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BACHELOR THESIS

DISRUPTIVE TECHNOLOGIES IN FOOD SUPPLY CHAIN MANAGEMENT. A MULTI-CASE STUDY FOR THE ANALYSIS OF DRIVERS, CHALLENGES AND OPPORTUNITIES

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For my bachelor thesis, it is a great concern for me to deal with new topics that were not yet part of my studies. I would like to take a closer look at the topic of supply chain, as the elective subject of operations has already aroused my interest. In addition to my purely economic studies, I would like to think outside the box and deal with technical topics that have not yet found their way into my student career.

However, I am not the only one responsible for the implementation of the work. Above all, I would like to thank my supervising professor, Professor Dr. Manuel Francisco Morales Contreras, who always gave me valuable advice from finding the topic to writing the conclusion and always had an answer to my questions.

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Abstract

The food supply is essential for the survival of every individual. A look at the last few months and years has shown that disruptions in the food supply chain still occur. The COVID-19 pandemic and the Ukraine war are well-known examples, which led to disruptions such as material shortages or energy price increases. Meanwhile, disruptive technologies are increasingly finding their way into supply chains, which is why the intention of the work is to find out to what extent technologies can be used in food supply chain management and what impact they can have on the supply chain. The objective of this bachelor thesis is to give an overview of the three selected technologies Blockchain, Internet of Things and Artificial Intelligence and how these technologies relate to the requirements and characteristics of the food supply chain. Based on selected literature, characteristics or drivers, advantages and challenges of the food supply chain and the technologies are described. In order to achieve the goals of the bachelor thesis, the existing literature is firstly analyzed and secondly, insights into practice are provided based on two case studies. In the discussion, the results of the two examination methods are compared. The literature and case studies show that food supply chains have special characteristics such as quality and safety, as well as sustainability. Variables such as traceability and resilience can have a positive impact on these food supply chain requirements and are often supported by disruptive technologies. Regarding the case studies, both companies studied use the Internet of Things and Artificial Intelligence in their supply chains, but Blockchain currently does not find their way in their supply chains. Among other things, the increased traceability of goods, increased efficiency and the creation of forecasts are mentioned, but also challenges such as raising awareness among employees and the administration and targeted use of the generated data. There are clear overlaps in content between the literature and the information from the experts in terms of the potential and challenges of the technologies. Nevertheless, the experts also find new challenges in the implementation of disruptive technologies in their supply chains that have not been considered in the literature.

Key words: Food Supply Chain, Disruptive technologies, Blockchain, Internet of Things, Artificial Intelligence, Traceability, Safety and Quality, Resilience

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List of Abbreviations

AI .... *Artificial Intelligence*
ANN .... *Artificial Neural Networks*
DL .... *Deep Learning*
FMCG .... *Fast Moving Consumer Goods*
FSC .... *Food Supply Chain*
IoT .... *Internet of Things*
ML .... *Machine Learning*
NN .... *Neuronal Networks*
RFID .... *Radio Frequency Identification*
SIoT .... *Social Internet of Things*
SMT .... *Smart Monitoring Technology*
SOA .... *Service-Oriented architecture*
WSN .... *Wireless Sensor Network*

1. Introduction

Empty supermarket shelves, shortages of medicines and rising prices are only a small part of the effects that companies and end consumers felt and still feel to some extent today. Many of the problems can be traced back to supply chain disruptions, such as the COVID-19 pandemic, the container ship in the Suez Canal or the Ukraine war, which had a significant impact on the food industry.

Food products are usually perishable, have strict quality requirements, and the origin and production are also in the interest of the end consumers. In this bachelor thesis, these requirements are examined in more detail and instruments are analyzed that help to meet the demands of a functioning food supply chain. The need for flexible, adaptable food supply chains has been highlighted by the disruptions mentioned above.

On the one hand, the complex global supply chain structures are important to meet the rapid changes in supply and demand, but they also pose a management challenge. This raises the question of the extent to which disruptive technologies can influence complexity and disruptions, on the food supply chain management. These technologies have already become an integral part of everyday private and professional life. For this reason, a connection will be drawn here between food supply chain management and disruptive technologies, both on a theoretical and practical level.

The bachelor thesis aims to provide an overview of how disruptive technologies such as Blockchain, Internet of Things or Artificial Intelligence can be used in an efficient supply chain management. Supply chains in the food industry will be considered in more detail. Drivers, advantages of the application and challenges will be examined.

The thesis consists of a literary part and scientific sources and is supplemented by case studies in the form of expert interviews from the food industry, which give the thesis a practical reference and describes connections and differences between theory and practice. The focus will be exclusively on the three technologies mentioned, which does not mean that these are the only technologies in this context, but that they are among the most relevant. Primary and secondary goals and questions are formulated for the thesis, which will be addressed in the following chapters.

Primary objectives

- Identifying the driving technologies in supply chains, describing benefits, challenges, and their level of implementation (Chapter 4)
- Examining which technologies are used in the food industry and their supply chains (Chapter 4, 5 and 6)

Secondary objectives

- Elaboration of the characteristics of the food supply chain and the resulting challenges (Chapter 3)
- Identifying the influence of COVID-19 on the food supply chain (Chapter 3)

To realize the objectives of the thesis and to answer the research question, the methodology has been designed as follows. First, the literature review and second, the two specifically elaborated case studies.

Within the two sections, the following chapters of the work can be found. The methodology is followed by chapter 3 which examines the food supply chain in more detail and its characteristics, which will later also act as drivers of the technologies. The 4th chapter deals in detail with the three selected technologies Blockchain, Internet of Things and Artificial Intelligence. Chapter 5 lists the results of the practical part, the case studies. These are compared with the theory section in the 6th chapter, the discussion section. The most important findings and limitations of the bachelor thesis are highlighted in the conclusion.

2. Methodology

The research for this bachelor thesis started in August 2022 and most of the literature has been established since the end of October 2022.

The research question aims to identify drivers, challenges, opportunities, and the implementation of new technologies. Therefore, an exploratory and inductive qualitative methodology was applied (Yin, 2014, p. 312). By the inductive approach we obtain as new and current insights into corporate practice as possible. This qualitative approach consists of (a) collection, review, and analysis of secondary sources and (b) two case studies. The review of secondary literature (a) is obtained through sources from databases and libraries. This involves collecting professional literature using the snowball method, conducting qualitative content analyses, and then organizing the literature using the Citavi literature software.

This information is complemented by two case studies in form of interviews (b) that provides practical insights. This methodology is particularly helpful in answering questions such as "how" or "why" (Yin, 2014, p. 312). Moreover, this type of case study is very efficient to collect empirical data, especially when the research question is specific, and it leaves a lot of room for qualitative insights. The aim is to realize a semi structured interview form to get ordered answers to partial questions and, if necessary, to go into specific details (Eisenhardt & Graebner, 2007, pp. 25–32). For the practical elaboration and the expert interviews, representatives from the food manufacturing industry were contacted in the early stages of October 2022. A script with qualitative questions based on the findings in the previous literature research, was created. This document was sent to the experts in advance. The script can be found in the appendix. In an online meeting, questions were asked, the answers recorded, and the interview transcribed. The collected answers and data were interpreted and compared with the results from the literature research using a qualitative content analysis.

Two companies from the food industry were selected and will be referred to as Company 1 and Company 2 below. According to Pettigrew, the number of cases plays a minor role here in order to get relevant and deep insights into the cases (Pettigrew, 1997, 342).

The first company (Company 1) to be used as a practical example for the bachelor thesis is a German confectionery manufacturer. Since the beginning of the 20th century, the company has been producing various brands of sugar confectionery and chocolate specialties. More than 7,000 employees generated about 3 billion in sales in 2021 and sold the products in about 100 countries worldwide. The expert interview took place with a process analyst in procurement and procurement controlling. The interviewee brings about nine years of experience in procurement and supply chain management and is currently pursuing a PhD.

The second company (Company 2) is a branded cheese manufacturer from Germany. The family-owned company reported sales of about 1.7 billion euros in 2021 and employs nearly 6000 people. The various cheese brands and their products are sold in more than 30 countries, and not only in supermarkets, but also to the food industry and gastronomy. The company's expert comes from the Digital Transformation department. The person has been working in the field of digital transformation for eleven years.

3. Food Supply Chain

To understand the characteristics of the food supply chain (FSC) more precisely and to distinguish it from other supply chains, the term "Supply Chain" is defined. The general supply chain is defined by Heizer, Render, and Munson as the totality of activities and organizations involved in the production and transportation of goods and services from the producers of raw materials to the end customer (Heizer et al., 2017). Another definition that is more complex and involves a broader and more integrative view of the supply chain is given by James B. James B. Ayers presents the definition "Supply chain as life cycle processes involving physical goods, information, and financial flows whose objective is to satisfy end consumer requisites with goods and services from diverse, connected suppliers" (Janvier-James, 2011, p. 195).

As the name suggests, FSC focuses on coordinating food production and delivery processes. “A FSC refers to all the processes that describe how foods from farms end up on our tables, including farming, processing, distributing, retailing, and consuming” (Chitrakar, Zhang, & Bhandari, 2021, p. 2).

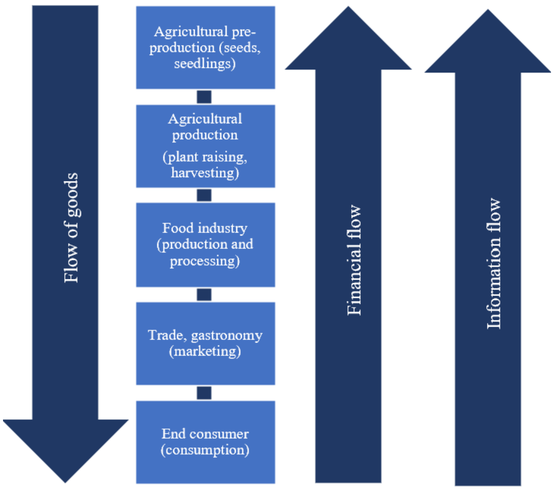

Figure 1: Simplified Food Supply Chain

Source: Adapted from Sommer, 2007

FSC brings with it special characteristics that make it very different from other supply chains. In a world where resources are finite, inefficient FSC management can lead various effects, such as food waste, disruptions and adverse health effects, among others (Haleem & Sufiyan, 2021, p. 72). For this reason, this chapter first lists the characteristics of the FSC and then describes the parameters or variables necessary for successful FSC management.

Since the pandemic had a major impact on the economy almost three years ago and is still part of our lives today, the impact of the COVID-19 pandemic on the food industry and its supply chains will be presented in the first paragraph of the FSC chapter.

3.1 Impact of COVID-19 on the FSC

In March 2020, the COVID-19 outbreak was announced by the World Health Organization as a pandemic of global proportions (Liu, Kuo, & Shih, 2020, p. 329). Since then, we have been living with the infectious respiratory disease, experiencing lockdowns, and implementing measures to contain the pandemic. Even though the most challenging period of the pandemic is over, the impact of the pandemic is still felt in everyday life today (Fink, 2020).

The food industry was greatly affected by the crisis, as food supplies were essential even during the lockdown periods. Despite this, there were shortages of supermarket products such as pasta, flour, and sugar, as fear of infection led people to buy in larger quantities than would have been necessary for the household. In addition, the virus can be transmitted through contaminated food, which restricted workers in food processing and thus also weakened the food industry's supply chains (Chitrakar et al., 2021, pp. 1–2).

According to Chitrakar et al., the pandemic has an impact on the following FSC factors. These three subcomponents are transportation, labor, and inputs. Transportation can be by rail, container ships by sea, or trucking, among others. Quarantine and lockdown regulations also resulted in transportation and travel restrictions, so container ports often required more turnaround time, which in turn led to container shortages. However, this effect was also reinforced by a lack of labor. Not only were they in short supply in the transportation sector, but also at the very beginning of the FSC, agriculture and food processing, which are very labor-intensive. A vivid example is the labor situation of American and Canadian farms. In these, seasonal Mexican workers are employed for the most part, who, due to the ban on crossing the border, could no longer perform their work. The third point mentioned by Chitrakar et al. is the availability of materials (inputs supply) for the production and transportation of food. These include, for example, agricultural inputs such as fertilizers and seeds, but also packaging materials, detergents, and fuels for the food processing industry.

Another point, which is described in more detail in the subchapter Food Quality and Food Safety, is the topic of food safety. In the context of the COVID-19 pandemic, especially the food industry came under intense attention regarding measures to ensure the hygiene of factories and products. Especially in meat processing industries and slaughterhouses, there were repeated scandals in connection with the COVID-19 virus. Due to the close physical contact of factory workers and the low temperatures in the factories, which are favorable for the spread of the virus, regular COVID-19 outbreaks occurred. Hygiene measures such as the wearing of gloves, disinfection of surfaces and hygienic transport packaging for products must therefore be constantly reviewed and expanded (Aday & Aday, 2020, pp. 169–170).

However, not only direct supply chain components, such as the above-mentioned transport, were influenced by COVID-19, but also indirect effects, such as the change in consumer demand behavior. Due to the temporary closure of restaurants, there was less frequent shopping in supermarkets for security reasons, but the shopping basket and spending on food was higher. Consumer buying behavior also changed, with increased demand for healthy and nutrient-rich foods such as fruits and vegetables, whole grains, and olive oil to keep the immune system intact (Muscogiuri, Barrea, Savastano, & Colao, 2020, pp. 850–851). However, a survey of 630 U.S. consumers also found that consumer behavior changed not only the contents of the shopping cart, but also the place of purchase. 70% of respondents reduced their food purchases in stores and preferred online shopping and delivery services during the pandemic (DeBroff, 2020).

The virus and the associated restrictions in private and professional everyday life had many negative effects on the flow of materials and the FSC. No matter if missing material, extended delivery times or partly empty supermarket shelves. Everything can be summarized under the umbrella term of supply chain disruptions. Chitrakar et al. already suggests that new technical interventions can help to reduce such disruptions and the impact of unpredictable crises, such as the COVID-19 pandemic, on the supply chain.

3.2 Characteristics of the FSC

To be able to optimize a supply chain and to design it resiliently, supply chain managers must deal with the specifics of the supply chain and the industry in which it operates. In this case, we will take a closer look at the characteristics of the FSC and will partly mention characteristics that have found resonance in the previous subchapter of the COVID-19 influence on the FSC. Whether it's fresh food or processed food, the FSC is fundamentally different from supply chains from other industries because of characteristics such as perishability, strict policy guidelines, varying consumer tastes, and resulting adjustments in food storage, processing, and transportation, among others (Zhanguo Zhu et al., 2018, p. 5700).

3.2.1 Food Quality and Food Safety

The quality aspect is essential to most businesses, but it is especially vital in the food industry as it affects food safety and consumer welfare. The quality of food can be divided into two parts. Intrinsic characteristics of quality, such as “product safety, sensory properties and shelf life, reliability, and convenience” (Haleem & Sufiyan, 2021, p. 77) and extrinsic characteristics, such as “production system characteristics and environmental aspects“ (Haleem & Sufiyan, 2021, p. 77).

ISO defines quality as "the totality of features and characteristics of a product that bear on its ability to satisfy stated or implied needs" (Van Reeuwijk, 1998). Thus, quality is the characteristic that satisfies a consumer's needs and expectations. However, since these expectations may vary from consumer to consumer, it is not only about the product characteristics, but also how these characteristics were achieved and produced (Aung & Chang, 2014, 167-177). The following example from the article by Galanakis, Rizou, Aldawoud, Ucak, and Rowan illustrates how a property of the product can be a quality attribute for consumers. So-called "bioactive compounds" represent an intrinsic property of food quality. Primarily due to the pandemic, products with additional functional components such as antioxidants or vitamins have become more popular and thus more commercialized. It is expected that this trend, while reinforced by COVID-19, will continue to receive increasing attention in the future. It can be inferred that product quality and food ingredients are becoming increasingly important, which has an impact on the FSC. First, it is conceivable that government and research institutions will increasingly cooperate and work together to meet this need and the associated regulations. Companies should therefore always have the needs of customers present in order to adapt products accordingly, which in turn may mean a change in supplier management (Galanakis et al., 2021, pp. 149–195).

It is agreed that safety in food is a prerequisite and therefore the most important component of quality, as the absence of safety can lead to health hazards or even death of the consumer. Safety is different from other quality attributes because it is often not visible to the naked eye, and hazardous substances may be present in the product environment during production or transportation (Aung & Chang, 2014, p. 177). The terms food safety and food security often come up in the context of the characteristics of a FSC. However, it should be noted that these terms should not be used interchangeably as they have different meanings. "Food safety is the need for people to have food that is free of contamination. Food security is the need for people to have access to food" (National Geographic, 2022). Food safety therefore means that the consumer is not harmed by the consumption of food and its foreseen method of preparation. However, it still happens that people fall ill due to contaminated food. At first glance, it seems that the problem clearly lies in the production and processing of food and beverages, but hazards to food can occur throughout the supply chain. Therefore, all links in the supply chain are responsible, namely "producers, processors, distributors, retailers and consumers" (Aung & Chang, 2014, p. 176).

One might assume that in developed countries, food safety is a given and does not require much additional effort, however, global supply chains are distinct. The differences in specifications and safety regulations often vary between different countries and different products. This is because the countries involved in the supply chain have different income levels, eating habits, climates, and government systems. This affects developed countries in that the volume of imports from developing countries is increasing, leading to more complex supply chain structures and challenges in food safety management. For example, imported fruits and vegetables often use irrigation water contaminated by fecal matter, as do aquaculture operations. In addition, developing countries often lack quality assurance systems, sanitation controls, and disinfection equipment. If there is no documentation or traceability of the work and transport steps, this can have serious consequences (King et al., 2017, pp. 161–162). By working with perishable food, a high input of energy is also required to keep the food fresh through refrigeration, which in turn has an impact on the subchapter “3.2.2 Sustainability" (Zhanguo Zhu et al., 2018, p. 5700).

But it is not only globalization and the associated purchase of food from other countries that is driving the relevance of food safety and the associated supply chain to ensure it. Another driver is the prevention of food safety accidents. Food safety-related accidents are frequently reported and are also on the rise. Between 2008 and 2018, Soon, Brazier, and Wallace identified a number of 2932 food accidents and/ or recalls. From year 2013 to 2014, there was a 50.2% increase in food safety accidents. However, an important note to this is that the Canadian Food Inspection Agency (CFIA) modified its reporting system, which contributed to expanded data collection and also caused the number of food accidents and recalls to increase after 2014 (Soon et al., 2020, pp. 5–7). Accidents occur most frequently in the handling of raw fish and in prepared foods. Soon et al. also identifies four categories responsible for such accidents. Biological, chemical, physical, and allergic causes can lead to food safety accidents, with allergic reactions, being the most common. The most frequently reported accidents involving allergens were related to milk (24.37%) and gluten (9.97%). For damage related to microbiological triggers, bacteria such as Listeria monocytogenes (32.91%), Salmonella spp. (29.85%) and E. coli (17.86%) were most frequently responsible. Triggers of such accidents are in most cases microbiological cross contamination, which is the unintentional transfer of contamination to an object, and undeclared allergens. For both main reasons of accidents with food, a reduction through a tracking supply chain is conceivable (Soon et al., 2020, pp. 7–16).

The consequences of low quality and missing or insufficient food safety are serious, especially for consumers, but also for companies, which can be affected by decreasing sales figures, large losses of sales or even a sales ban (Aung & Chang, 2014, p. 176). The two concepts of quality and safety are closely related and have a great influence on consumer confidence (Aung & Chang, 2014, p. 176). “Without food safety, we cannot have food security and achievement of the Sustainable Development Goals” (King et al., 2017, p. 171)

3.2.2 Sustainability

Currently, there are over 7.96 billion people on the planet, with a growth rate of 66 million people per year, or 180,000 people per day (Rundfunk, 2022). It is expected that by 2050, 9 billion people will inhabit this planet if they all get enough food. The prerequisite for this is a balanced FSC and sufficient resources. In recent decades, the response to strong population growth has been industrial production systems, intensified agriculture, and factory farming. While these measures were necessary to respond to the increased demand for food, resources were used that are finite. The new form of food processing shows many negative effects on the environment caused by CO2 emissions, water scarcity, pollution and loss of biodiversity, to name a few (King et al., 2017, p. 161). In addition, the production and transport of food often emits large amounts of greenhouse gases (Zhanguo Zhu et al., 2018, p. 5700). “Food contributes 31% to the EU-25’s total GHG emissions based on a regional analysis in Europe” (Garnett, 2011, pp. 463–466). Therefore, sustainable design of food production systems and supply chains is a must (King et al., 2017, p. 161).

We look at three dimensions of sustainability in the supply chain. This is where the famous ESG criteria appear, namely environment, social, and governance. To the governance point, we add the economic dimension, which plays an important role in supply chain management after all (Ganse, Werhahn, & Gschmack, 2012, p. 260). In the first section of the sustainability subchapter, the environmental dimension has already been discussed in more detail. Ganse et al. also identifies three main drivers for sustainable supply chain design. The first driver is the management of business risks and relates to the governance dimension. This driver is influenced by regulatory measures taken by the legislator to comply with emission guidelines, for example. In addition, compliance with sustainability standards can lead to protection against reputational risks and the brand name. Finally, compliance with ESG criteria reduces potential operational risks, such as fluctuating commodity prices or natural disasters. The second main driver for sustainable supply chain management is the realization of performance potential. Sustainability is often associated with high costs, but this is a misconception, as lower waste production, reduced packaging, and energy costs, for example, can result in a reduction in overall company costs. In addition, the implementation of sustainable supply chain processes often reveals bottlenecks, which in turn leads to efficiency improvements and thus to increased performance. As a third main driver, Ganse et al. names the generation of sustainable products. Most often, this demand is made by customers and suppliers, which can lead to sustainable product innovations and in turn reduce negative ESG impacts along the supply chain. However, it is not only customers and suppliers who are increasingly demanding sustainable product alternatives, but also stakeholders such as governments, employees, environmental activists, shareholders, and expert groups, among others. One can take advantage of these demands by involving stakeholders in the development process of a sustainable supply chain, thereby responding to their demands, and directly implementing their knowledge and ideas. These three main drivers are also goals for companies that prepare them well for a more sustainable future (Ganse et al., 2012, pp. 161–162).

The figure below shows how sustainability influences the FSC. Various categories of the FSC, such as food safety, fairness and energy consumption, are assigned to the ESG criteria (Zhanguo Zhu et al., 2018, p. 5704).

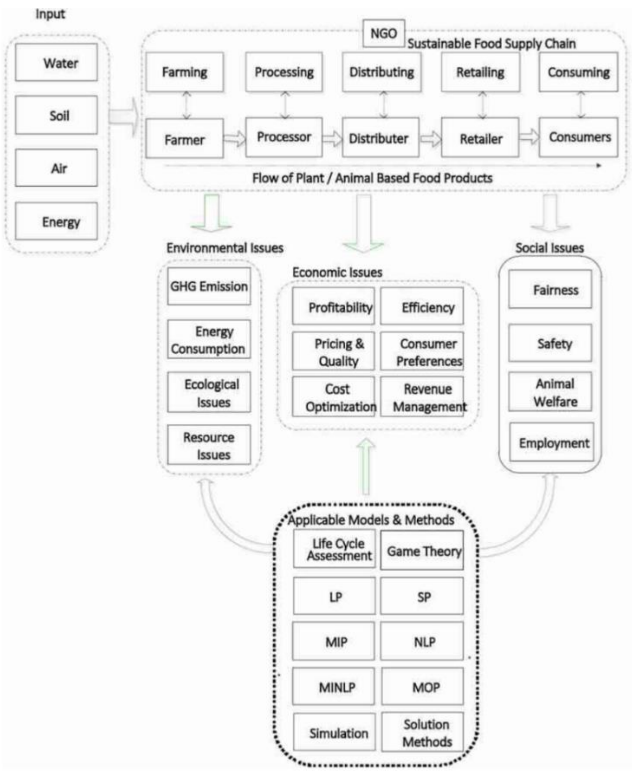

Figure 2: Sustainable Food Supply Chain

Source: Zhanguo Zhu et al., 2018, p. 5704

The linear economic system used until now, was created for the reason to serve the increased consumption needs of the growing population. This is achieved by increasing production, but we now know that this is an inefficient use of finite resources. For example, a more sustainable solution is the circular bioeconomy approach, which improves resilience because biomass is converted into biobased products. The goal is therefore to make the FSC more energy efficient and environmentally friendly. The traditional, linear approaches to dealing with food waste that have been addressed include landfilling and incinerating it, which creates toxic gases and hazards to people and the environment. Circular bioeconomy means using biorefineries to process this food waste into new products and energy sources such as biofuels, green energy, or biofertilizers. However, bio-based materials can also serve for sustainable packaging that would otherwise be made of conventional plastic. Turning to the topic of packaging, the direct relationship of sustainability to the supply chain can again be seen (Galanakis et al., 2021, p. 197).

It is also possible to see a direct link between the food safety issue discussed above and sustainability. An effective traceability system, which is necessary for food safety, also helps to successfully implement sustainability in the supply chain. A traceability system starts at the raw material, where environmentally friendly production and "fair trade" labor can be directly verified (Haleem & Sufiyan, 2021, p. 78). However, traceability is discussed in more detail in the chapter "3.3 Important Variables". When talking about sustainability, within the FSC you're talking about dimensions like "animal welfare, biotechnology, health and safety, labor and human rights, procurement, fair trade, community, and the environment" (Maloni & Brown, 2006, p. 38).

In the last lines it has already emerged that sustainability does not only mean sustainability on our environment, but also sustainability in terms of human resources and social responsibility. In spite of globalization, today one notices partly a declining trend, which tends to local and regional products and fair production (Zhanguo Zhu et al., 2018, p. 5704). According to Zhanguo Zhu et al., the social components of the concept of sustainability in the FSC include fairness, safety, animal welfare, and employment.

Fair trade initiatives often bring together small farmers from developing countries, such as coffee growers, with consumers from developed countries. The number of these initiatives has grown significantly in the last decade. The Fairtrade industry employs more than 1.2 million farmers who generate around 60% of their sales from food products such as fruits, coffee, wine or cocoa (Zhanguo Zhu et al., 2018, p. 5715). However, Zhanguo Zhu et al. also notes in his academic work that while the social dimension is on everyone's lips and issues like shopping local are important, there is still a lack of scientific data available on it, which in turn makes sustainable social realities global supply chains an important research topic.

3.3 Important Variables

In the previous chapter, the typical characteristics, and challenges of the FSC were listed. These challenges can be overcome by suitably designed and resilient supply chains. The following chapter presents variables that can have a positive influence on these critical characteristics of the FSC.

3.3.1 Resilience

Due to globalization of supply chains, shorter product cycles and higher demands from customers, supply chains experience undesired interruptions and disruptions with operational and financial impacts. To reduce the risk of consequences such as lost sales, cost increases or loss of market share, preparation for unexpected events and an efficient and effective response to them is required, which is described by the term “resilience” (Ponomarov & Holcomb, 2009, p. 124). There is no uniform definition of resilience for this either, but in the following lines an approximation is made by various authors.

When it comes to the design of the supply chain, the term resilience often comes up. Hofmeier and Lechner understand resilience as the complex of robustness and adaptability and the flexible response to disruptions and disruptive changes in the supply chain. The construct of resilience can be subdivided into resilience in relation to disruptions in the supply chain (upstream and downstream) and resilience in relation to disruptions within the company. An important concept when it comes to resilience is vulnerability, which is the susceptibility and likelihood of occurrence of disruptions and disturbances. Likewise, the term coping capacities, i.e., maintaining or quickly restoring the functionality of the supply chain, often comes up (Hofmeier & Lechner, 2021, p. 915).

One of the first to try to define resilience in supply chains is Serhiy Y. Ponomarov und Mary C. Holocomb. Their paper looks at certain perspectives in relation to resilience. From the ecological perspective, resilience is the response to disruptions from the ecosystem. From the psychological perspective, resilience means that the three factors Control, Coherence and Connectedness serve as buffers so that people can respond to stress and adversity. A third perspective is economic, which describes the ability of a system to absorb or mitigate damage or loss. Organizational resilience, on the other hand, includes aspects such as adaptivity, flexibility, maintenance, and recovery. Last, Ponomarov and Holcomb mention resilience in emerging interdisciplinary research streams, identifying the four stages of emergency management, namely "hazard mitigation, disaster preparedness (readiness), emergent response, and disaster recovery" (Ponomarov & Holcomb, 2009, p. 129). All these perspectives considered served the authors to formulate the following definition of supply chain resilience „The adaptive capability of the supply chain to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function" (Ponomarov & Holcomb, 2009, p. 131).

In this chapter, we also revisit the question of how resilience affects the FSC. In the subchapter "3.3.1 Impact of COVID-19 on the FSC", we already mentioned that there were several extreme demand and supply shocks during the pandemic. However, because the food industry is highly dependent on external factors, such as nature, it is often more difficult to take preventive measures. Examples are differences in the length of breeding cycles or seasonal cropping patterns lead to different reaction rates of commodities. In addition, the food industry often deals with perishable commodities, which means that short-term interruptions in the FSC can often lead to food waste, such as milk that must be thrown away, rotting fruits and vegetables, or animals that must be euthanized. So it was primarily through the pandemic that the problem arose that FSCs are vulnerable and not resilient enough (Hobbs, 2021, pp. 190–191).

In addition to product quality, transportation and distribution are also potential weaknesses within the FSC, especially when dealing with long geographic trade routes and crossing international borders. However, through the pandemic, it could be observed that it is of high importance to maintain open borders to maintain the material flow of essential goods. The pandemic has revived the discussion on FSC and there are two different views on this issue. One side says that the current food system is efficient and effective and therefore benefits from economies of scale and scope, which improves resilience. The other argument says that there is a need for a more diversified food system, i.e. more smaller companies and more local supply chains, to better counteract exogenous shocks (Hobbs, 2021, p. 192).

In large food processing factories, food can be reliably processed in “normal” times due to the efficiency and effectiveness effects. Nevertheless, as we have learned from the COVID-19 pandemic, certain points of vulnerability must be identified and addressed. One point of vulnerability that has been identified is a consequence of occupational safety measures such as social distancing measures in slaughterhouses. This involves slowing down production lines and reducing throughput. It should be noted here that this affects not only large factories but also smaller processing plants. While this is a short-term adjustment that can also result in efficiency losses, there are also more long-term measures for the resilient design of the FSC. In keeping with the theme of the bachelor's thesis, Hobbs cites an increasingly common use of automation and digitization in food processing, which reduces reliance on human labor. As human labor in standardized processes becomes not only more error-prone but also increasingly expensive, increased automation is likely in this sector (Hobbs, 2021, p. 193). In the chapter “4.3 Artificial Intelligence” the automation and its use in the FSC is discussed in more detail.

Another consequence of the pandemic that impacted supply chain resilience is the increased online commerce as it relates to groceries. There was a peak in online grocery sales and delivery services in April 2020, but there are no reliable predictions yet on how consumer shopping behavior will evolve post-pandemic. With increased traffic in online grocery shopping likely, resilience measures such as investing in delivery structures, apps and software can be beneficial. This is especially true for brick-and-mortar retailers, as otherwise there is a risk that third-party providers, such as Uber Eats or DoorDash, will siphon off sales from brick-and-mortar retailers (Hobbs, 2021, p. 194).

Through the preceding examples, one can see that adaptability and flexibility in the FSC are key resilience tools, and likewise the use of digital technologies will help make FSCs resilient. There is therefore an incentive for companies to invest in more resilient supply chains, so that disruptions can be reduced and, not least, the company's reputation is protected (Hobbs, 2021, p. 195).

3.3.2 Traceability

Due to the globalization of the food trade, the distances between food producers and end consumers have steadily increased over the years. It can be concluded that safety and quality aspects along the FSC became a greater challenge. In the past, food scandals and accidents were uncovered, which made the demands of consumers and policy makers for high quality, safety guarantees and transparency louder. The term "traceability" describes another important tool besides resilience to comply with safety and quality standards, with the aim of meeting consumer demands. A traceability system should provide information about the origin, processing, distribution and destination of the food product (Aung & Chang, 2014, p. 173).

Definitions of traceability are usually very broad, since it is a tool through which numerous goals are to be achieved and since food is also a complex product. According to ISO 9000, traceability is „the ability to trace the history, application or location of that which is under consideration" (Aung & Chang, 2014, p. 173). The definition revised by Bosona and Gebresenbet, relates directly to food traceability. "Food traceability is defined as a part of logistics management that capture, store, and transmit adequate information about a food, feed, food-producing animal or substance at all stages in the FSC so that the product can be checked for safety and quality control, traced upward, and tracked downward at any time" (Bosona & Gebresenbet, 2013a, pp. 32–48). The basis of a functioning traceability system is trace-back and trace-forward capabilities in every single step of the supply chain. From this goal of the end to end supply chain, numerous expressions such as "Field to Plate", "Seed to Shelf" or "Farm to Fork" have come into existence over time (Aung & Chang, 2014, p. 174).

In addition to different definitions of traceability, there are also different approaches to subdividing traceability into subcategories. Golan et al. divided traceability into three necessary characteristics. First, breadth, such as the amount of information collected; second, depth, which is how far forward or backward the system tracks the information; and third, precision, which is the accuracy of locating a product (Elise Golan, Barry Krissoff, Fred Kuchler, Linda Calvin, 2004, p. 3). In addition, traceability is also distinguished in the active or passive sense. Passive traceability is used to provide transparency as to where a particular product is located, whereas active traceability is also used to optimize supply chain processes with the available data. (Jansen-Vullers, van Dorp, & Beulens, 2003, pp. 395–413).

The drivers and objectives for product traceability can be summarized in three main points according to Golan et al. The use of traceability systems is intended to improve supply management, facilitate food traceability to ensure safety and quality, and differentiate market foods with subtle or non-traceable characteristics. The benefits of these objectives are lower costs of distribution systems, lower expenses for recalls of goods and higher sales of products with difficult to decipher characteristics (Elise Golan, Barry Krissoff, Fred Kuchler, Linda Calvin, 2004, p. 4). Bosona and Gebresenbet name the regulatory aspect, the safety and quality aspect, the social aspect, the economic aspect and the technological aspect as driving factors for food traceability (Bosona & Gebresenbet, 2013b, p. 37).

From the consumer perspective, traceability systems build trust in the food system, while producers and processors benefit from both a cost-effective quality and safety system and a data basis for continuous improvement (Aung & Chang, 2014, p. 174). In summary, a traceability system brings benefits such as increased customer satisfaction, improved food crisis management, improved FSC, improved competitiveness, scientific and technological contribution, and contribution to agricultural sustainability (Bosona & Gebresenbet, 2013b, p. 38).

The following figure provides a clear overview of the driving factors of traceability in the FSC. Traceability should answer the questions who, what, when, where and why regarding food safety, quality and visibility.

Figure 3: Drivers for Traceability

Source: Adapted from Aung & Chang, 2014, p. 175

The driving factors justify the importance of implementing traceability, which is why the rough structure of such a system will now be explained. First, technical requirements are needed to identify products, to process information in real time, for data analysis, for warehouse and transport monitoring and, finally, to integrate systems. Technologies are needed that consist of hardware (such as measuring instruments, identification tags and labels) and software, so-called information systems (Aung & Chang, 2014, p. 180). As technical instruments, for example, alphanumeric codes, bar codes, radio frequency identification (RFID) or wireless sensor network (WSN) can be used (Aung & Chang, p. 181).

RFID is most often associated with traceability. RFID creates transparency in the FSC by making information available in real time about, for example, stock levels or contamination of the entire distribution network. What sounds good in theory, however, is not yet fully and efficiently implemented in practice. Perfect information is rarely available, and because only a fraction of items is identified, incomplete information is available. Nevertheless, RFID offers the possibility to tag products on item level and thus to track them, but this is associated with a large financial and technical effort, which is why often only pallets are tagged. These problems need to be solved so that traceability in the FSC becomes more efficient (Zhanguo Zhu et al., 2018, p. 5716). In addition to the challenges of RFID application, Bosona et. al summarize the general challenges of traceability development and implementation as follows. There is a resource limitation, meaning that both financial and technological resources are scarce, which can slow down and complicate implementation. In addition, the information limitation means that complete, up-to-date, and true information is not yet fully available, as systems often focus only on the origin of products, but not on quality and safety aspects. The standard limitation is responsible for the fact that there are no uniform traceability systems, as different companies use different systems and these in turn have different degrees of accuracy. Another challenge is the capacity limitation which is especially important for small companies as they often do not have enough technically trained staff to operate and monitor such a system. Finally, there is the awareness limitation, which means that the benefits of a well-functioning traceability system are not seen and no investments are made (Bosona & Gebresenbet, 2013b, p. 40).

In this subchapter, it became clear what great advantages a functioning and standardized traceability system promises, but current obstacles and challenges to the implementation of the systems were also discussed. The extent to which new technologies can have an influence on improved traceability is described in the following chapter "New Technologies".

Table 1: Summary table characteristics of FSC

Impact Area	Specific Impact	Source
Characteristics of the FSC		
Quality	• Bioactive compounds as intrinsic property of food quality • Increasing importance of product quality and food ingredients due to COVID-19	• Galanakis et al., 2021, pp. 149–159 • Galanakis et al., 2021, pp. 149–159
Safety	• Safety as the most important component of quality • Food hazards can be caused within production and supply chain • Different safety regulations between countries due to globalization • High input of energy required to keep food safe and fresh • Prevention of food safety accidents	• Aung & Chang, 2014, p. 177 • King et al., 2017, pp. 161–162 • King et al., 2017, pp. 161–162 • Zhanguo Zhu et al., 2018, p. 5700 • Soon et al., 2020, pp. 5–7
Sustainability	• FSC as a prerequisite for the nutrition of the global growing population • Mass food production causes severe damage on the environment • Dimensions of sustainability in Supply Chain: Environmental, Social, Governmental, economic • Drivers for sustainable supply chain design: business risks, performance potential, sustainable product innovations • Circular economy approach • Sustainability is linked to safety if the traceability system is applied • Sustainability in terms of fairness and employment	• Zhanguo Zhu et al., 2018, p. 5700 • Zhanguo Zhu et al., 2018, p. 5700 • Ganse, Werhahn, & Gschmack, 2012, p. 260 • Ganse et al., 2012, pp. 161–162 • Galanakis et al., 2021, p. 197 • Maloni & Brown, 2006, p. 38 • Zhanguo Zhu et al., 2018, p. 5715

Table 2: Summary table of important variables of FSC

Impact Area	Specific Impact	Source
Important Variables		
Resilience	• Shorter product cycles and higher demand as some of the reasons for SC disruptions • Resilience as the preparation for unexpected events and efficient and effective response to them • COVID-19 as an example of demand and supply shocks and therefore the need for resilience in FSC • Characteristics of FSC such as seasonal cropping patterns and perishable commodities can lead to short-term interruptions • Tension between, on the one hand, efficient production facilities and globalized supply chains and, on the other hand, regionality and shorter delivery routes to counteract exogenous shocks • Automatization can have a positive impact on resilience • Online commerce and resilience	• Ponomarov & Holcomb, 2009, p. 124 • Ponomarov & Holcomb, 2009, p. 124 • Hobbs, 2021, pp. 190–191 • Hobbs, 2021, pp. 190–191 • Hobbs, 2021, p. 192 • Hobbs, 2021, p. 193 • Hobbs, 2021, p. 194
Traceability	• Safety and quality aspects are more challenging due to larger distances between food producers and end consumers • Traceability as tracking tool, colloquially called "Farm to Fork" • Drivers: improve supply management, facilitate food traceability to ensure safety and quality, and differentiate market foods with subtle or non-traceable characteristics; regulatory aspect, the safety and quality aspect, the social aspect, the economic aspect and the technological aspect • Benefits: increased customer satisfaction, improved food crisis management, improved FSC, improved competitiveness, scientific and technological contribution, and contribution to agricultural sustainability • Driving factors of traceability: legislation, labor/ cost reduction, process/ SC efficiency, Chain communication, trade globalization, competitive advantages, quality, safety • Need for hardware (e.g., RFID) and software (e.g., WSN) for the implementation of traceability • Chances and challenges of RFID	• Aung & Chang, 2014, p. 173 • Aung & Chang, 2014, p. 174 • Elise Golan, Barry Krissoff, Fred Kuchler, Linda Calvin, 2004, p. 4 • Bosona & Gebresenbet, 2013b, p. 37 • Bosona & Gebresenbet, 2013b, p. 38 • Aung & Chang, 2014, p. 175 • Aung & Chang, p. 181 • Zhanguo Zhu et al., 2018, p. 5716

4. Disruptive technologies and their application in supply chain management

The following chapter examines a selection of disruptive technologies, describing their functionality, benefits, applicability in the supply chain, and challenges. Blockchain, Internet of Things and Artificial Intelligence (AI) are examined in more detail.

Blockchain as a technology is very disruptive and the term is known to most people, especially in recent years. In theory, this technology seems to bring a number of benefits, such as the security of transactions and transparency (Ashcroft, 2021). However, this bachelor thesis will show whether this technology is also currently used of two food manufacturers or will be used soon based on the case studies.

Since the Internet of Things is known to provide a high level of traceability, this fits well at first glance into the food industry, where safety and quality of products are paramount, which in turn is supported by traceability and tracking. Moreover, this technology is already used by many companies and has been for over 15 years, and yet this technology holds enormous potential, especially in combination and as a prerequisite for other technologies. In 2013, around 20 million smart sensors such as RFID were installed in supply chains. According to Deloitte, around 10 trillion sensors will be in use by 2030 (Ashcroft, 2021). This example shows the still enormous potential of the technology.

Many expectations are placed on Artificial Intelligence and its possible applications go far beyond economic problems. In a Gartner study, supply chain organizations expect the degree of machine automation in supply chain processes to double in the next 5 years (Jacobs, 2022).

All three technologies can theoretically be applied to the supply chain. It is true that there are other disruptive technologies, such as 3D printing, self-driving cars, and many others. Nevertheless, the scope of a bachelor thesis should not be exceeded, which is why we focus on the three technologies mentioned above.

4.1 Blockchain

“Blockchain in agriculture and food will reach a value of $1.48 billion by 2026” (Carter, 2022, p. 6). This statistic from BIS Research's report describes the revolutionary change Blockchain is having on the food industry and its supply chains.

Blockchain is no longer a foreign word to most people, however, it is most often associated with the decentralized payment system Bitcoin, although the possibilities of applicability go far beyond that (Hinckeldeyn, 2019, p. 1). Therefore, the following chapter takes an approach to the topic and evaluates what application potential Blockchain has in the FSC.

4.1.1 Definition and Functionality of Blockchain

The term Blockchain can be classified under the umbrella term Distributed Ledger Technology (DLT). "Distributed ledger technology is a system with multiple participants that functions without a central control authority despite the unknown reliability of these participants” (Hinckeldeyn, 2019, p. 5). According to Hinckeldeyn, Blockchain is a special case of DLT, which allows information to be stored in a data structure of blocks concatenated with hash values. A more detailed definition of Blockchain technology is provided by Risius and Spohrer. „Blockchain technology refers to a fully distributed system for cryptographically capturing and storing a consistent, immutable, linear event log of transactions between networked actors. This is functionally like a distributed ledger that is consensually kept, updated, and validated by the parties involved in all the transactions within a network. In such a network, Blockchain technology enforces transparency and guarantees eventual, system-wide consensus on the validity of an entire history of transactions“ (Risius & Spohrer, 2017, p. 386).

Taking a look at the literature, the history of bitcoin and thus Blockchain begins on November 1, 2008, when a person with the pseudonym Satoshi Nakamoto published the paper "Bitcoin: A Peer-to-Peer Electronic Cash System" (Hönig, 2020, p. 111). The technical foundations of the technology are described here, which combines several cryptographic concepts, including hashes, signatures, Merkle trees, which together create a decentralized transaction system (Hönig, 2020, p. 111).

The following is an overview of how a Blockchain works.

Figure 4: Functionality of a Blockchain

Source: Adopted from Prinz, Rose, Osterland, & Putschli, 2018, p. 313

(1) The process begins with the transaction to be executed being generated and digitally signed by a sender. This can be a simple document or an invoice, for example.

(2) The transaction is then sent to the network and distributed to the participating nodes.

(3) Now comes consensus building, where the participating nodes first ensure the validity of the transaction and then validate it using various consensus building methods. One common method is the proof-of-work algorithm, in which a number (nonce = number used only once) is to be found that, together with the already existing Blockchain, results in a so-called hash value. This method is particularly useful if the Blockchain network is public and has no access restrictions. This is the case, for example, with the classic Blockchain application of bitcoin. Another method that is mainly relevant for private Blockchains is the proof-of-stake method.

(4) The transactions are then stored in a block and standardized by hash functions. These hash values are then hierarchically condensed in a so-called hash or Merkle tree. This is where the security argument of the Blockchain comes into play, as a change in the transaction would change the hash value of the block and thus the hash tree would no longer be consistent.

(5) Finally, the blocks are chained together to create a Blockchain.

Simplified, a Blockchain can be thought of as a distributed database that is organized and monitored by participants. This decentralization is significantly less error-prone compared to centralized approaches (Prinz et al., 2018, pp. 313–316). Further characteristics and advantages can be derived from the Blockchain system, which are presented below.

4.1.2 Benefits of Blockchain

Blockchain is often associated with the argument of security against manipulation (Hinckeldeyn, 2019, p. 2). Depending on the Blockchain application, documents and assets can be uniformly encoded in a counterfeit-proof manner. In addition, the transfer between the senders and receivers of the transaction is stored in the Blockchain. This storage is irreversible, so it cannot be reversed, and furthermore, the storage is traceable because it is based on consensus building and encryption. As a result, the security component of Blockchain is often emphasized (Prinz et al., 2018, p. 312).

Another beneficial characteristic of Blockchain is decentralization, which means that an intermediary does not always have to be used to create value for the company (Hinckeldeyn, 2019, p. 2). It verifies transactions in what is known as a peer-to-peer (P2P) network, that is, by the other members of the Blockchain, rather than by a central authority, which can increase the speed of transactions (Prinz et al., 2018, p. 312).

Among other things, decentralized control can simplify administrative processes (Hinckeldeyn, 2019, p. 2) and transactions are verified and executed (Dujak & Sajter, 2019, p. 32). This process can be executed by so-called smart contracts. Smart contracts or chain codes are programs within the Blockchain network that handle processes, independent of external entities. This makes it possible to model complex processes and execute transactions between entities reliably and immutably. Actions are not only executed by smart contracts, but also documented at the same time (Prinz et al., 2018, p. 317).

Thus, a Blockchain can serve not only as a transaction platform, but also as a database that enables tracking of objects (Hinckeldeyn, 2019, p. 2) and monitors guarantees of origin. Visibility and transparency are resulting properties of the Blockchain, which are important variables especially in the supply chain (Dujak & Sajter, 2019, p. 34).

Finally, Blockchain also contributes to an improved environmental footprint, not only by driving digitization and automation of business processes, but also by reducing paper consumption through digital documentation (Dujak & Sajter, 2019, p. 34). That in turn, just like many of the benefits of Blockchain mentioned above, can lead to significant cost reductions and increased efficiency (Hinckeldeyn, 2019, p. 2).

4.1.3 Application of Blockchain in the FSC

In the previous section, some characteristics, and advantages of Blockchain were listed. How these advantages can be applied in the supply chain and especially in the FSC is described in this subchapter.

A functioning FSC depends above all on the variable "traceability," as already explained in the traceability subchapter. It is a matter of documenting the origin of the product with information about place, time and manufacturer and the route the product takes to the end consumer. On the one hand, tracking offers better planning reliability and optimization opportunities for the company. On the other hand, it creates high added value for consumers by providing reliable information about the product. A combination of RFID technology, i.e., transponders or tags, and Blockchain technology can provide a reliable tracking system for the FSC. The information generated by the RFID sensors about, for example, the location, temperature, and vibration of the products is mainly exchanged via the IoT. However, what is missing is the authenticity and verification and security of the collected information, which the Blockchain ensures by verifying the data through the decentralized system by the Blockchain members. Particularly in the FSC for fast-moving consumer goods (FMCG) retailers, Blockchain provides a platform to achieve rapid problem identification and significantly accelerate product recalls in the event of safety defects. Examples of successful Blockchain applications in the grocery industry abound. Walmart managed to reduce the tracking of a pack of mangoes from farmer to supermarket from days or weeks to two seconds through Blockchain implementation.

Another example is the U.S. agribusiness that used Blockchain technology to enable its customers to track their thanksgiving turkey back to the grower (Dujak & Sajter, 2019, pp. 33–36). Not only can Blockchain facilitate the tracking of food and thus transparency and customer confidence, but also simplified customs clearance for international deliveries is frequently mentioned. The exchange of tamper-proof data can be simplified with Blockchain and processes can thus be simplified and accelerated (Hinckeldeyn, 2019, p. 47).

Another application of Blockchain technology is demand forecasting. Demand management is an important part of supply chain management, and the goal is to balance demand and supply to maximize profits of the entire supply chain. Demand management can be defined as follows. "Demand management in the context of supply chain management can be defined as the preparation of supply chain members for future events in the supply chain through coordinated efforts to forecast expected future demand, jointly influencing demand and accordingly creating their supply" (Dujak & Sajter, 2019, p. 37). Successful demand forecasting that works over the long term requires transparency and, at the same time, security and accuracy of the information exchanged, which the Blockchain can provide. In non-collaborative supply chains, information can often be lost due to a lack of trust towards other supply chain members, which is why individual supply chain members derive their demand forecasting from past demand data. This disparity in information can result in an overabundance of inventory, which is what the Bullwhip Effect describes. Again, the Blockchain can provide an advantage because of its independence and security of information. It can help determine the so-called independent demand, which is identical for all parties in the supply chain, preventing the bullwhip effect. Realized through data exchange between supply chain members, this shared, collaborative prediction of demand eliminates the trust problem. The Blockchain property of security and accuracy of data can thus help make more accurate predictions without questioning the accuracy of the data (Dujak & Sajter, 2019, pp. 36–39).

Depending on the Blockchain model, the information it contains is accessible to everyone or only to a limited group. This access to information through open access brings advantages such as less paper consumption, reduction of direct communication between actors or more information for the end user. The benefits of open access are enormous, especially in the transportation sector. Through the original exchange of information, about 200 communications were measured by the container ship shipping company Maersk during a transport of flowers from Kenya to Rotterdam. This costs not only time but also money, so it is estimated that the process of communication and documentation for shipping containers costs as much as the physical transport itself. However, if the Blockchain takes over this document and information workflow, thereby reducing national and international direct communications, errors, waiting times and other types of waste can be avoided and faster material flows can be enabled. Thus, according to the Marine Transport International estimation, the Blockchain application can save around $300 in labor and documentation time per container, which, at 70 million containers annually, brings significant potential savings. The Blockchain can also have an influence on the availability of empty containers and, through the open access approach, ensure that better utilization of containers is possible through process optimization. The sustainability aspect should also not be overlooked in the open access application, as the decreasing need for paper for documentation purposes results in more environmentally friendly behavior on the part of companies and consumers. By tracking the ecological footprint of a product, ecologically successful companies can be rewarded and less environmentally friendly companies can be penalized, for example through higher CO_2 taxes (Dujak & Sajter, 2019, pp. 38–39).

Moreover, by verifying the origin and authenticity of products through the open access approach of Blockchain technology, fraud and counterfeiting of products can be countered. However, this feature of Blockchain is largely used in the pharmaceutical and luxury jewelry industries. Furthermore, even across industries, counterfeit products or products with quality defects are more likely to be tracked down by the Blockchain (Dujak & Sajter, 2019, pp. 39–40).

The smart contracts already mentioned are being used extensively in supply chain networks. The main advantages of self-executing transactions are that they replace intermediaries and thus function much faster and cheaper, resulting in fewer errors or interruptions in the execution of transactions. Contracts are governed by a predefined set of rules consisting of digital code that can only be subsequently modified with the unanimous agreement of all Blockchain participants. An example is shown by the

Kouvala Innovation Organization, which is working to connect pallets with shipping tasks to freight forwarders. The pallets carry RFID sensors that send signals for shipping needs. Once there is a match between the best forwarder's offer and the price and service terms, a contract is automatically executed on the Blockchain (Dujak & Sajter, 2019, pp. 40–41).

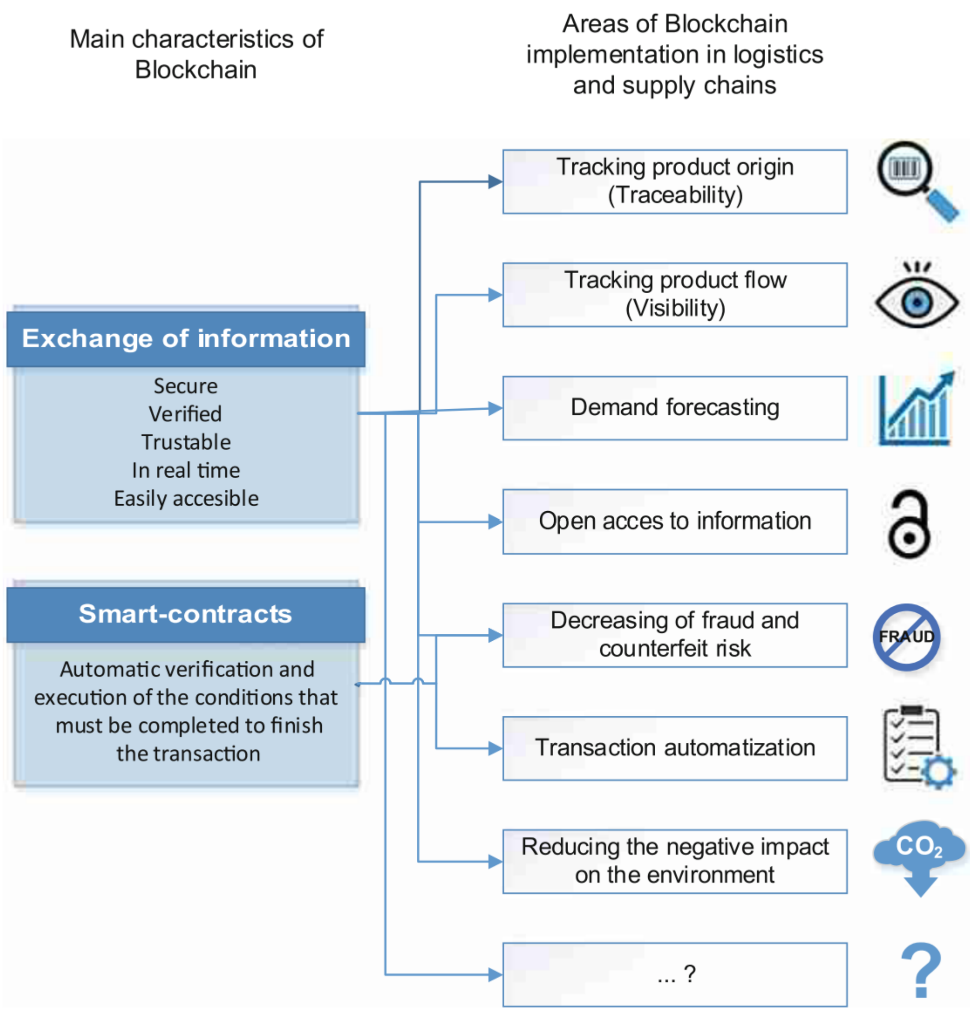

Figure 5: Blockchain in Supply Chain

Source: Dujak & Sajter, 2019, p. 33

4.1.4 Challenges of Blockchain

Even though Blockchain has evolved tremendously since the paper was published in 2008 and has generated a lot of hype, the technology is still very much in the early stages of its development. Of course, there are already companies using this technology in various applications, but based on some studies, it is estimated that it may take up to 30 years before Blockchain is applicable to the masses (Hinckeldeyn, 2019, pp. 48–50).

The challenges are mainly of a technical nature, such as better scalability but also the very high energy consumption of proof of work consensus algorithms (Hinckeldeyn, 2019, pp. 48–50). Scalability is a so-called "scalability trilemma", as Ethereum founder Vitalik Buterin calls it. According to this, it is a major challenge to ensure decentralization, scalability, and security at the same time. Scalability indicates how high the capacity of the network is, i.e., how many transactions can be completed per second via the platform. According to Buterin's approach, only two of the components can be guaranteed at the same time; for Bitcoin, that is currently decentralization and security. High scalability can eventually lead to security risks, while low scalability can lead to transaction congestion and slowdown of the network. It is concluded that it is likely that Blockchain within the FSC could often only be applied in niche areas, such as organic products due to scalability issues (Duan, Zhang, Gong, Brown, & Li, 2020, pp. 11–12).

In addition, Blockchains are not yet interoperable. Since there are currently different variants of Blockchains, it must be ensured that no users are "locked in" on just one platform. Developing the open source approach further can be the solution here (Hinckeldeyn, 2019, pp. 48–50).

It is not only technical barriers that need to be removed, but also social acceptance. One solution approach for social acceptance is to educate people about Blockchain technology and inform them about the benefits of its use. To this end, the still complex user interface must be structured in a more user-friendly and comprehensible way (Hinckeldeyn, 2019, pp. 48–50). Often, supply chain employees still struggle to fully understand the potential of Blockchain, which in turn strongly influences their attitude towards the technology. Of course, it is important to keep in mind that different stages of the supply chain have different technological requirements, and Blockchain application may not always make sense. Therefore, on the one hand, there is a need for a fundamental analysis of the costs and benefits of technology application in certain areas, and on the other hand, the aforementioned user-friendliness (Duan et al., 2020, p. 11).

Legal issues around Blockchain also still need to be addressed to protect users' rights and to protect internal information, as Blockchain is an open-access data platform. There needs to be regulation around what data should be uploaded, who owns the data, and how the data is used and secured. This lack of rules and regulations is a barrier to the widespread adoption of Blockchain technology (Duan et al., 2020, pp. 12–13).

Not to be forgotten are all stakeholders within the FSC. The goal of Blockchain is to unite as many supply chain participants as possible in the system to improve transparency and efficiency of information. From the supplier of the raw material to the end consumer, everyone should benefit from real-time information. For small and medium-sized enterprises, as well as for developing countries, the implementation of Blockchain infrastructure involves high investment costs, which is a barrier to the overarching use of Blockchain. Blockchain must therefore be not only easy to use, but also associated with lower investment costs (Duan et al., 2020, p. 12).

More Blockchain applications also need to be developed in general, both in the supply chain and in other areas, because there are few applications so far beyond Bitcoin or other cryptocurrencies. In order to exploit the potential of Blockchain, time and investment are needed (Hinckeldeyn, 2019, pp. 48–50).

4.2 Internet of Things (IoT)

Internet of Things is currently one of the most popular and disruptive technologies with application in a wide variety of sectors (Affia, Luh, & Aamer, 2019, p. 2). It describes the networking of everyday objects and things in a wide variety of categories. A distinction can be made between previously unnetworked devices, such as cars, toasters or washing machines, already networked devices in the home, such as TVs, smartphones and smart homes, and classically networked devices and coupling elements, such as surveillance cameras or routers. As can already be seen from the examples, this technology is often already hidden in everyday life and can therefore be used to link or simplify everyday as well as business processes (Bök, Noack, Müller, & Behnke, 2020, p. 321).

4.2.1 Definition and Functionality of IoT

As is often the case, there is also no universally valid definition for this technology. In a highly simplified form, the German Bundestag describes the technology of the IoT in 2012 as "the technical vision of integrating objects of all kinds into a universal digital network" (Bök et al., 2020, p. 321).

In 2019, Ben-Daya, Hassini, and Bahroun define the concept of IoT as "[...] a network of physical objects that are digitally connected to detect, monitor, and interact within an enterprise and between the enterprise and its supply chain, enabling agility, visibility, tracking, and information sharing to facilitate timely planning, control, and coordination of supply chain processes (Ben-Daya et al., 2019, p. 4721). Ben-Daya et al. derived this definition from numerous existing definitions and point out four main components of the IoT definition. "IoT" is a term from the world of the Internet of Things: (i) the requirement for digital connectivity of physical things in the supply chain; (ii) the nature of this connectivity is proactive, enabling the storage, analysis, and sharing of data; (iii) communication includes both processes within an organization and transactions between organizations, covering all major processes in the supply chain; and (iv) IoT will facilitate the planning, control, and coordination of processes in the supply chain (Ben-Daya et al., 2019, p. 4721).

In the early 1990s, the precursor to IoT was born at the Auto-ID Centre at MIT. The term IoT was created by Kevin Ashton, the center's director in 1999. Two years earlier, he had applied RFID tags for tracking purposes of products within the Procter and Gamble supply chain. Today, the networks in which the collected information is stored are enriched with GPS devices, smartphones, social networks, cloud computing and data analytics, creating the modern version of the IoT. In Europe and especially in Germany, IoT is one of the defining technologies during the Industry 4.0 era within the manufacturing sector (Ben-Daya et al., 2019, p. 4720).

The IoT network consists of four essential layers that describe the structure and operation of an IoT system. Da Xu, He, and Li describe the combination of the four layers as service-oriented architecture (SOA).

(1) Sensing Layer: This layer mainly refers to the hardware, such as sensors and RFID tags, whereby data is generated. This hardware forms the things of the IoT.
(2) Networking Layer: Here, the generated data is forwarded to wireless or wired networks. Thus, the networking layer has a connecting function. In addition, the networking layer can add the information collected by the sensing layer to existing information from IT systems, thus creating an integrative function.
(3) Service Layer: The goal of the Service Layer is to manage and integrate services and applications through middleware. All service-oriented tasks, such as information exchange and storage, data management or communication, are also handled by the service layer.
(4) Interface Layer: At this level, information is made available in a clear form and made accessible to users so that they can interact with the system (Da Xu et al., 2014, p. 2235).

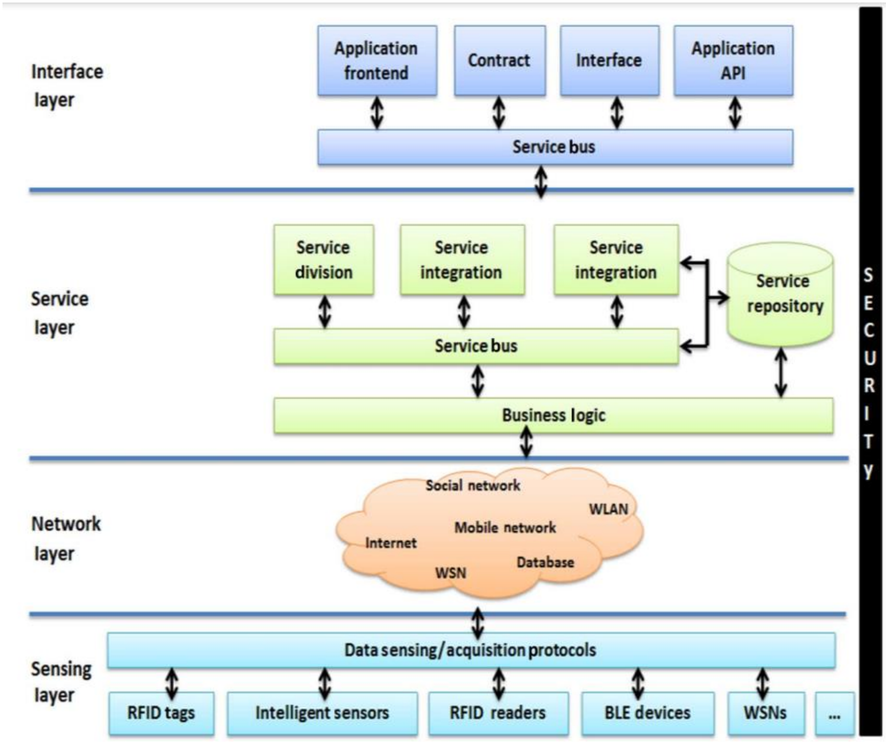

Figure 6: Service-oriented architecture of IoT

Source: Da Xu et al., 2014, p. 2236

4.2.2 Benefits of IoT

The IoT can store and processing large amounts of data (Big Data) through the implementation of services and applications. However, data can not only be stored in large quantities, but also collected in a faster way from different sources. In the literature, the characteristics of Big Data, namely volume, variety and velocity are described as the triple "V" baseline (Birkel & Hartmann, 2020, p. 4). In terms of time, IoT is not only fast, but provides information in real time and makes this information available to all actors involved, whereas traditionally SC information was only passed from one actor to the next. The author calls this real time supply chain management (Abdel-Basset, Manogaran, & Mohamed, 2018, p. 3). By collecting, generating, processing and exchanging data within clouds or data centers, supply chain risk management can be significantly improved in terms of data availability and process management (Birkel & Hartmann, 2020, p. 4).

In terms of supply chain management, IoT can contribute to improved inventory management, after all, real-time visibility of inventory is provided by IoT. Previously, inventories were often measured based on estimates or the data was collected manually, which sometimes led to inventory errors due to the human factor. Meanwhile, attaching sensors generate an inventory accuracy rate of 100% (Abdel-Basset et al., 2018, p. 3).

Moreover, unlike Blockchain technology, scalability is particularly high, as additional sensors can easily be attached or additional information from other systems can be integrated (Birkel & Hartmann, 2020, p. 4).

One of the most mentioned advantages of IoT technology is the identification and tracking technology, which includes RFID systems, barcodes, and smart sensors. The RFID system consists of the RFID tag and the RFID reader, which can identify and track the physical goods. These systems are mainly used in logistics, supply chain management and healthcare monitoring. Through the RFID system, accurate real-time information about the goods is available, labor costs are reduced, business processes are simplified, inventory accuracy is increased, and business efficiency is enhanced (Da Xu et al., 2014, p. 2237). A higher level of transparency can be achieved through the tracking function of the sensors. Locations, temperatures, shocks and other parameters are measured and exchanged in the IoT, which promotes agility and visibility (Birkel & Hartmann, 2020, p. 4). Abdel-Basset et al. recognize that this can increase transparency within logistics. By using smart objects (things), transport conditions or destination of goods can be made visible throughout the supply chain, maximizing monitoring and thus protection of goods. This also minimizes return shipping costs and increases customer satisfaction (Abdel-Basset et al., 2018, p. 3). Chitrakar et al. calls this tracking technology "Smart Monitoring Technology" (SMT) and points out that this approach is a necessity, especially during the pandemic, because it does not require human intervention to collect data. He lists several different types of sensors, each of which can measure different parameters such as humidity, CO_2, ethylene and gas composition (Chitrakar et al., 2021, p. 4).

Da Xu et al. cite service management as a further advantage of IoT technology. It is derived from the service layer described above. It describes the implementation of quality management to meet user needs. As mentioned above, information from multiple sources comes together in IoT systems and to hide this heterogeneity from the user, the information is made accessible in an understandable way in a unified user interface. In addition, the general service of IoT is that virtual and physical objects can communicate, which can significantly increase the efficiency of devices and networks (Da Xu et al., 2014, 2237 ff.).

Affia et al. summarizes the benefits of IoT implementation and confirms that researchers and users agree that IoT-enabled supply chains offer benefits such as "real-time information sharing, cost reduction, efficiency, transparency, traceability, and sustainability". They also increase business productivity and market competitiveness. Affia et al. calls these benefits "performance perceived benefit" (Affia et al., 2019, p. 6).

4.2.3 Application of IoT in the FSC

The FSC is highly distributed and complex, covering large geographic distances and having to do so in a relatively short time frame. Promising IoT technologies offer an answer to this complexity. Challenges such as traceability, visibility and controllability can be ensured by these systems. With the help of IoT, the so-called farm-to-plate can be covered and a safer and more efficient FSC can be achieved. The typical IoT solution for FSC consists of three parts. First, the field devices, such as RFID readers/tags. Second, the backbone system, i.e., databases, clouds, or servers connected by distributed computers that hold the collected data. The third component is communication infrastructures such as WLAN, cellular, satellites or the like. With the collected data, Big Data analyses can be performed and decisions can be made more easily (Da Xu et al., 2014, p. 2238). Specific use cases of this basic structure of the IoT in the food supply chain are presented in the following section.

As already mentioned in the first chapter of the FSC, the classic supply chain consists of production, processing, distribution, retail, and consumers. Since the FSC is mainly based on production, processing and distribution, these steps will be examined in more detail and areas of application for IoT in these levels of the supply chain will be mentioned.

Within the production level, IoT can be applied to agricultural water productivity, for example. To make irrigation as productive as possible, irrigation scheduling must be maximized so that agriculture can conserve water without sacrificing yields. The IoT concept comes into play here in the form of smart irrigation. Workers can thus monitor irrigation digitally without visiting the site, and a smart irrigation system autonomously regulates optimal watering. Certain sensors collect data on temperature, soil conditions and moisture, which in turn are relayed to cloud services, to what is known as the networking layer, as described earlier. Another application of IoT within the production stage is in plant disease control. This depends on the sensing, assessment, and treatment aspects, each of which can be supported by IoT technology. Sensory tools in the form of IoT camera traps can be deployed, triggering a sprayer as needed to control the pests. The data is again relayed directly to the Internet cloud system, and the logs give workers an early warning regarding pest problems. Also, in the field of poultry farming, the success of production depends heavily on environmental conditions such as humidity, temperature, and lighting. Again, sensors can measure these parameters and relay them to cloud services to determine the condition of the poultry in real time. From the measured parameters, the stress level and comfort of the poultry, among other things, can be read, facilitating decision making about the management of the poultry. An increase in quality in terms of health and welfare is the result and provides an answer to the quality and safety aspect demanded by both consumers and producers, as described in the chapter "3.2 Characteristics of the FSC" (Maulana, Lorena Br Ginting, Aryan, Restu Fadillah, & Nurajmi Kamal, 2020, pp. 105–107).

The processing stage involves the processing of raw materials such as milk, vegetables, or grains into a food product, such as yogurts or pastries. Here, too, IoT collects data in real time so that intelligent algorithms in the control software can make better decisions. Three application areas IoT technology brings to the table. Monitoring, traceability, and packaging. For instance, monitoring the processing phase in real time, can have a positive impact on maintenance. If certain parameters, such as temperature, are conspicuous, preventive measures can be taken, which can prevent limit values from being exceeded and thus damage to machines in good time. Beyond monitoring, IoT also offers the traceability function, which is likewise considered important by consumers and companies in the "3.3 Important Variables" subchapter. Again, RFID tags or other tracking media can be applied to better monitor production processing steps and optimize the production line in the processing phase to increase efficiency. An example of an SMT producing sauces shows an increase in income of over 30% compared to previous income through the application of IoT technology. The third point "Packaging" is in a way also still part of the processing phase but serve to protect the food from external influences such as humidity, temperature, light and others. Through IoT, packaging is becoming more interactive and secure, which is summarized by the term "Smart Packaging". This is an interactive and intelligent packaging concept, whereby the packaging environment interacts with the food to actively protect food products. As with the aforementioned applications of IoT technology in FSC, RFID or smart labels are used inside the packaging to reliably transmit data to a cloud platform, which can be analyzed to improve quality and product safety (Maulana et al., 2020, pp. 107–109). In addition, one recognizes again the interface between new technologies such as IoT and sustainability as a characteristic of the food supply chain.

The distribution stage includes warehouse management and the distribution of processed products to distributors. A wide variety of food products can be stored in the warehouse, which is why it must be managed properly and optimally so that fast and precise execution of all functions can be ensured to meet customer requirements. At the same time, the condition and quality of food products in the warehouse must be ensured. IoT technology can help warehouse management identify abnormal conditions, such as unsuitable product locations or low product inventories. Sensor technologies such as RFID or perception technologies such as voice and video surveillance are used for this purpose. The IoT concept for warehouse management systems can also be used to improve the required traceability. Not only during storage, but also during distribution of food products, attention must be paid to the quality, freshness of the product, and damage to the product. If strict controls are not carried out during distribution, product quality, such as spoilage or bacterial growth, can quickly deteriorate, especially in the case of food products. Likewise, the choice of distribution channels plays a crucial role in the quality assurance of goods. Key technologies here also include RFID, sensor technology, video surveillance and mobile communication technologies in the form of GPS. Humidity and temperature sensors are incorporated into both trucks and product packaging, which transmit product-related data in real time to a monitoring center (Maulana et al., 109 ff.).

The subchapter “4.2.3 Applications of IoT in the FSC” showed again how strongly this technology is linked to the demands of the food supply chain, such as quality, security, and sustainability and therefore how traceability is used above all.

4.2.4 Challenges of the adoption of IoT

Although IoT is already being applied in many cases within the supply chain, there are still challenges or factors that inhibit the implementation of IoT. The authors Aamer, Al-Awlaqi, Affia, Arumsari, and Mandahawi and Affia et al. overlap in many approaches to describing these challenges and future challenges. Aamer et al. categorizes the challenges into six broad overpoints:

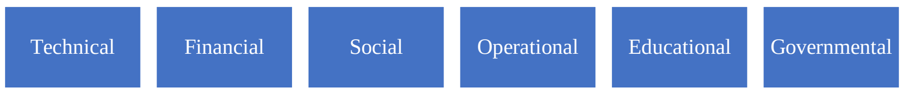

Figure 7: Challenges of IoT

Source: Own illustration

One of the biggest challenges is the technical component, which includes technical hardware skills, network structure, interoperability and integration, big data management and internet availability (Aamer et al., 2021, p. 2525). Since IoT is a very data-driven technology that generates and analyzes large amounts of data, there is a need for skilled and knowledgeable employees who can deal with these conditions and perform effective data management. From previous studies, data complexity is a significant barrier for many companies to adopt IoT technology in supply chain management (Affia et al., 2019, p. 7). Well-trained specialists and analysts are therefore a prerequisite for successful implementation of the technology. For the application of IoT, it must be ensured that all users involved have sufficient competence to work with the technology. Companies usually already have existing systems to manage their supply chain, so one challenge and prerequisite for an IoT system is to connect the new technology with the old one, This compatibility or interoperability ensures a certain standardization, which must be checked before the IoT system is introduced (Affia et al., 2019, p. 7).

The cost factor is another point that represents a challenge for the company and can be assigned to the umbrella term "Financial". Whether the cost expenditure pays off later and is worthwhile should be determined in advance in a cost-benefit analysis (Affia et al., 2019, p. 6). For example, the costs incurred through IoT should not influence the final price of a particular product, as this could result in a change in customer purchasing behavior. Especially low-scaled food companies are not yet ready to adapt IoT because of the high financial costs involved. The biosensors, which are mainly used in the food supply chain and were already mentioned in the chapter "4.2.3 Applications of IoT in the FSC", require high investment sums, which are usually only feasible in large companies (Aamer et al., 2021, p. 2527).

One challenge in the social category is cooperation among supply chain players, such as farmers, manufacturing companies, retailers, and consumers. Establishing a functioning infrastructure for data exchange between the stakeholders, who may all have different amounts of access to information, presents IoT with a major challenge. Especially in food companies, a constant exchange between different companies is a prerequisite for maintaining quality standards (Aamer et al., 2021, p. 2528).

Managing the supply chain IoT system is also a challenge, forming the fourth pillar, operational matters. The complexity results mainly from the food supply chain generated data, the disruptive technology and the complexity of the supply chain network (Aamer et al., 2021, 2528 ff.). To create a functioning IoT system requires the acquisition of hardware and infrastructure that must be integrated into the supply chain. This includes devices such as RFID sensors, protocols, applications, and connectivity to design a functioning IoT ecosystem so that all stakeholders can access it. Consequently, this acquisition and deployment of the system comes at a cost and also needs regular maintenance (Affia et al., 2019, p. 6). Security and privacy concerns are also frequently listed, as an implementation of IoT in industry often lacks the will to share data. Therefore, there must be sufficient understanding of the technology in advance to make a decision that is consistent with the company's affinity for risk (Affia et al., 2019, p. 6).

All the technologies listed are new, disruptive technologies that are still in their early application phases, so potential benefits of the technologies may not yet be tangible or imaginable to some companies. This may prevent companies from adapting this technology in the short term (Aamer et al., 2021, p. 2529). The fundamental willingness of companies to use IoT technology in the supply chain therefore plays a central role. This depends on the extent to which the technology has an influence on various factors or KPIs. According to studies, a company tends to be more inclined to use IoT if it can reduce costs and lower the electricity bill (Affia et al., 2019, p. 7). Most of the challenges arise from the misperception to the IoT implementation and the uncertainty associated with the technology from the perspective of various stakeholders. This readiness to adapt a technology is summarized under the umbrella term "Education", as the company's knowledge and information about the IoT technology has a significant influence on its implementation (Aamer et al., 2021, p. 2529).

However, it is not only the readiness of companies that influences the use of technology; business partners and the state also play a significant role. Supporting measures of material and immaterial form from external parties often lead to facilitation of implementation. It can also be seen that external pressure has a positive effect on the company's readiness, as it strengthens the partnership with suppliers who also use this system (Affia et al., 2019, p. 7). However, the state should not only provide financial incentives, but also set rules and regulations, as this is fundamental especially for standards within food safety and traceability (Aamer et al., 2021, p. 2530).

In the future, existing techniques such as RFID are expected to be expanded and improved, and international collaborations will be strengthened to address the above challenges. Another research trend is the integration of social networking with IoT solutions to improve communication, called Social Internet of Things (SIoT). Given the high electricity consumption of most new technologies, research will be conducted to develop green IoT technologies to provide more energy-efficient solutions. The middleware described in how IoT works, is currently not context-aware, which means that the amount of data measured is often not yet filtered, and therefore more sensitive solutions need to be explored. Another issue is the integration of IoT with Artificial Intelligence, so that future IoT systems exhibit features such as "self-configuration, self-optimization, self-protection and self-healing" (Da Xu et al., 2014, p. 2240).

4.3 Artificial Intelligence (AI)

"As soon as it works, no one calls it AI anymore". This observation by John McCarthy, pioneer of Artificial Intelligence and inventor of the programming language LISP, shows that everyday situations and processes, such as the personalized display of advertising, are now perceived by us humans as a self-evident function. This results, among other things, from the fact that the research field of Artificial Intelligence has existed for more than 60 years but has only received public attention in recent years. This is mainly due to the fact that the computing power of computers has increased extremely, that the digital world produces large amounts of data, and that companies bring digital products to the market that challenge legal and ethical principles (Dengel, Socher, Kirchner, & Ogolla Shirley, 2019, p. 13).

4.3.1 Definition and Functionality of AI

To define and understand Artificial Intelligence, the two components of the term should be defined. Ludwig Wilhelm Stern, German psychologist, defined intelligence in 1871 as follows "Intelligence is the ability of the individual to adjust his thinking consciously to new demands; it is the general mental adaptability to new tasks and conditions of life" (Dengel et al., 2019, p. 15). After World War II, when digital computers emerged, research on Artificial Intelligence began. In 1956 at Dartmouth College in Hanover, New Hempshire, well-known scientists such as John MacCarty and Marvin Minsky discussed for the first time how programs could be used to create Artificial Intelligence. Out of that conference came a working definition of AI as the science of designing machines that behave intelligently. Marvin Minsky, one of the pioneers of AI, defined AI as follows "AI is the science of making machines do things that would require intelligence if done by men" (Dengel et al., 2019, pp. 15–17).

A distinction is made between "strong AI" and "weak AI". Strong AI is still trying unsuccessfully to form a general Artificial Intelligence that emulates all aspects of human thinking. Weak AI, on the other hand, focuses on rationally solving specific problems. An important concept in AI is machine learning (ML), which according to Erik Brynjolfsson and Andrew McAffe of MIT is the most important enabling technology of our age. The basic concept of ML is that a machine or software is trained based on experience (data) to acquire certain capabilities. ML can be divided into three types.

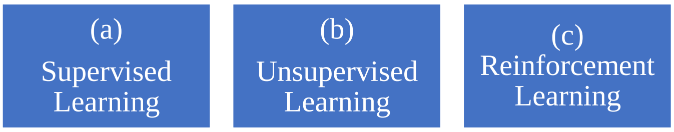

Figure 8: Challenges of IoT

Source: Own illustration

(a) Supervised learning refers to algorithms that are trained with a lot of "labeled" data to make decisions independently. For example, an algorithm is presented with several thousand images of cats and dogs, and each is labeled so that the algorithm knows which animal it is. After training, supervised-learning algorithms are tested with a test data set to verify the goodness of the trained model. The way this learning is done is very similar to human learning.

(b) Unlike supervised learning, unsupervised learning attempts to find patterns in existing data. In the example of animal pictures, unsupervised learning would not tell the machine what animal it is. Therefore, the machine has to categorize itself. It does not have to categorize by a specific type of animal, but can also categorize by other categories, such as color. This can be used to reduce and clean up datasets, which is why this type of learning is often used in compression methods.

(c) Reinforcement learning aims to learn an optimal strategy for a given problem. The goal is to maximize an incentive or reward function. The algorithm does not know which action is best in which situation, but it receives feedback on the chosen action at certain points in time, which translates into reward or penalty.

Nowadays, the method of supervised learning is most often used, as the many possible applications give the principle a great advantage (Buxmann & Schmidt, 2021, pp. 7–13).

The term Deep Learning (DL) has also been used frequently recently and has so-called Artificial Neural Networks (ANN) as its basis. With the help of these multilayer networks, they can recognize simple correlations and benefit more from a larger number of training data. The basic idea of ANNs is to simulate the human brain, which is why these networks consist of nodes (neurons) and edges (synapses) (Buxmann & Schmidt, 2021, p. 14).

The following diagram shows the terms Artificial Intelligence, Machine Learning and Deep Learning in context.

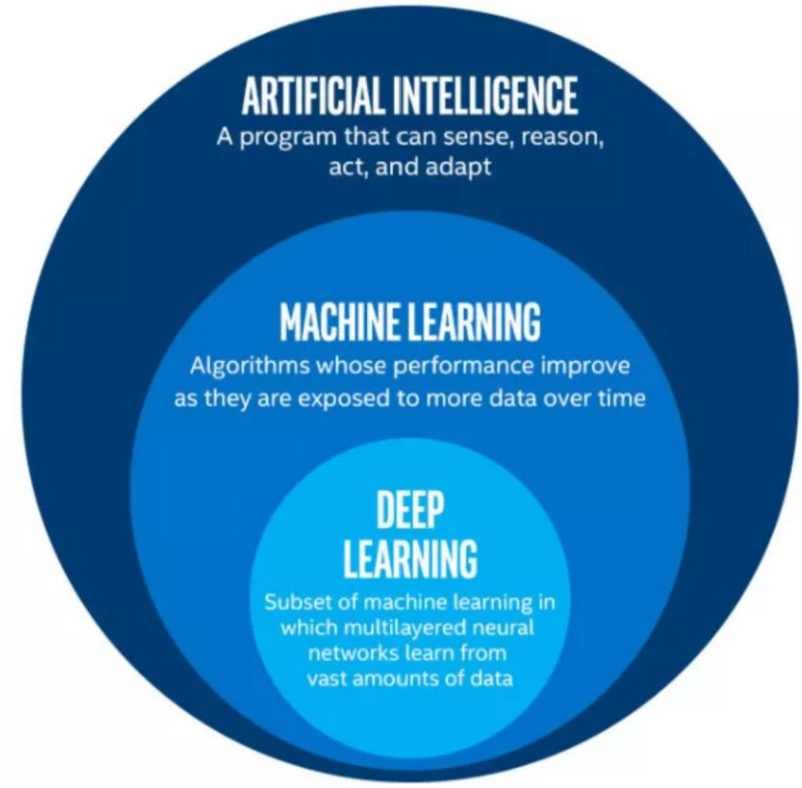

Figure 9: Artificial Intelligence, Machine Learning and Deep Learning in comparison

Source: Wuttke, 2022

4.3.2 Benefits of AI

Many reports have been devoted to the opportunities and risks of AI in recent years. Nevertheless, it is difficult to single them out as such without referring to specific application. Indeed, the benefits depend heavily on how AI is developed, used, and embedded. Nevertheless, there are typical benefits of AI that are frequently cited.

The use of AI often leads to an increase in the efficiency of processes, for instance, a better ratio between resources used and results. This can be seen, among other things, in cost savings, as AI can take over primarily mechanical and repetitive tasks that would otherwise have to be performed by humans. The increase in efficiency is noticeable through high reliability, speed and permanent availability (Djeffal, 2019, p. 5). Adriano et al. also cites time gained as a subcategory of efficiency gains. This time gained can henceforth be used by more productive work or relaxation, while employees are relieved of heavy mechanical work (Adriano et al., 2015, p. 4).

Another important aspect is the increased safety resulting from AI application. One much-discussed topic is the use of AI in self-driving cars. According to one study, 1.24 million people died in traffic accidents worldwide in 2010 due to human error. Driverless cars are therefore already proven to be safer than vehicles driven by people. This was just one of many examples from different fields, including medicine, that highlight the safety component of AI (Adriano et al., 2015, p. 4). This security results, among other things, from the fact that AI can absorb and combine enormous amounts of information. In medicine, for example, this makes the AI application "Doctor Watson" superior to his human colleagues in cancer diagnostics. In general, it can be said that the statistical reasoning of algorithms is ahead of the judgment of human experts and can decide about human lives in the medical example (Adriano et al., 2015, p. 4).

Humans often tend to overestimate their own abilities and are therefore sometimes less competent at statistical judgment than AI technology. This phenomenon is called "overconfidence bias," which is one of many human cognitive biases that can lead human reasoning astray. AI, on the other hand, can be programmed and designed to eliminate these cognitive biases. This leads to an increase in rationality that can provide help in social and political decision-making. Here, it is important to preserve human autonomy of action (Adriano et al., 2015, p. 4).

Apart from the points mentioned, AI also has a positive influence on the standardization of products. All over the world, customer demands on the product and its quality have increased, which is why companies feel obliged to win and retain customers with their products. This works best with standardized products, because this ensures that the products always meet customer expectations and in all places. Only if companies manage to maintain the product's element of success and offer consistency in the product will customer demands be satisfied and the company's chances of success increase. Artificial Intelligence can therefore be used by companies to increase the level of standardization and achieve better results (Nadimpalli, 2017, p. 3).

4.3.3 Application of AI in the FSC

In the following, different application areas of AI during the supply chain are considered.

Kollia, Stevenson, and Kollias have found in their study that AI and ML can enrich the supply chain with efficiency, safety, less food waste, and less pollution. At the very beginning, there is food production. Especially in food production in greenhouse environments, AI is expected to have a major impact. AI algorithms can be used to make accurate predictions about the growth and yield of fruits, for example. Also, the ripening processes of fruits can be optimized so that they are harvested at the right time, and that time correlates with consumer demand. DL models can be used to explore the relationship between crop ripening, greenhouse climate parameters, and soil environment. In addition, market demand forecasting can be linked to greenhouse climate control to not only provide high quality food, but also increase profits and reduce CO2 emissions (Kollia et al., 2021, 15 f.).

In FSC, after harvesting, food often goes into processing and classification. The ability of AI technologies to recognize objects can increase the thoroughness of food classification. With the help of Neural Networks (NN) and DL, for example, coffee beans or eggs can be classified into categories with 100% and 95.4% accuracy. This has an impact on the food quality found in the supermarket and on food safety. Especially in the post-COVID-19 era, it is advantageous for food to have as little contact as possible with humans during processing to eliminate contamination (Chitrakar et al., 2021, p. 6).

After food has been processed, it usually needs to be stored in cold storage systems. Another case study by Kollia et al. tested the use of DL approaches that can predict the energy consumption of large food distributors, such as large supermarket chains. This can be used to temporarily shut down retail refrigeration systems, depending on the existing refrigeration defrost period on site. The authors emphasize the importance of creating a complete food production and supply pipeline that considers information, needs, and constraints of all stakeholders so that a complete, interactive interface system is created. This model can and should be combined with other models that consider, for example, food perishability in the supply chain. By combining different AI models, energy consumption and CO2 production can be reduced and food safety can be ensured (Kollia et al., 2021, 16 f.).

In the supply chain, food distribution and consumption usually follow. The third case study by Kollia et al. shows that DL methods can effectively detect the expiration date on real food packaging. By checking the expiration date and visualizing the decision-making process, food safety, consumer health, and food waste reduction can be achieved. Supermarkets are notified through early warning pushes, for example. In addition, not only can expiration dates be checked, but barcodes of allergen labeling, or other nutritional information can be inspected. Still, AI systems must be able to incorporate employee experiences and link them to similar contexts so that optimal results are achieved and systems continue to be believed in and used (Kollia et al., 2021, 17 f.).

Heinrich and Stühler also cite certain competitive advantages in the supply chain through AI and DL. Suppliers are necessary before or after almost every step in the supply chain. AI can help identify innovative suppliers. This research follows four steps: first, Global Market Analysis and identification of potential suppliers. DL methods can consider and analyze enormous amounts of data in this process. Second, the scalable sourcing (crawling) of supplier information. Here, AI can help to merge information from different sources and enrich it with existing data. Third, the development of processes and algorithms to recommend ideal candidates. Using vectors, similarity analysis, and graphical maps (GOUs), a "sort list" of relevant top 10 candidates can be generated by the algorithm from the large number of potential suppliers. Fourth, machine training. Finally, it is very important to feedback and an assessment of the results to the machine, so that sustainable quality is ensured. This AI-based supplier research provides a comprehensive, global market analysis of the relevant suppliers by means of keyword search and helps to find the suitable supplier (Heinrich & Stühler, 2018, pp. 83–85).

Customer-supplier relationships also create a strategic advantage in supply chain management and can be used to hedge risks. Depending on the company and industry, it is not uncommon to have a database with several million data points and supplier relationships. This data is integrated in a so-called scoutbee platform and can be used for strategic supplier search and supply chain risk management. The risk of failure of a particular supplier on the own supply chain, can be calculated by the algorithm within a few seconds. The overflow of data and information to which managers and decision makers are exposed can be counteracted by an AI application by providing this information in a bundled and intuitive way. Supply chain events are displayed on a central map and supply chain managers can facilitate decisions with the help of the intuitive user dashboard (Heinrich & Stühler, 2018, pp. 85–87).

AI can also have a positive impact on the resilience variable, which has already been explained in detail in the FSC chapter. Especially after COVID-19, many companies started to look more into AI to strengthen the resilience of their supply chains and preparation for other disruptions. Through AI, risks at various nodes can be detected early and a recommendation made about the level of localization based on data trends. While traditional supply chains were not equipped with scenario planning, AI technologies can visualize and assess risks, simplifying strategic decisions in compliance, capacity, and inventory and logistics planning (Modgil, Gupta, Stekelorum, & Laguir, 2022, pp. 138–140).

Overall, it can be stated that "companies that move away from rigid processes with fixed workflows as well as data flows and towards agile, self-learning companies (...) have a greater chance of emerging as profiteers" (Heinrich & Stühler, 2018, p. 88).

4.3.4 Challenges of AI

AI brings with it certain special features, which pose challenges, especially in ethical and legal terms. While traditional machines take on clearly structured activities and are usually programmed according to if-then logic, AI-supported programs make independent decisions, adapt to new situations, and learn independently from mistakes by means of deep learning. Due to their continuous development, results are more difficult to predict, verify and track. These aspects and peculiarities have an impact on the specific ethical and legal evaluation of the technology, which makes AI applications very challenging today (Beck, 2020, p. 4).

Legal issues and principles are generally important to promote the further development of AI and to create legal certainty for stakeholders. A first important point is the handling of data and information. AI programs are fed large amounts of data at the beginning and for continuous development. By sharing and linking data between AI systems, information can be attributed to specific individuals, which can limit the protection of the data owner. Data protection regarding the data owner is currently very extensive, but the right of disposal of data users is still legally unclear. Similarly, the law is responsible for assessing and limiting risk. Any new product or technology initially poses risks to bystanders, which is why it requires legislative approval. However, AI poses a great challenge to legislators in terms of assessment, as the machine is always evolving through self-learning and is never a "finished" design. Instead of a simple initial assessment, it would be conceivable to have different authorities carry out an approval test that has to be renewed again and again. Another intensively discussed topic, which belongs to the area of legal challenges, is liability or responsibility due to the damage caused by AI. A distinction is made here between liability, i.e., material compensation for the damage caused, and individual responsibility, which is usually criminal. AI programs are neither foreseeable and controllable ex ante, nor traceable ex post, which means that an error is usually not attributable to a human individual. However, if the error falls on the machine at first glance, it must be considered that a human has trained the algorithm to achieve certain goals, and therefore may not be held directly out of account. As one of the solutions to this problem, there is a demand for the introduction of an "electric person" with his own assets, but here, too, it is not clear how the causation of damage should be structured. Therefore, a thorough revision of the legal basis is required. (Beck, 2020, pp. 7–12).

Another point that poses a challenge for the use of AI is its enormous potential for discrimination. This is where the ethical and legal challenges overlap because the question of what is considered discriminatory is currently not fully regulated, either socially or legally. There is a risk that AI can not only adopt but also exacerbate already existing discrimination, as the machine ultimately learns based on past data. One solution could be an independent body that offers training and education to employees who work with AI systems and their outputs (Beck, 2020, 11 f.).

In addition to the legal challenges, the ethical challenges are no less important. There is still skepticism about the automated decisions AI can make. There is criticism that machines do not know what it means to be human and to have feelings, which is why they cannot be empathetic. In the end, only statistical findings are evaluated, which do not consider the individual case. In addition, the low creativity of the decisions is criticized since existing solutions are used as a guide. Nevertheless, this criticism also brings out strengths. Although there is criticism of the morality of decisions, further development of AI in the European area cannot be dispensed with, since this technology represents an important branch of industry and, moreover, competition from the USA and China is not absent. AI oriented to moral values could therefore represent a competitive advantage of European technology development. Another point of discussion is the concern about jobs. AI will be able to take over more and more tasks in many areas of work, which is why fewer people will consequently be needed in these areas. Nevertheless, new jobs will also be created by the disruptive technology, according to one of the most frequent counterarguments. However, these newly created jobs usually do not require the same qualifications as the jobs that AI will take over from now on. For this reason, the world of work must be adapted without AI putting those who are already socially disadvantaged at a disadvantage. This implies that legal and ethical expertise should be brought into the development and programming phases. This expertise presupposes an increased development of ethics and law professorships (Beck, 2020, pp. 13–15).

Table 3: Summary table of Blockchain

	Benefits	Applications	Challenges
Blockchain	• Security against manipulation (Hinckeldeyn, 2019, p. 2) • Decentralization (no intermediaries and no central authority) (Prinz et al., 2018, p. 312) • Simplification of administrative processes (e.g., smart contracts) (Hinckeldeyn, 2019, p. 2) • Transaction platform and database (tracking of objects, monitoring of origin, visibility and transparency) (Dujak & Sajter, 2019, p. 34) • Improved environmental footprint (digital documentation, ...) (Dujak & Sajter, 2019, p. 34)	• Documentation of tracking information retrieved from RFID (traceability, data verification) ((Hinckeldeyn, 2019, p. 47) • Demand forecasting (independence and security of information which makes demand forecasting reliable (especially important for FSC) (Dujak & Sajter, 2019, pp. 36–39) • Open Access (Blockchain takes over documentation and communication which is labor and cost intensive (Dujak & Sajter, 2019, pp. 38–39) • Open Access (reduces fraud and counterfeiting risk) (Dujak & Sajter, 2019, pp. 39–40) • Smart contracts (Dujak & Sajter, 2019, pp. 40–41)	• Scalability (Duan, Zhang, Gong, Brown, & Li, 2020, pp. 11–12). • Interoperability (Hinckeldeyn, 2019, pp. 48–50). • Social acceptance (Duan et al., 2020, p. 11) • Legal issues and data security (Duan et al., 2020, pp. 12–13). • Investment costs especially for smaller and medium sized companies (Duan et al., 2020, p. 12)

Table 4: Summary table of IoT

	Benefits	Applications	Challenges
Internet of Things (IoT)	• Storing and processing Big Data (Birkel & Hartmann, 2020, p. 4) • Real time information (Abdel-Basset, Manogaran, & Mohamed, 2018, p. 3) • Improved inventory management (Abdel-Basset et al., 2018, p. 3). • High scalability (Birkel & Hartmann, 2020, p. 4). • Identification and tracking technology (Da Xu et al., 2014, p. 2237) • Service management → information from multiple sources come together in a unified user interface (Da Xu et al., 2014, 2237 ff.).	• Practical application in three parts (field devices; backbone system; communication Infrastructure) (Da Xu et al., 2014, p. 2238). • Production: e.g., water productivity; plant disease control; poultry farms (Maulana, Lorena Br Ginting, Aryan, Restu Fadillah, & Nurajmi Kamal, 2020, pp. 105–107). • Processing: monitoring, traceability, and packaging (Maulana et al., 2020, pp. 107–109) • Distribution: warehouse management; distribution of processed products (Maulana et al., 109 ff.).	• Technical: data complexity, network structure, interoperability (Aamer et al., 2021, p. 2525) (Affia et al., 2019, p. 7) • Financial: difficult for low-scaled food companies, high investment sums only feasible in large companies (Aamer et al., 2021, p. 2527). • Social: functioning infrastructure for all stakeholders which all might have access to different amount of information (Aamer et al., 2021, p. 2528). • Operational: acquisition of hardware and infrastructure and integration in SC; regular maintenance (Affia et al., 2019, p. 6). • Educational: willingness of companies to adapt (Affia et al., 2019, p. 7) • (Aamer et al., 2021, p. 2529). • Governmental: external parties influence the implementation; not only financial incentives but also rules and regulations (Affia et al., 2019, p. 7). • (Aamer et al., 2021, p. 2530).

Table 5: Summary table of AI

<table>
<tr><th></th><th>Benefits</th><th>Applications</th><th>Challenges</th></tr>
<tr><td>Artificial Intelligence (AI)</td>
<td>
Increase in efficiency of processes (repetitive tasks can be performed in more economic ways; less mechanical work for humans; …) (Djeffal, 2019, p. 5)
Increased safety, e.g., self-driving cars; medicine and operations (Adriano et al., 2015, p. 4)
Elimination of cognitive biases → increase of rationality (Adriano et al., 2015, p. 4).
Standardization of products: costumer demands will be satisfied, better results for company, ... (Nadimpalli, 2017, p. 3).
</td>
<td>
Food production: e.g., in greenhouse environment due to predictions and actions taken by AI (Kollia et al., 2021, 15 f.)
Processing and classification: e.g., increase thoroughness of food classification; increase quality and safety; less contact with humans→ less risk of contamination (Chitrakar et al., 2021, p. 6).
Storage in storage Systems: temperature regulation in retail refrigeration systems --> influences perishability and therefor safety and quality, sustainability (Kollia et al., 2021, 16 f.).
Detecting of expiration dates and allergen labeling/ other nutritional Information (Kollia et al., 2021, 17 f.).
Identification of suitable and innovative suppliers → competitive advantage; recommendation of ideal candidates (Heinrich & Stühler, 2018, pp. 83–85).
Improvement of costumer-supplier relationship (Heinrich & Stühler, 2018, pp. 85–87).
Positive impact on resilience (detection of risks and scenario planning) (Modgil, Gupta, Stekelorum, & Laguir, 2022, pp. 138–140).
</td>
<td>
Continuous mprovement → results more difficult to predict, verify and track (Beck, 2020, p. 4).
Legal issues:

○ Data protection (Beck, 2020, pp. 7–12).
○ Assessment (self-learning, machine is never finished (Beck, 2020, pp. 7–12).
○ Liability or responsibility for damage caused by AI → electric person? (Beck, 2020, pp. 7–12).
○ Enormous potential for discriminiation (Beck, 2020, 11 f.).

Ethical issues: (Beck, 2020, pp. 13–15).

○ Skill skepticism about automated decisions of AI
○ Low creativity
○ AI oriented to moral values could be competitive advantage of European technology development
○ Job loss for repetitive tasks</td></tr>
</table>

5. Findings

This chapter presents the results of the expert interviews. The results are summarized in the following tables. The structure is similar to that of the theoretical part of the bachelor thesis. In addition, the tables compare the two companies directly so that similarities and differences become apparent.

Table 6: Summarized transcript of the FSCs of the interviewed companies

Subject area	Company 1	Company 2
Supply Chain structure	• Raw material dependent, e.g., cocoa: smallholders, pisteurs, transisteurs, local buying stations, shipping by traders and delivery	• Raw material, e.g., milk: around 1000 farmers mostly regional, packaging suppliers, herb suppliers, ..., delivery to 2-3 plants in Germany, production, logistics warehouse, forwarding agents • Customers: Food retail chains, restaurants, hotels, catering, processors
Effects of COVID-19	• Confectionery demand increased during crisis • No short-time work in production	• Uncertainty • COVID-19 was in the foreground, which is why many other issues came to a standstill • Production: no critical stations/teams were allowed to fail (e.g., milk delivery) • Supplier failures due to illness or economic issues • Delayed delivery times • Consumers are increasingly turning to branded products
Safety and Quality in FSC	• Safety precautions already in place to avoid cross-contamination, etc., e.g., training in food handling and focus on internal cooperation • Quality is set extremely high, as this is also associated with the	• Suppliers: strict process of how they are qualified • Multi-level hygiene concepts • Large QM department

	company, e.g. allocation of own best-before dates, which are always shorter than those of the manufacturer (ensuring the quality of the end product) • Audits and professional development projects	
Subject area	**Company 1**	**Company 2**
Safety and Quality Challenges	• Unlike the coffee market, no uniform standards in the cocoa market; therefore, alternative values such as the FCC standard framework are used • Products that bring changes in taste due to their natural heterogeneous nature (sun exposure, length of fermentation, ...) should always have the same taste in the final product	• Different standards, e.g., export to Asia, which limits apply to which ingredients • Products subject to refrigeration: Cold chain must be maintained • No long shelf-life dates make it challenging to ensure that products are always fresh as specified, not only in production, but throughout the supply chain • Plastics, packaging, films with food contact
Sustainability measures in the supply chain	• Measures are implemented • No further information, as this question was skipped	• Alternative raw materials to milk, as the biggest emissions are at the beginning of the supply chain • Start-ups offering plant-based alternatives to dairy products • 1.5°C target
Relationship between resilience and traceability to quality and safety	• Ability to change and adapt conflicts with resilience • Quality has the highest priority • Resilience measures are implemented but many things, such as harvest cycles, cannot be influenced • Enormous detection requirements at various stages of production to ensure there is no degradation of food quality and safety	• Traceability requirements are becoming more stringent • Batches must be identifiable in order to be able to intervene in a targeted manner in the event of disruptions • EU-wide "farm-to-fork" requirements are constantly evolving • Resilience as an economic issue in order to be able to react quickly to changes

		• Resilience here not so strongly linked with food quality and safety
Subject area	**Company 1**	**Company 2**
Specific resilience measures	• Differentiation between risk management and resilience • Risk management: short-term • Resilience can be both short- and long-term and requires knowledge or reasoned assumptions • Leading a very proactive and forward-looking risk management program, which is the same as risk management • E.g., alternative sourcing, suppliers, involvement in development of raw materials or of materials	• Do not become too dependent on suppliers, which in turn has an impact on costs • Production cycles are becoming shorter and shorter

Table 7: Summarized transcript of Blockchain application in the companies

Subject area	Company 1	Company 2
Blockchain Application yes/no	• Currently no use of Blockchain in purchasing (classic example would be in contract management)	• Currently no use of Blockchain in the company
(no) Analysis of possible Blockchain applications	• Yes, application areas have already been analyzed • E.g., international contract management, standardization of communication processes • However, there are also other standards or possibilities that fulfill these application areas • Especially COVID-19 has shown that framework agreements have a different validity and are sensitive, which is why framework agreements are still often concluded face-to-face	• Belief in technology exists in theory, but no / hardly any fields of application in the corporate context • Focus from strategic digitalization point of view, as essential advantage of Blockchain Supply Chain is there across, …
(no) Implementation Challenges	• Applicability in the company • Smart contracting requires standardized contracting; if this is the case, there are other ways to transmit them that are more established or simpler than Blockchain • Development of Blockchain is already advanced, which is why this technology is already integrated in many commodities	• … But this is also the biggest challenge, as all players must play along • Currently no economic incentives to cooperate • Blockchain applications are currently not yet ready for scalable operational use

Table 8: Summarized transcript of IoT application in the companies

Subject area	Company 1	Company 2
IoT Application yes/no	• Yes, the company works online-based, cloud-based, with decentralized data • The trend is towards a solely online application or web-based services, e.g., Microsoft 365 represented in almost all companies	• Yes, many sensors, barcodes, etc. in use, for example, for pallets, trucks • Goods flows are mapped into information flows (suppliers, internal logistics, production machines with sensors, energy flows, robots in production, ...) • Already integrated for a long time, otherwise the flow of goods cannot be mapped
(yes) IoT advantages	• Flexibilization and dynamization, so that data can be accessed worldwide • RFID as a tracking option; can be found above all in containers and the nature of the goods transported in them • Data collection, for example on hazelnut plants, to predict yields and other data or to adjust certain parameters that influence plant growth	• Real-time information • Inventory management • Integrity of goods and information flows • Scalability • Transparency • Traceability • IoT brings new opportunities, e.g., data that turns flows of goods into flows of information, which in turn is the basis for being able to work with Artificial Intelligence
(yes) IoT challenges	• Data security • Linking of data; a lot of data is collected, and it has to be coordinated which data is needed • Data handling and processing is time consuming • Rivalry when a company is part of multiple supply chains; with competitive interests, IoT applications add very little value with their variety of data	• Volume of information and data points to handle and link properly • Too much data brings security risks, such as hacker attacks • Managing hardware, software, understanding and acceptance of employees • Data protection is not an accelerator of technology

Table 9: Summarized transcript of AI application in the companies

Subject area	Company 1	Company 2
AI Application yes/no	• Yes, there are AI applications in the enterprise, around price forecasting (e.g., listed commodities); machine (experiential) learning • Algorithms for specific questions	• Yes, there are several projects • E.g., in production, where data from machines and chemical compositions of cheese are pooled to predict and prevent malfunctions, such as blockages • Data use by carriers to predict when product will arrive at the plant • Planning, such as how much cheese will be sold in the coming weeks and months • Predicting milk and energy prices
(yes) AI advantages	• Predictive maintenance • Planability is increased, which is enormously important in the food industry (quantities, prices, ...); this planability allows production processes to be adapted to it • AI measures can enrich the context for strategy planning	• General: problems are solved that cannot be solved by other means • Problems can be solved better than by humans alone; humans program and evaluate results • Extended predictability in the long term • Data and information flows take on greater importance
(yes) AI challenges	• Data access inter- as well as intra-organizational • It must be programmed what value is attached to the past, and how much it should affect the future (problems can occur during, e.g., pandemics) • Algorithms are programmed for specific issues and manually adjusted as needed • AI is rule-based, which means there must always be someone to teach and teach and interpret things • Need for ongoing empowerment • ethical challenges currently less important in purchasing area	• Similar to IoT • Hardware, sensors, collect data in the right quality and structure, processes, skills to work with the data, mindset to deal with change • Bringing data-driven world together with analog and physical world of cheese • Ethical and legal issues are not major problems now, but still need to be addressed

Table 10: Summarized transcript relationship between FSC and technologies

Subject area	Company 1	Company 2
Relationship between FSC characteristics and disruptive technologies	• Technologies are shaping the way people collaborate by providing new and different insights • People can access and control faster through technologies • Early warning signals from technologies influence quality, safety, and resilience	• Technologies encourage and require all supply chain players to be more process and data oriented • Disruption is not attached to a technology, but data orientation leads to keeping a finger on the pulse and becoming agile • Technologies can impact characteristics such as safety, quality, traceability, and transparency • The companies that can get more out of technologies have competitive advantages
Further disruptive technologies in the company	• Additive manufacturing to strengthen risk posture • Big Data, data analytics	• E.g., protein not just from dairy or plants, but protein produced by fermentation in the lab; when development gets to the point where this is mass-market ready, it is extremely disruptive to the business
Short and long-term tasks for the company to implement the technologies	• Raising employee awareness • Reflection that technologies are needed • Empowerment • Pilot projects to quickly demonstrate added value	• Create awareness and understanding of what the technologies can do • Translate technologies into everyday business and explain how the technologies relate to quality, safety, etc. • Create technical conditions • Focus on AI, as IoT is already quite widely applied and Blockchain is still very far away

6. Discussion

This chapter is concerned with linking and interpreting the results from the literature research with the results from practice obtained through expert interviews.

The results of the case study meet the criteria of validity, reliability, and objectivity. The results are valid because the interviews were conducted with subject matter experts from the business community who freely agreed to this. Reliability is ensured by a standardized questionnaire agreed upon in advance with experts. Furthermore, the results from the survey are also objectively reproduced. The fulfillment of the three criteria makes the results scientifically valid (Pfeiffer, 2018, pp. 1–6).

The secondary objectives "Elaboration of the characteristics of the food supply chain and the resulting challenges" and "Identifying the influence of COVID-19 on the food supply chain" were answered by literature review in chapter 3 "3. Food Supply Chain". The primary objectives of the thesis "Identifying the driving technologies in supply chains, describing challenges, trends, and their level of implementation" and "Examining which technologies are used in the food industry and their supply chains" were dealt with in chapter 4. The discussion will now examine the first primary objective and the level of practical implementation of the technologies.

6.1 Comparison of theoretical availability and practical application of Technologies

6.1.1 Blockchain in theory and practice

Blockchain technology scores among others with the advantages of decentralization (Prinz et al., 2018, p. 312), security of transactions and simplification of administrative processes (Hinckeldeyn, 2019, p. 2). Likewise, the literature review identified application areas such as demand forecasting (Dujak & Sajter, 2019, pp. 36-39) or the use of smart contracts (Dujak & Sajter, 2019, pp. 40-41).

Company 1 does currently not implement the Blockchain technology specifically in its business. However, the expert from the confectionery manufacturer also states that a classic application possibility is contract management in purchasing. The confectionery manufacturer has already analyzed possible applications, which could be in international contract management or the standardization of communication processes, for example. Nevertheless, according to the confectionery manufacturer, there are also other standards to fulfill these application areas. In addition, the expert of company 1 states that also through COVID-19, the sensitivity of framework agreements became clear, and therefore they are still often concluded face-to-face. The challenge for company 1 is the general application of the technology. Since smart contracting requires standardized contracting, there are other, simpler ways to identify them. It should also not be forgotten that Blockchain is already integrated in parts in commodities, but just do not have the name "Blockchain", but the name of the software.

Company 2, the cheese manufacturer, believes in this technology, but the company does not yet have any concrete application areas where this technology would bring added value compared to other systems. According to the expert, the main advantages of Blockchain come into play when this supply chain is applied across the board. This would mean that all players would have to "play along" and there are currently no economic incentives for this. This is also what the literature says, as interoperability is also cited as a key challenge here (Hinckeldeyn, 2019, pp. 48-50). In addition, the cheese manufacturer cites the scalability challenge, which is also listed in the subchapter “4.1.4 Challenges of Blockchain” (Duan, Zhang, Gong, Brown, & Li, 2020, pp. 11-12).

It can be concluded that Blockchain is a disruptive technology, and the benefits are equally well known to companies. Nevertheless, this technology still needs to be more easily applicable in companies to create an advantage over the technologies and systems currently in use. These circumstances mean that Blockchain is not yet being used in companies. Nevertheless, the future will show to what extent the Blockchain technology will be implemented by companies.

6.1.2 IoT in theory and practice

In addition to Blockchain, IoT also has several advantages to offer and is closely associated with the term "Big Data", as these systems generate and store large amounts of information about objects (Birkel & Hartmann, 2020, p. 4). Probably the most important advantage for the food industry, is the possibility of tracking and tracing given by IoT (Da Xu et al., 2014, p. 2237). Unlike Blockchain technology, IoT can be found in a wide variety of designs in the companies surveyed, to track deliveries by RFID tags or to monitor growth processes by sensors, for instance (Maulana et al., 2020, p. 109).

According to company 1, IoT brings advantages such as flexibilization and dynamization of data so that it can be accessed worldwide. As with many companies, RFID technology is mainly used in containers and in the procurement of transported goods. But also, as described in the chapter "4.2 Internet of Things", the confectionery manufacturer also uses the sensors, for example, to collect data from the hazelnut plant to estimate future yields or to regulate certain parameters that influence plant growth. According to the company 1 expert, the main challenges of IoT technology are data security and data linkage. In addition, he says, data handling and processing is time-consuming. Lastly, the confectionery manufacturer also cites the issue of rivalry between companies, which makes IoT applications less attractive, or useful, as competitive interests mean that data should not be equally available to all members of the supply chain.

The cheese producer, company 2, also uses IoT, emphasizing the variety of applications that can be counted among it. Sensors, barcodes, and many other solutions to generate and store data are in use at company 2, especially in the logistics area for pallets or trucks.

The expert emphasizes that through IoT flows of goods are mapped into flows of information, and the IoT application has been integrated in the company for a long time, otherwise the flows of goods cannot be mapped sufficiently. The cheese manufacturer cites benefits such as real-time information, inventory management, integrity of goods and information flows, scalability, transparency, and traceability. Many of the benefits mentioned by Company 2, such as transparency generated by IoT, traceability, and inventory management, are just as described in the literature (Birkel & Hartmann, 2020, p. 4). In addition, expert 2 mentions that the data generated from IoT creates an important foundation for Artificial Intelligence that works and learns based on data (Birkel & Hartmann, 2020, p. 4). The challenges associated with IoT overlap in many ways with the candy maker, as well as the literature. Expert 2, like expert 1, cites that it is a challenge to properly process and link the volume of information and data points. Similarly, the cheese manufacturer reports that a lot of data, always comes with an increased security risk and data protection is also not an accelerator of this technology. In addition, the acceptance and understanding of the company's employees must always be strengthened. This thesis also emerges from the literature, where not only the acceptance of the employees, but also of the company as a whole is required (Affia et al., 2019, p. 7).

IoT is the application within the three technologies studied that has been in use in most companies for several years to satisfy basic needs such as the tracking of flows of goods and the generation of real-time data. Data security, privacy, and data complexity and processing are challenges for the surveyed companies, as also described earlier in the theory (Aamer et al., 2021, p. 2525). While the technology is not the most recent, it is still conceivable that this technology will create an important foundation for other disruptive technologies due to its power to generate important data.

6.1.3 AI in theory and practice

Artificial Intelligence differs from the two aforementioned technologies in the different benefits and risks that this technology brings, depending on the area of application. While IoT is widely used in the enterprise environment, AI has applications far beyond that, such as in the healthcare sector, self-driving cars and many more. As a result, while benefits and challenges can be found in large numbers in the literature, they often relate to different applications. Basically, however, it emerged from the literature that an increase in efficiency through AI can be noted especially in repetitive tasks (Djeffal, 2019, p. 5). Moreover, cognitive biases, which are quite automatic due to human influence, can be eliminated by AI (Adriano et al., 2015, p. 4).

The confectionery manufacturer, company 1, is already using AI in purchasing for price forecasting, for example. Similarly, algorithms are in use for certain specific questions. For the confectionery manufacturer, AI applications increase the company's ability to plan, which is very important in the food industry when it comes to quantities and prices. The AI measures can enrich the context on which strategic planning is based. Challenges are posed for Company 1 to optimize programming for their needs. While programming itself is not too much of a hurdle, it is necessary to determine what value is placed on the past and how it should impact the future. An example of this is the COVID-19 pandemic. In addition, there is always a need for a human component that teaches the AI application things and interprets them. Ethical challenges do exist and bring potential for discussion, but these are currently less relevant in purchasing. Also found in the literature is the challenge of continuous improvement, adding that this constant change that comes from learning makes results more difficult to compare (Beck, 2020, p. 4). While ethical and legal challenges are very present in the literature and relate to different application areas of AI, they do not yet play a predominant role in Company 1, as there is currently no issue for this in purchasing.

Just like the confectionery manufacturer, company 2, the cheese manufacturer also finds application areas for AI for certain issues and problems. Just as with Company 1, AI technology provides prediction that can be helpful in avoiding potential problems. For example, it predicts milk and energy prices, or cheese sales in the following weeks and months. This leads to increased predictability, as also mentioned by Company 1, and furthermore, it can solve problems that cannot be solved by other means. Challenges are for the cheese manufacturer like IoT, to collect the data in the right quality and structure, as well as to strengthen the mindset of the employees for this change. There are currently no ethical and legal challenges for cheese manufacturers in its use cases, and yet, according to expert 2, it is important to address them.

Company 1 and company 2 are very similar in their statements about benefits and challenges related to AI. Increased predictability and price forecasts are the most important benefits for the companies, and yet for both companies it is important to constantly train the algorithms, as well as the employees who enable them, to be able to draw benefits from the application. Ethical and legal issues are not yet a major topic in the corporate context of the companies surveyed, and yet they are being addressed.

In summary, the companies are similar in some answers and views. Regarding the literature, there is also a lot of overlap, especially when it comes to the extent to which new technologies can positively influence the aspects of food safety and quality, as well as traceability. Since IoT and AI are already in use in both companies, it remains exciting, especially for the future, whether and to what extent this technology can be integrated in the mass of companies.

7. Conclusion

As a company, dealing with new technologies is indispensable in the 21st century. The supply chains of the food industry offer particular potential due to their specific characteristics and requirements. These characteristics, as well as blockchain, IoT, and AI technologies, were considered and related in this thesis.

Most food supply chains have a high demand for food safety, quality, and sustainability. The perishable nature of food is one of the reasons that a high level of food safety is necessary to provide consumers with the best possible quality. Due to global population growth and finite resources at the same time, sustainability is also an important characteristic of FSC. Traceability offers the ability to trace goods from farm-to-fork, providing transparency to the company and consumers. Together with resilience, traceability provides tools to meet the quality, safety, and sustainability requirements of companies.

The food industry was heavily impacted by COVID-19. While food was essential during the crisis, there were sometimes shortages of certain product categories due to various factors. Food safety, which was also a high priority before COVID-19, also came back into focus.

In addition to other disruptive technologies, the technologies Blockchain, IoT and AI were examined in more detail. Blockchain finds many supporters in theory, who see high potential in the supply chain, especially through the security aspect and smart contracts. However, the expert interviews with companies in the food industry did not have Blockchain application yet and pointed out the difficult practical applicability, low scalability and other technologies and systems that are alternatives to Blockchain use so far. IoT is closely related to traceability, whereby using various sensors, flows of goods are converted into flows of information, generating a large amount of data, and ensuring transparency in the supply chain. The real companies surveyed have also been using this technology for several years, especially in transport logistics. However, data generation always requires data to be processed and used to gain value from it. AI and machine learning could unleash enormous potential in many companies, but also present them with challenges. Using data, among other things generated by IoT, AI can present solution approaches to specific problems. According to the literature as well as experts, forecasts can be made, which in turn lead to increased predictability. While the literature mainly mentions ethical and legal challenges, in practice it is often the skepticism of employees and their acceptance that will initially train companies.

This paper provides a theoretical and practical insight into the possibilities of implementing new technologies in the food supply chain. Likewise, this work can provide new insights into the subject in both academic and corporate settings.

The survey of the two companies, is mainly to provide references to the theory in the work and to look at the real business world. Due to the limited amount of time for the bachelor thesis, two companies were surveyed. Limitations of the case studies are the small number of interviewed companies, which is why the results cannot be projected to all companies in the food sector. Furthermore, the industries of the surveyed companies and especially their products are very different, which on the one hand leads to different insights, but equally cannot be blindly transferred to other industries. It must also be emphasized that both companies are German, and therefore no conclusions can be drawn about companies outside Germany. Due to the explorative approach of the case studies, the focus was placed on a qualitative content analysis. This leaves room for future research in the context of a more in-depth qualitative study that considers a larger number of companies.

In conclusion, the technologies Blockchain, IoT and AI can have a major impact on food supply chain characteristics such as quality, safety, sustainability, traceability, and resilience. However, the extent to which the broad mass of companies has implemented the three technologies and whether the technologies will have the same value in the future as they do today remain an open question.

Appendix

Figure 10: Questionnaire Expert Interview

COMILLAS
UNIVERSIDAD PONTIFICIA
ICAI ICADE CIHS

ESB
BUSINESS SCHOOL

Expert Interview Bachelor Thesis

Disruptive technologies in food supply chain management. A Multi-Case study for the analysis of drivers, challenges, and opportunities.

Part 1: Food Supply Chain

1. Please explain to me the rough structure of your supply chain (suppliers, raw material, intermediaries, transport routes, means of transport, retailers, ...).
2. What impact did the Corona pandemic have on your company, especially in terms of production and supply chain (e.g., food safety, delayed delivery times, short-time work, consumer behavior, ...)?
3. What is the role of quality and food safety in the company and how can this be seen in the supply chain?
4. What challenges do you face as a company when it comes to quality and safety in the FSC (e.g., global supply chains and different standards and norms, ...)?
5. What measures are implemented towards more sustainable production and supply chain management (ESG criteria, circular economy, energy saving measures, packaging, fairness, ...)?
6. Do the variables "resilience" and "traceability" in your supply chain influence the critical characteristics (quality and safety) from question 3?
7. Are there specific resilience measures that make your supply chain more resistant to disruptions?

Part 2: Disruptive Technologies

(1) Blockchain

8. Is there a Blockchain application in your company's value chain? If yes, in which area?

No	Yes
9. Have you or colleagues already dealt with the topic and analyzed possible applications in your company?	10. What **advantages** does the Blockchain bring to your company (e.g., security, increased efficiency, traceability, automation of business processes (smart contracts), ...)?
11. What is currently preventing you from using this technology? What are the challenges you face?	12. What **challenges** do you face (scalability, interoperability, social/business acceptance, technical barriers, skills shortages, legal issues, ...)?

(2) Internet of Things

13. Is there an IoT application in your company's value chain? If yes, in which area?

No	Yes
14. Have you or colleagues already dealt with the topic and analyzed possible applications in your company?	15. What are the **benefits** of IoT technology for your company (data mining, real-time information, inventory management, scalability, transparency, traceability, ...)?
16. What is currently preventing you from using this technology? What are the challenges you face?	17. What **challenges** do you face (technical (data complexity, skilled labor, interoperability, ...), financial, social, operational (hardware and infrastructure), educational (readiness of the company to implement this technology), legal (rules and regulation), ...)?

(3) Artifical Intelligence

18. Is there an AI application in the value chain of your company? If yes, in which area?

No	Yes
19. Have you or colleagues already dealt with the topic and analyzed possible applications in your company?	20. What are the advantages of AI technology for your company (e.g., increased efficiency, security, standardization, ...)?
21. What is currently preventing you from using this technology? What are the challenges you face?	22. What challenges do you face (e.g., ethical, legal, ...)?

Part 3: Connection of disruptive technologies and food supply chain

23. Do you see a connection between the characteristics of the supply chain (quality, safety, traceability, ...) and the applications of disruptive technologies in your company? Are there any concrete successes in this regard?
24. Are there other disruptive technologies that you apply in your company in the supply chain?
25. What are short- and long-term tasks in your company to successfully implement new technologies in the FSC?

Declaration of Originality

I hereby declare that I have prepared this thesis independently and without outside assistance. Text passages, which are based literally or in the sense on publications or lectures of other authors, are marked as such. The work has not yet been submitted to any other examination authority and has not yet been published.

Madrid, 29.03.2023

Luisa Häußler

Luisa Häußler

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