crops, land and livestock (López-Morales et al., 2020). Potential applications of ICT solutions in agrifood are very diverse, including, among others, software for supply chain or financial management, mobile applications for farm management, agricultural land use optimization, precision agriculture applications and others which fall into other categories of ICT-enabled services (Salampasis & Theodoridis, 2013). Motivated by digital transformation, the agricultural sector is offering its farms new services and devices (drones and satellite images, sensors, actuators, weather information) to optimize resources, increase efficiency and at the same time reduce the effect on the environment (López-Morales et al., 2020).

Digital transformation can significantly contribute to the improvement of products and/or services and the management of operations in a more efficient way. It can also trigger costs reduction or can help to gain a competitive advantage in the market. Ulas (2019) pointed out several driving factors expediting digital transformation: globalization, the advancement of technology and innovation, electronic commerce, and social media. The idea of an interconnected world has also gained attention from the industry sector, and the vision of the digital revolution is emerging, popularly known as Industry 4.0 (Kang et al., 2016).

Experts highlight four areas in which digitization technologies will have the most significant impact: productivity, revenue growth, employment, and investment (Rußmann et al., 2015). The development of Industry 4.0, artificial intelligence, the Internet of Things (IoT), blockchain, cloud computing, augmented reality, 3D printers, chatbots, big data, and nanotechnology have been speeding up the process of digitalization.

The *digital agricultural revolution* is a new term explaining the changes that the agrifood industry's traditional approach is undergoing as part of a fundamental transformation. As stated by Schwab (2016), this no doubt offers significant opportunities through the availability of highly interconnected and data-intensive computational technologies as part of Industry 4.0.

The term *logistics* could be interpreted in many different ways. Various authors emphasize different aspects of its definition. Logistics is the core of production and marketing organization (Movahedi et al., 2009). The quality of marketing depends on how the products

are delivered to the final customer. The value of logistics for the agrifood industry has become more widely recognized by organizations worldwide. Agrifood logistics is an important part of the economy and an interconnected system that controls, coordinates, and organizes different flows of logistics, ranging from production through points of storage, processing, and trade to the final consumer. The aim is to provide the final consumer with uninterrupted supplies of safe food products with minimum logistics costs and under environment-friendly conditions (Wajszczuk, 2016).

When it comes to agricultural logistics, we need to look more broadly and include the supply chain concept. Supply chain management is a core component of the performance of companies' value chains (Hult et al., 2007). Supply chain management is the management of trading off products and information in the logistics process of companies, ranging from sourcing raw materials to delivery to the customers (Felea & Albastroiu, 2013). The supply chain includes a substantial number of manufacturers, suppliers, and consumers and is undoubtedly responsive to many complexities. Subsequently, it is one of the key concerns in the supply chain management sector (Emamisaleh et al., 2018). Logistics is a supply chain activity that plans, implements, and manages the reliable, efficient transportation and storage of products, services, and information to meet consumer needs (Croom et al., 2018).

Researchers have identified five dimensions of supply chain management and integration activities: strategic supplier partnerships, relationships with clients, sharing of quality information, operational lean practices, and postponement (Mogaka et al., 2020). Considering agrifood business, supply chain management means that agrifood products reach the market in time.

The field of supply chain processes and logistics for agriculture and food produce is, to some degree, unpredictable. Over time, the supply chain mechanism for such products has grown into an increased chain of facilities, such as in-time deliveries, centralized specialized manufacturing processes, and the maintenance of low loading rates. Agrifood companies produce raw materials for agricultural processing and fresh products, which are delivered to the consumer directly or indirectly. The quality of raw materials, products and the costs generated by agrifood companies and enterprises will have a significant impact on the efficiency of the entire supply chain. Due to their direct interaction with the environment and living organisms, the types of production technologies and logistics will affect these costs and quality (Wajszczuk, 2016). Mathur et al. (2018) specified that if a company can start measuring customer satisfaction related to what a supply chain can do and also link customer satisfaction in terms of profit or revenue growth, then it can attach customer values to profit and loss, and even to the balance sheet.

Essential success elements for retailers and manufacturers are the efficiency of the logistics and the technology used. The entire process needs to be controlled effectively to ensure that the correct products are delivered, to the right location, in the proper condition, within a reasonable period of time, while maintaining cost efficiency for all parties involved. It is essential to highlight the maintenance and spare parts and tools, specifically among supply chain activities. In short, the challenges to be met are related to the quick and reliable delivery of the spare parts inventory at minimum costs (Lozano et al., 2017).

Wajszczuk (2016) summarizes the many studies conducted, identifying that the main challenges related with logistics are: the issue of receiving aligned-quality goods from various small farmers; different sources of supply of raw material batches; contamination issues; the presence of numerous and independent links in the entire supply chain; the formation of very long marketing channels, where an unequal balance of power appears in the supply chain; poor infrastructure and limited access to the required means; and difficulties in establishing horizontal farm cooperation, mainly due to the lack of trust, mostly in developing countries (the lack of proven business models, modern storage infrastructure, ICTs, etc.).

In general, the ratio between the profits and the costs arising from the supply chain helps to evaluate the efficiency of the logistics system. Elements such as the aggregate costs of logistics, the level of logistics service quality, the performance of the business system, the overall duration of the logistics processes in the system, and its quality (logistics services' level) are common KPIs, or key performance indicators, for any logistics system (Tyapuhin, 2007). The latter are widely used in the comparative evaluation of business entities and their logistics systems, and, as such, they are measurable. Moreover, these KPIs are the backbone of the planning of operations, tactics, and strategies of modern companies and the monitoring of the effectiveness of the logistics system and business entity's management accounting system.
Elements such as transportation costs, storage costs, goods-processing-affiliated costs, inventory management costs, order management costs, costs related to the exploitation of logistics information systems, stock formation costs, raw material maintenance costs, finished product costs, the costs of potential damages arising from the manifestation of the logistics risks or from the insufficiency of logistics services comprise a general classification of logistics costs by functional areas (Arshinina & Kiseleva, 2020)
To continue, the evaluation of the quality of logistics services is a necessary undertaking that is evaluated directly during its provision. It is also important to place logistics services on a high-level corresponding with the potential consumer's needs. To sum up, the extent of congruity between the consumer expectations regarding the logistics system and the actual level of this service's provision defines the logistics service's quality. The level of logistics service provision is expressed through a set of quality criteria such as the physical environment of the service, consumer behavior, the reliability of the logistics service provider, responsibility, maturity of the service, and security (Tyapuhin, 2007).
Logistics system resources are inputs, whereas the outputs reflect the results, and the quality of all logistics services depends on their structure, quantity, and composition. For this reason, it is necessary to assess the accuracy of the time and the place of delivery, range and the quantity of products supplied, quality indicators, and compliance with the prices on the market so that we can formalize the procedure on how to evaluate the efficiency of logistics.

Data and methodology

Applying technologies to any parts of the food supply chain enables stakeholders to collect and analyze data which was previously not accessible. The result becomes the foundation for further improving existing agrifood value chain logistics processes and creating new ones. IoT technology is one of the crucial elements of effective logistics in any industry (Da Xu et al., 2014). The rising usage of smart sensors, smart carry bar codes, and different tags, enabling precise, real-time tracking through the entire food supply chain, are good examples of how the IoT makes logistics more effective.
The purpose of this paper is to analyze the role and impact of digital technologies, the IoT in particular, in the logistics of the food supply chain and underline the effectiveness of the logistic system when technology is applied in real-world conditions.
The research objective is to analyze and create new knowledge about digital technologies used to improve and make more effective food supply chain processes. An exploratory case study methodology helps to investigate a large consortium based on IoT technologies, implemented in pilot cases at the farm level and measuring their performance over a period of four years. The paper seeks to better understand and provide insights into how digital technologies, the IoT in particular, are being used in logistics to bring more value to the food supply chain.
This is an interpretative study, and the method of semi-structured interviews and document review for collecting the data was used. Experts on the agrifood sector's digitalization were selected. They had no less than ten years of experience working with digital innovation

technologies and tools, creating products, implementing them into the market, and conducting analyses. At least five experts were selected who directly took part in implementing the IoF2020 project. A total of 15 interviews were conducted. The different methods of analysis of the final data were implemented to achieve the paper's objectives.

Referring to the IoT in the agrifood sectorial context means that particular layers of the system, usually three (device, network, and application), are applied (Villa-Henriksen et al., 2020). Such application enables gathering data from each step of the agrifood supply and value chain processes. IoT technologies are considered the most important digital innovations that influence the largest amount of valuable data collection in the agrifood sector (Tzounis et al., 2017). It is expected that by 2050, IoT technologies have the potential to increase agricultural productivity by 70%. This will enable, for example, achieving higher crop yields with less cost, improvng the nutritional value of food significantly, and improving care quality and herd productivity in livestock (Sarni et al., 2016).

A significant amount of food in many cases is wasted due to logistics problems. The most significant loss occurs during transportation and storage. In total, this amounts to over 20% of the world's food production. IoT solutions applied to the food supply chain can reduce this number by 10%–15% (PwC, 2013).

During the COVID-19 crisis, there were many restrictions on transportation. Due to this, a significant disruption in the food supply chain has emerged. The transportation of fresh food and maintaining quality from farm to table, or distributing and then collecting from warehouses and delivering to the consumer, has become crucial. Technologies, and especially the IoT, have become the primary tool to fight this.

Digitalization of the agrifood sector is one of the priorities moving towards the EU's twin transition. The European Commission (2020b) has approved various large-scale projects to accelerate digital innovations into the sector. During the past five years, a vast number of various use cases have been approved and successfully applied in everyday food supply and value chain processes. The usage of sensors, smart planning, smart animal health monitoring, plant disease monitoring systems, etc., are helping farmers to continue their daily operations while reducing their environmental impact and maintaining their competitiveness in the market. EU funding has laid a solid foundation for such possibilities and solutions to be commercialized and available to the market.

IoF2020, DEMETER, ATLAS, and SmartAgriHubs are four large-scale piloting initiatives that have secured a total of €80 million for research and innovation into the application of emerging technologies for the agricultural sector. IoF2020 was founded in January 2017 to promote the IoT in the food and agriculture industries. This initiative, which has received a €30 million investment, puts together two ecosystems – agribusiness and advanced ICT suppliers – that have boosted digital innovation in agriculture (European Commission, 2021). This is why the IoF2020 has been chosen as a use case to analyze.

The IoF2020 project's main objective is to set a strong foundation for implementing IoT technology in agrifood to provide safe and healthy food, help farmers stay competitive, and increase the competitiveness of the food supply and value chain in the EU. The project's main result is the EU's consolidated leading position in the global IoT industry. This has created a healthy ecosystem through the whole food value chain, involving: farmers, the food industry, technology providers, and research institutes. Led by the highest ranking educational institution in agrifood research, Wageningen UR University, IoF2020 was joined by 73 partners acting in 22 EU member states. This is by no means the biggest pilot project of its kind.

There are 19 use cases divided into five types of trials: arable, dairy, fruits, vegetables, and meat. The pilot's purpose was to demonstrate the use of innovative digital IoT solutions for a vast number of application areas.

The project has taken a multi-actor approach choosing key performance indicators (KPIs) closely related to user acceptability, stakeholder engagement, sustainable business models, new components improving the technology, and market readiness levels. These factors are significant in analyzing the effectiveness of the logistics of the food supply chain.

In general, a KPI is a value that indicates the degree to which a strategic goal has been accomplished. In selected pilot use cases, KPIs are used to determine if established goals have been met at different levels. Each use case measures the effect of the IoT solution on various industries, business priorities, and society at large. Consequently, primary success metrics show observable performance in meeting the critical market goals. In the scope of the IoT, three levels of KPIs are indicated: operational (number of sensors installed, number of farmers participating, number of ICT component used), strategic (yield increase, efficiency, improved market access, less water use, work time efficiency, etc.) and visionary (less CO_2, user satisfaction, work stress reduction, farmers' livelihood, etc.). For this analysis, strategic and, in some cases, visionary KPIs have been considered.

A well-coordinated distribution plan for use case results and project learnings, backed up by customers and consumers, guarantees a high degree of business exposure and a quicker learning curve. As a result of IoF2020, data-driven farming, autonomous operations, virtual food chains, and personalized nutrition for European citizens are now feasible.

The pilot use cases demonstrated solid results on IoT technologies; for example, on an average farm using IoT, yield rises by 3.75%, and energy costs drop by 27% to €36 per hectare, while water use for irrigation falls by 12%.

Based on the experts' suggestion, the pilot cases most suitable for analysis in agrifood supply chain logistics based on IoT technology were chosen. They were selected from three areas of trials: arable, fruit/vegetable, and beverage. According to experts, these are some of the most important areas where food supply chain logistics must be effective and sustainable.

The implemented pilot project's main objective is the traceability of food and feed logistics. The use case has developed a smart system that ensures adequate feed logistics and maximum traceability of the distribution process. It incorporates a revolutionary method that secures and authenticates the transportation of goods in the agrifood chain, ensuring that feed and food are shipped without fear of losing quality and being contaminated. For the capability to control and monitor such a process in a healthy and traceable procedure for their goods before they leave the factory, producers of animal feed and human food allocate a significant amount of time and money.

The use case involved the task of providing a system that can control the goods' transport and delivery to the customer's silo or warehouse. It provided an additional management system to ensure that these items are shipped and distributed correctly. As a result, it eliminates the possibility that products will be shipped to the incorrect storage areas or polluted and spoiled, causing harm to the consumer.

An integrated IoT-based automatic storage detection system can ensure that the proper merchandise is shipped, as well as keeping track of its transportation and registration information. The use case demonstrates that the whole procedure is entirely traceable, and the possibility of pollution is reduced.

In this case, logistics in the food supply chain addresses essential food safety issues and sustainability requirements while increasing productivity and significantly increasing user satisfaction. The target group of users was animal feed and bulk-goods buyers. Nevertheless, the use case targeted farms, consumers, supply chain managers, and warehouse/silo owners directly.

The increase in consumer trust in food delivery and the availability of sufficient knowledge to make food choices reflect consumer satisfaction. This data was structured, analyzed, and shared with customers and other stakeholders.

Consumer trust is one of the crucial factors in the food supply chain, so the IoT technologies in the use case were projected to solve that. Consumer confidence in food on the market can be strengthened, and this particular use case the application of the IoT tool has proved this.
This particular use case has an obvious supply chain process, which needs to be improved in management. The crucial roles here are played by relations with clients, strategic supplier partnerships, and, of course, the sharing of quality information.
The supply chain starts at the silos/warehouses and continues to the end-users. In between, some processes could affect the final delivery result. Controlling and monitoring such processes as trailer equipment and loading procedure, silo device, and unloading procedure is essential. The possibility to share accurate information with drivers, logistics managers, and consumers creates added value. Operating such data brings different value propositions to different stakeholders. For example, a farmer receives a transparent process, which requires less paperwork and is equipped with online monitoring and digital signature. This helps with the easy delivery of the right food to the right animal. The transport manager enjoys less paperwork and holds data on which exact quality bulk-goods are being delivered, and tracks the trailer's exact location. For the driver of the trailer, automatization means reliability in the process and less human error, and importantly in times such as the COVID-19 pandemic, this creates a contact-free process. The measurable value created for the customer is the significant reduction of the risk of wrong warehouse or silo delivery by up to 90%, which helps maintain good quality relations with the clients. Overall, the logistics controlled by such a system become leaner in management processes.
The use case significantly contributes to solving logistics' main challenges in the agrifood sector. The implemented system tends to reduce the risk of animal feed contamination by up to 20% and reduce human food contamination by up to 22%.
When food becomes polluted during handling and transportation, it increases food waste. In many cases, cleaning processes cannot be applied, nor is it possible to clean to the point that the food would regain its previous quality. Thus, the reduction of waste by contamination is also an important value proposition created by the use case. Simultaneously, increased security of bulks goods delivery is observed, which lowers the lack of trust in the whole supply chain.
Food supply chain stakeholders are provided with the possibility to trace the food and its quality up and down the supply chain. Improved traceability by up to 25% is expected using this system.
The performance and overall impact of the use case consist of all the value propositions which arise from it: reduced risk of animal and human feed contamination, reduced waste by contamination, improved traceability, and increased security of bulks goods delivery. Measuring its effectiveness, it is important to underline the reduction of recovery costs and reduced additional transport compared to the usual logistic process. Moreover, the increased user satisfaction using IoT systems on silo devices is 7.9 (on a scale from 0 (not satisfied) to 10 (extremely satisfied)) and on trailer equipment 7.65 (on a scale from 0 (not satisfied) to 10 (extremely satisfied)).
Real-time data distribution and tracking of all trailers, secure delivery procedures via traceability from the factory to customer, accurate monitoring of the discharging process, direct warning in the event of anomalies during deliveries, data collection for analysis and prevention, and enhanced food safety all contribute to new and easily measurable value in the food supply chain.
Overall, the use case demonstrates improvement in the business system's performance, rising user satisfaction, and service quality. Furthermore, it reduces the cost of recovery and transport.
The IoT-based tool enables the traceability of trays, anti-theft functionality, and temperature monitoring. The system connects different parts of fruit supply logistics: farm production, the processing industry, transport, and finally retailer and end-consumer.

Since fruits and vegetables are perishable, returnable transport items (RTI) are essential in bringing products to the market. Millions of different kinds of RTIs are used daily, both inside and outside the supply chain. These stakeholders feel an urgent need to remove inefficiencies to assure product quality and security while protecting company assets.

It was discovered that this method could go beyond simply being a monitoring and tracking system. It can also collect data, store it, and retrieve it when needed. The amount of collected data can be vast and overwhelming in detail. However, the system can quickly analyze complex value chains or commodity flows and deliver the output simply and understandably. As a result, by relieving pressure on supply chains or commodity flows, the approach positively impacts sensitive market situations. Customers can receive single, project-based implementation and end-user training to help them use innovative trays independently. Customers and the entire supply chain need to know where those assets are at any given time. It is crucial to consider the number of RTIs required during peak harvesting seasons versus the number required during the quieter winter months.

Using closed scenarios and targeted data provides a more precise and informative analysis and evaluation. Thus, IoT technology contributes to gathering and analyzing big data that was missed, and provides results that can contribute to optimizing everyday business planning processes.

The system enables players to see issues across the supply chain by providing information on bottlenecks, thereby facilitating pinpointing opportunities for expansion, developing new processes, analyzing trends, and increasing the efficiency of the supply of raw materials. Quality information and its analysis is therefore making a big difference for stakeholders.

All along the line there is tremendous potential for increasing the management effectiveness of the supply chain and finding bottlenecks or other problems at an early stage, which involves maintaining the best possible partnerships with suppliers and clients and creating new ones based on the efficient management of processes.

RTI flow lacks transparency and cannot be fully tracked by the service provider. At the same time, all value chain stakeholders cannot experience optimal customer support, which leads to a lack of trust and inefficiency.

UC.2 shows that the market needs to adjust very quickly to rising demand in the supply chain, and every stakeholder must be highly adaptable to respond to it. The analysis of big data helps not only to solve the existing challenges, but also – crucially – helps to predict the upcoming pressure on the food supply chain.

When consumer needs and expectations have been estimated, every end-user is assured of the expected supply. The process thus becomes efficient, and sustainability increases significantly. The system assesses the freshness of shipped goods such as fruits, and eventually this can be adapted for the shipment of vegetables. This means a significant reduction of spoilage and a contribution to preventing food waste.

Real-time product monitoring brings the service quality to the next level – pool efficiency increases by 25%. At the same time, the high-security level for distribution is increased by 15%.

Food quality and traceability are also some of the main achievements in this use case. The improvement of traceability infrastructure by 50% strongly contributes to preserving product quality and increasing the supply chain system's performance.

By improving the logistics and packaging, the use case achieved an increase of food safety by 5%, reducing the food waste by 5%. Moreover, the service quality was raised by the faster reaction time to real-time data, which improved by 5%.

The production costs lowered – the RTI loss rate was reduced to –5.5%, and the recovery rate increased by 80%.

This prevents variability in wine quality during transportation, wine production, and management, which is supported by smart sensors that monitor everything including temperature, humidity, and shock. Tracking and monitoring proceed from wine producer to consumer based on the IoT system.

The logistics path from manufacturer to customer is a process that can degrade beverage quality. This use case aims to eliminate such risks by equipping beverage supply chain stakeholders with extensive data analysis of the distribution process.

An automated system tracks the entire wine and beverage distribution chain to prevent harm from integrity-related issues during shipping and storage. It also develops a direct relationship between producers and retailers, and builds a vast database to schedule secure shipments, enabling new and customized IoT-based security solutions. The use case provides software as a service to monitor distribution-related variables, including temperature and humidity, to help control beverage quality.

Multi-actor data analytics in the beverage industry is still an empty field. Integrity management systems have not yet been established in the same depth in this supply chain as they have in other industries. The main reason behind this is the complexity and number of stakeholders involved in the process, making it difficult to control. The provided system disrupted the supply chain with the capabilities to control and acquire the data.

A system which monitors beverage delivery routes and keeps a data record of every transaction brings much more transparency to the stakeholders and enables them to take full advantage of the features brought by data analytics. Data provides monitoring of the locations and changes of the beverage containers, and expands the information with environmental details contained in those boxes. For consumers, it becomes possible to track their wine bottle back to the winery. This gives visibility and traceability to the beverage supply chain.

The system aims to gather a wealth of information about temperature during shipping, shocks that cause bottle ruptures, closure leakage, and the percentage of bottles with defects like cork taint, label damage, pressure loss, and oxidation.

The database can also provide information on customer satisfaction, marketing problems, and communication effectiveness.

This data collection is beneficial for the wine and beverage industry, and it is now available to many value chain actors for the first time.

Such supply chain management, by providing quality information, strengthens the relations with clients and brings significant value for strategic partnerships. Seeing all of the parts and pieces of the supply chain, a link is made with all stakeholders.

This is particularly important in closing the gap between wineries and wine shops since their connection previously was the importer’s responsibility.

When delicate products, such as food or drinks, enter the supply chain, an environment with various parameters must be strictly monitored for the proper temperature and freshness to keep the quality from the beginning point to the end-consumer. Different stakeholders, such as producers, carriers, dealers, retailers, and insurance firms, are involved in the beverage logistics industry. Stakeholders have identified the practical issues of the everyday beverage supply processes and their impact on the system to validate the integrity of logistics. With so many stakeholders taking part in the management of logistics in order to improve the service, many bottlenecks must be solved.

UC.3 brings lean practices into the beverage supply chain, controlling many processes and stakeholders, as a result of which it is usually very complex and complicated. In this case, used by operators, it is first and foremost a tool that visually presents the documented beverage journey and serves as evidence of delivery at the goods’ final destination. Finally, it offers valuable information to help retailers understand market demands and sell the product.

The beverage supply chain experiences increased sustainability. Traceability of the beverage from the first stop to the consumer brings transparency and ensures quality products.
UC.3 made a breakthrough in cost reduction and monitoring of wine and beverage quality during transport. This directly led to the improvement of the distribution conditions and an increase in the logistics' overall satisfaction. A satisfaction index (usefulness of the tool, from 1 (not useful) to 5 (very useful)) of 4 was achieved.
Improvement in transport quality and reduction of product damages enabled the beverage supply chain's efficiency to be achieved. The amount of product returned due to damage claims was measured as 5 (respondents were asked if data was useful to reduce complaints of the damage and improve product handling, from 1 (not useful) to 5 (very useful)).
Increased client satisfaction was rated 4 (asked if the tool is useful in helping to have a stronger relationship with the client, from 1 (not useful) to 5 (very useful)).
Connecting producers and retailers, a crucial factor which became possible due to supply chain visibility, was rated 4 (asked if chain visibility improved with the provided data from 1(not improved) to 5 (significantly improved)).
The system helped increase IoT user satisfaction due to improved transportation, reduced greenhouse gas emissions, and reduced shipping costs.

IoT technology results and discussion. As the analysis of the pilot use cases implemented in the food supply chain revealed, Internet of Things technology is revolutionizing logistics. The mass connectivity of parcels to the end-consumer is enabling supply chain and logistics stakeholders to conduct real-time tracking and management decisions that increase operating performance and asset monitoring, and at the same time keep the quality of products and contribute to the Green Deal goals, such as reducing food waste and greenhouse gas emissions. Table 1 presents accumulated analysis results from all three uses cases' performance indicators connected to IoT technology.

Table 1. Summary of the results collected during the research and from the IoF2020 project documentation. *Source: Created by the authors*

Dimension	Categories	Indicators	Technology impact (productivity, revenue growth, employment, investment)	Food supply chain management (strategic suppliers partnership, relations with clients, sharing quality information, operational lean practices)	Challenges solved (quality products, traceability, contamination, lack of trust, increased sustainability)	Use case
Economic	Productivity increase	Preserve product quality	Yes	Yes	Yes	UC.2, UC.3
		Reduction of loss rate	Yes	Yes	Yes	UC.2
		Recovery rate increase	Yes	Yes	Yes	UC.1, UC.2
		Increase security of bulks-goods delivery	Yes	Yes	Yes	UC.1
	Efficiency improvement	Reduced product return due to damage claim	Yes	Yes	Yes	UC.3
		Real time product monitoring	Yes	Yes	Yes	UC.2
		Increased reusability of transport	Yes	Yes	Yes	UC.2
		Improve logistics and packaging	Yes	Yes	Yes	UC.2

	Cost reduction	Production costs reduction	Yes	N/A	Yes	UC.1, UC.2, UC.3
		Reduce additional transport	Yes	Yes	Yes	UC.1
		Reduce shipping costs	Yes	Yes	N/A	UC.3
		Reduce recovery costs	Yes	Yes	N/A	UC.1
	Quality improvement	Improve distribution conditions	Yes	Yes	Yes	UC.3
		Increase transport quality	Yes	Yes	Yes	UC.3
		Reduce risk of animal food contamination	Yes	N/A	Yes	UC.1
		Reduce risk of human food contamination	Yes	N/A	Yes	UC.1
Environmental	Reduced waste	Reduce product damages	Yes	Yes	Yes	UC.3
		Reduce food waste	Yes	Yes	Yes	UC.1, UC.2, UC.3
		Reduce waste by contamination	N/A	Yes	Yes	UC.1
	Lower emissions	Reduce greenhouse gas emission	N/A	N/A	Yes	UC.1, UC,2 UC.3
	Resource use efficiency	Lower paper documentation use	Yes	Yes	Yes	UC.1, UC.2, UC.3
		Facilitation of equipment	Yes	Yes	Yes	UC.2
Social	Transparency of food chain	Increased supply chain visibility and traceability	Yes	Yes	Yes	UC.1, UC.2, UC.3
		More data available	Yes	Yes	Yes	UC.1, UC.2, UC.3
		Trust on the quality of food products	N/A	Yes	Yes	UC.1, UC.2, UC.3
	User satisfaction	Increase IoT user satisfaction	Yes	Yes	Yes	UC.1, UC.2, UC.3
		Satisfaction index	N/A	Yes	Yes	UC.3
		User satisfaction	N/A	Yes	Yes	UC.1
		Increase client satisfaction	N/A	Yes	Yes	UC.3
		Connect producers-retailers	Yes	Yes	Yes	UC.3

In notoriously complex food supply chains with a vast number of stakeholders and a myriad of different levels of processes, the visibility task turns into an unnecessarily long and drawn-out

process – a process that hardly anyone would take on the challenge of solving. Thousands of supply chain puzzle pieces would never fit together and, in many cases, would fall apart. Or so it was until digital technologies stepped in.

As shown by the goals achieved by the use cases, the IoT has simplified supply network management, streamlined operations, reduced operational expenses, increased quality of transportation, and connected all players along the chain. Data was the missing puzzle piece to set everything in order. The pilot cases reduced the number of supply chain management components. As a result, operational costs are being reduced even while food and beverage production capacity is growing. Digitalization experts stated that IoT technology is expected to significantly impact logistics in the food supply chain by reducing operational costs by at least 50% over the next 5 years and helping double shipping amounts.

IoT technology is driving the agrifood sector towards greater collaboration. The potential of food supply chains as full-scale collaborative ecosystems is vast. The digitalized distribution system transforms the food supply chain into one that is secured, based on providing outstanding and precise data in a highly scalable manner for every player and helping the emergence of innovative business models reliant on big data. The knowledge obtained from such a single network enables stakeholders to improve supply chain productivity.

As described by the experts and based on the use case findings, food traceability and the transparency of the whole food supply chain are among the most significant issues in the agrifood sector. Traceability in food supply chain logistics is related to the ability to collect data and ensure the quality of the final product. This means that data needs to be collected, analyzed, and delivered, involving correct information about the food, feed, and food manufacturing process at all stages of the food supply chain. This allows the product to be certified, for example, as organic, or checked for quality and safety control – all of which can be traced through the food supply chain.

The amount of data that systems can gather and manage is unforeseen. A logistics manager can access the dashboard at any time to receive real-time updates on the exact location of an asset, its distance, and its expected time of arrival based on actual travel conditions. These real-time warnings help players in the food supply chain to stay flexible and adapt quickly through a dynamic transportation network. Delays in the supply chain can often cause significant losses, but logistic managers acquire the knowledge they need to mobilize quickly. Due to IoT technology, an expensive disturbance is usually transformed into a temporary issue.

If any food and beverage product requires special handling or temperature control, geolocation capabilities can be coupled with the monitoring of transportation conditions for added value. The manager is also alerted if an asset falls outside a predetermined temperature range or receives unexpected vibrations or shocks.

As interconnectivity is becoming the logistics sector's practice, the industry must recognize the value of digital security. Connected systems help monitor all objects, and asset tracking logistics applications help monitor deliveries, warn the management team if anything is missing, increase the transparency of who visits the warehouses at any given time, and more.

Since anything from rising temperatures in containers to security breaches can be tracked remotely, IoT technology reduces the need for physical supply chain supervision. The Internet of Things is changing security by allowing for more open supply chain solutions. On the other hand, technology is widening the digital space and increasing the need for data protection.

With the ambitious goals being set up in the Green Deal, IoT technology is a tool to help achieve them.

As presented by the use cases, there is no doubt that the demand for environmentally sustainable logistics in the food value chain is expanding and will grow in the coming years. This means that environmental concerns should be at the core of every food supply chain stakeholder plan. Although there is no one solution to the climate problem, the Internet of

Things helps reduce the agrifood industry's environmental footprint by making logistics processes smarter.
Food chain logistics stakeholders can use data collection, analysis, and machine learning to forecast traffic flow and reduce the number of unused trailers, boxes, etc., on the road at any given time. This strategy not only reduces cost – it also lowers total carbon emissions.
The transparency provided by IoT technologies significantly aids in the reduction of food waste and goods loss and damage. This is particularly valid for perishable products such as fruits, vegetables, etc. The systems help achieve better cargo control and establishes leaner, more effective food supply chain logistics processes as a whole.
By making the processes automated, controlled, and visible, a new path is created to a leaner and greener food supply chain. The transformational potential for the IoT in the logistics food supply chain, making it sustainable, is undeniable.

Conclusions

IoT-connected sensors and systems in food and beverage supply chain logistics offer real-time visibility and data-driven analytics, allowing stakeholders to improve performance, cut operating costs, conduct predictive maintenance to avoid downtime, and even decrease energy usage or reduce negative environmental impacts.
With the responsibility of logistics in the agrifood sector to fulfill two-day, overnight, or even same-day service obligations and at the same time to trace the origin and keep the quality of the products unaltered, the Internet of Things is a crucial component in assisting players in meeting the demands of today's fast-paced, global economy.
The pilot use cases in the agrifood sector have demonstrated many ways that IoT technologies can transform food supply chain logistics from the ground up.
Through the IoT, the management of supply chain processes is better regulated, and as a result, production risks are reduced. The ability to predict performance levels accounts for improved product delivery planning.
A vast amount of data is being collected by smart sensors using IoT technologies. This information can be used to monitor all stakeholders' overall efficiency in agrifood supply chains and their employee results, equipment quality, and more.
Agrifood industry logistics cost management and significant food waste reduction are possible due to increased control over supply chains. By being able to see disruptions in traffic flow, quality, or risks of contamination of goods, stakeholders can take measures to reduce or avoid losses.
The IoT, through automation and machine learning, helps to increase efficiency down the supply chain. Using smart devices provides the opportunity to automate multiple processes and significantly reduce physical supervision.
Keeping product quality and at the same time not lowering volumes of production becomes a common process. Better control over the logistics process helps maintain higher standards for food and beverage quality, and retains production growth capacity through the whole food and beverage supply chain.
The results of applying IoT technologies to food and beverage supply chain logistics processes provide higher revenue for all stakeholders.

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