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# Blockchain and Internet of Things enabling the United Nations Zero Hunger goal: A decentralised digital marketplace for surplus food redistribution via Social Supermarkets

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# Author's Declaration of Originality

I here declare that, to the best of my knowledge and belief, this Master Thesis titled: ¨Blockchain and Internet of Things enabling the United Nations Zero Hunger goal: A decentralised digital marketplace for surplus food redistribution via Social Supermarkets¨ is my own work. I confirm that each significant contribution to and quotation in this thesis that originates from the work or works of others is indicated by proper use of citation and references.

Tallinn, Estonia.

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This thesis is written in English and is one hundred and eighteen (117) pages long, including seven (7) chapters and nine (9) appendices.

# Abstract

Do you have food at home? Many not. Currently, there are still more than one billion people suffering from chronic hunger, and paradoxically the third part of the food produced is lost or wasted. The paradox of food waste amidst food poverty has attracted much public concern. The United Nations Sustainable Development Goals (SDGs) aimed at creating a more sustainable future. These goals seek to solve issues such as hunger, poverty, environmental degradation, and climate change by 2030. While this deadline may be ambitious, one area of focus which can have a significant impact on the achievement of these goals is the surplus food redistribution to alleviate poverty and hunger.

Nevertheless, Charity Organisations face different challenges to increase their operational efficiency to manage decentralised coordination among the stakeholders, the unpredictability of surplus food supply, comply with traceability requirements and deliver food products with quality and freshness within a limited time.

This thesis explores how blockchain and Internet of Things can shift a fragmented and unstructured food donation chain into a collaborative, transparent and accountable system. This study has been performed by conducting a holistic single case study of the Austrian social supermarket model. This thesis is based on a qualitative study where content analysis technique and semi-structured interviews were used as data collection methods.

The results of this research cast a new light on the understanding of the operating model of the Austrian social supermarket concept from a systems engineering perspective, which shows that it is an effective intermediary tool to capture and deliver sustainability value. It also shed light on what capacities blockchain and Internet of Things can enable in the food donation chain, such as increasing its visibility capabilities, inter-organisational collaboration, implementation of sustainable supply chain practices and others.

A decentralised digital marketplace powered by the blockchain analytics and Internet of Things features is proposed to address one of the most challenging issues for surplus food redistribution which is to match the offers and food demands between donors and social supermarkets. This study contributes to providing an integrated guide of what technological components, practices and tools can be implemented to build a digital transformation strategy for the food donation chain that can lead to enabling the UN Zero Hunger goal.

**Keywords:** United Nations, SDGs, Zero Hunger, Social Supermarkets, Surplus food redistribution, Blockchain technology, Internet of Things, Decentralised Digital Marketplace, Blockchain Analytics

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## Abbreviations

| | |
|---|---|
| SDGs | The Sustainable Development Goals of the United Nations |
| UN | The United Nations |
| GDP | Gross Domestic Product |
| EU | European Union |
| USAID | United States Agency for International Development |
| IoT | Internet of Things |
| FAO | Food and Agriculture Organisation |
| B2B | Business to Business |
| B2C | Business to Consumer |
| FBO | Food Business Operators |
| RO | Redistribution Organizations |
| CO | Charity Organizations |
| FEBA | The European Federation of Food Banks |
| RL | Reverse Logistics |
| CLSC | Closed-loop Supply Chain |
| VAT | Value Added Tax |
| SSMs | Social Supermarkets |
| OECD | Organisation for Economic Cooperation and Development |
| NGO | Non-Government Organisation |
| RFID | Radio Frequency Identification systems |
| EVM | Ethereum Virtual Machine |
| DLT | Distributed Ledger Technology |
| ECR | Efficient Consumer Response |
| WSN | Wireless Sensor Network |
| GPS | Global Positioning System |
| GIS | Geographical Information System Mapping |

# 1 Introduction

The scale of food losses and food waste globally is unprecedented. According to the Food and Agriculture of the United Nations, it estimates that every year 1.3 tonnes of food is lost or wasted, which accounts for the third part of the food produced (FAO 2015). Food loss and wastage also amount to a major squandering of resources, including water, energy, labour and capital, as well as, to produce greenhouse gas emissions and carbon footprints, which contribute to global warming and climate change (FAO 2015).

On the other hand, paradoxically, hunger is a social pressing global issue nowadays. According to USAID, it is estimated that almost 1 billion people suffer from chronic hunger. Notably, children are suffering from severe malnutrition who are nine times more likely to die. Hunger costs developing countries around $ 450 billion per year in loss of GDP, and hunger is one of the root causes of social conflicts, such as violence, civil conflict, rioting and others (USAID 2015). Furthermore, it is estimated that the global population will grow over 30% by 2050, which implies an increasing demand for food, and thus, a need for food production will increase by 70% (USAID 2015).

The paradox of food waste amidst food poverty has attracted much public concern. The United Nations since 1992 has pursued, as part of the strategic goals, the design and implementation of policies and actions to fight against hunger, poverty and waste, under its plan of action for sustainable development at the Earth Summit in Rio de Janeiro, Brazil. From 2015, all these goals are part of the integrated agenda called SDGs (United Nations 2018). The Sustainable Development Goals (SDGs) are 17 key objectives, accepted by all United Nations Member States (UN), aimed at creating a more sustainable future. These goals seek to solve issues such as hunger, poverty, environmental degradation, and climate change by outlining strategies to globally improve health and education, reduce inequality, and urge economic growth (United Nations 2018).

The United Nations aims to have these goals entirely implemented by the year 2030 (United Nations 2018). While this deadline may be ambitious, one area of focus which can have a significant impact on the achievement of these goals is the surplus food redistribution to alleviate poverty and hunger.

Food donations have acted as the source to limit the generation of surplus food by redistributing it to Charity Organisations (Schneider et al. 2015). Food Banks and Social Supermarkets have served as back-line and front-line charity organisations to collect and redistribute surplus food to socially endangered people, alongside to provide economic and environmental benefits across the food supply chain (Schneider et al. 2015).

Although food donation is a growing phenomenon, it still represents a small fraction of surplus food of the overall edible food in the European Union. In 2016, the European Federation of Food Banks

(FEBA) distributed 535 000 tonnes of food to 6,1 million people, which represents a small fraction of the food wasted annually in the European Union (European Commission 2017).

The food donation process faces different challenges since it is less structured and less organised than the typical food supply chain (De Boeck et al. 2017). According to (Holweg, Lienbacher, and Zinn 2010), one of the challenges of food donation is that the activity of Charity Organizations takes places in the last stages of the supply chain, particularly at the distribution and consumption stages. Consequently, the implementation of sustainable practices is vital to deal with the return, reallocation and waste disposal of foodstuffs, such as reverse logistics and Closed-Loop Supply Chain design (CLSC) (Holweg, Lienbacher, and Zinn 2010).

Other factors that make the food donation process challenging to manage are the complex decentralised coordination among donors, contributors and receivers (Defourny and Borzaga 2018; Holweg, Lienbacher, and Zinn 2010); the need of implementing food traceability systems and procedures to comply with regulations at the local and regional level (European Union 2013), as well as, the unpredictability of surplus food supply to plan the necessary resources for food redistribution such as transportation, storage and labour (Defourny and Borzaga 2018). What is more, the importance of factors like food safety, quality and freshness within limited time make the donation process in the food supply chain complex and challenging to manage (Defourny and Borzaga 2018; Holweg, Lienbacher, and Zinn 2010).

Blockchain technology has proved to be a technological innovation that ensures the reliability, traceability and authenticity of the information shared across the supply chains (Nikolakis et al. 2018; Saberi et al. 2019). Notably, several studies have shown the efficient implementation of closed-loop design using Internet of things and blockchain technology, such as (Kouhizadeh et al. 2019; Rezaee 2019; Saberi et al. 2019; Tian 2016).

Prior studies evaluating the applicability of blockchain technology and Internet of Things observed consistent results on their traceability benefits in the food supply chain (Behnke and Janssen 2020; Galvez et al. 2018; Pearson et al. 2019). However, these studies have not provided insights into the context of the food donation chain, which particularly touches aspects of food recovery, food reallocation and variability of the food supply. Even more, the study of concepts and frameworks regarding food waste management and sustainable supply chain practices have been studied individually by researchers of their domain.

At this stage of the research, the preliminary literature review has been conducted identifying the following aspects: (1) the concept of social supermarket has shown promising potential to complement food aid programs for surplus food redistribution to address the core causes of food insecurity and hunger (EU Fusions Project 2014). (2) Social supermarkets require the optimisation of processes and systems so as this model can be replicated across the rest of EU members (EU Fusions Project 2014). (3) one of the most critical challenges for surplus food redistribution is the adoption of sustainable supply chain practices for both donors and Charity Organisations (Holweg and Lienbacher 2011). (4) blockchain technology and Internet of Things have the potential to move Charity Organisations to the next level of operational efficiency, leverage the emerging digital supply chain models, and provide the information flow across the surplus food redistribution process.

This study aims at providing an integrated framework that guides in the adoption and implementation of blockchain technology and Internet of Things to support the food donation process by answering the following research question:

> How can blockchain technology and Internet of Things enable the UN Zero Hunger Goal by supporting the surplus food redistribution through Social Supermarkets?

The research was performed following a holistic single case study approach in software engineering. Document analysis and individual semi-structured interviews with experts were used as the main techniques for data collection. The research explores the blockchain and Internet of Things potential, identifies practices, tools and incentives for adoption to increase the operational efficiency of the surplus food redistribution between retailers and social supermarkets in the European Union.

The thesis is laid out in 7 chapters. The thesis begins this process by outlining the theoretical framework in Chapter 2. This chapter begins with an analysis of the current literature review and theories. At the end of this chapter, the research propositions are formulated and presented in chapter 3. Chapter 3 presents the research methodology, research propositions, data collection and data analysis methods used to conduct this thesis. Chapter 4 analyses the case of study of Social Supermarkets (SSMs) in Austria from a systems engineering perspective. This chapter comprises three main sections, it starts with the background, followed by the case description, including the operating model, logistics, business process identification, legal context and information management requirements. Finally, the case is analysed using two methods, a structured methodology to determine what blockchain architecture is suitable for the food donation process, and secondly, the use of an engineering framework called blockchain sustainability canvas to identify the impact and incentives for adoption. Chapter 5 analyses the findings from experts' consultations regarding practices and tools for the adoption and implementation of blockchain and Internet of Things in the food donation chain. Chapter 6 discusses the findings and introduces a conceptual design of a decentralised digital marketplace for the food donation chain using blockchain technology and Internet of Things. Finally, chapter 7 concludes and provides recommendations for future research.

## 1.1 Problem Statement

Surplus food redistribution via donations is one of the best solutions to alleviate hunger and to achieve the integration of environmental sustainability with economic benefits (Schneider 2013). Nonetheless, the food donation chain has shown to be more fragmented and less structured than the typical food supply chain (De Boeck et al. 2017). The food donation process requires an active collaboration of multiple stakeholders, as well as to comply with requirements, enforced by law, to ensure the conditions of food hygiene and food safety. On the other hand, the increasing implementation of sustainable practices to achieve the Corporate Social Responsibility argument in the retail sector, alongside with the emerging digital supply chains are factors that could impact food donations if Charity Organisations do not increase their operational efficiency.

Blockchain technology and Internet of Things can transform the fragmented donation process into a collaborative, transparent and accountable ecosystem. The combination of properties of both technologies can enable the logical and physical traceability of foodstuffs, administer the food donation agreements, as well as tracking the implementation of social programs, which are managed in coordination with government agencies. Nonetheless, there is not any framework that guides the adoption and implementation of blockchain technology and Internet of Things in the context of the food donation chain.

This thesis aims to fill this gap in developing an integrated guide for the adoption and implementation of a sustainable blockchain-based solution with Internet of Things for the food donation process. It is expected that the use of this guide in practice enables the achievement of the UN Sustainable Development Goals 2 and 12.3, which aim to end all forms of hunger and malnutrition and to set sustainable production and consumption patterns, respectively.

## 1.2 Research Objectives

This research seeks to contribute to the existing literature of blockchain technology and Internet of Things for sustainability, food waste management and food supply chain management. The guide resulted from this thesis can be used as a reference to define a digital transformation strategy for surplus food redistribution (food donations) considering three factors: the inter-organisational collaboration of multi-stakeholders, the principles of closed-loop supply design, and the adoption of blockchain technology and Internet of Things. This guide provides insights into the social supermarket model in Europe and the tools to implement a technological solution to increase the operational efficiency for the food donation chain using blockchain technology and Internet of Things. Consequently, this guide can be useful to the United Nations, social entrepreneurs, policymakers and any actor involved in the food donation chain. The objectives of the study are:

1. Examine concepts and frameworks of sustainable practices for redistribution of surplus food between retailers and social supermarkets within the European context.
2. Analyse the requirements of the Social Supermarket model from a systems engineering perspective.
3. Analyse the impact of the implementation of a blockchain-based solution, sustainable practices in terms of traceability and inter-organisational collaboration for the food donation process between retailers and social supermarkets.
4. Present a comprehensive description of how blockchain technology and Internet of Things can be applied in the food donation process between retailers and social supermarkets.
5. Design an integrated guide that describes the best practices and methods for the adoption and implementation of a blockchain-based and Internet of Things solution for the food donation process that enables the Zero Hunger of SDGs.

## 1.3 Context

Blockchain technology is a revolutionary innovation in decentralised information management with the capability to transform existing systems into a more transparent, collaborative, distributed and secure systems (Saveen A. Abeyratne and Radmehr P. Monfared 2016). It was first created to manage currencies and digital assets, and, in the last decade, it has identified that its properties can be applied to new and different use cases and applications (Saveen A. Abeyratne and Radmehr P. Monfared 2016).

Blockchain technology has shown promising potential to generate economic value in many use cases of different sectors, including agriculture, government, business, distribution, energy, food, finance, healthcare, manufacturing, transport and logistics, and others (Kumar and Mallick 2018).

Some studies observed the electrical power consumption as a source of concern, since Proof of Work, the consensus mechanism used by the first blockchain network, requires much computational power to verify the transactions (Agung et al. 2019). However, blockchain technology has evolved leading to the emergence of new consensus mechanisms to address this issue in a fully public decentralised system, such as Proof of Stake and others (Agung et al. 2019). Additionally, it led to the design of new and specialised blockchain frameworks providing flexibility in terms of permissions and decentralisation to increase their performance (Rauchs and Hileman 2017), and they require less computational power and provide higher scalability (Carson et al. 2018).

Recently, blockchain technology has raised attention to shift towards the appropriation of use cases to tackle global challenges with a social and environmental focus (Kewell et al. 2017), positioning blockchain as a ‘green technology’ (Imbault et al. 2017).

Key organisations such as the United Nations are actively seeking to take advantage of the blockchain capacity for achieving the SDGs, for instance, blockchain technology has been studied to meet the information management requirements for identity provision and financial inclusion (Kewell et al. 2017).

Blockchain technology can play an important role to reduce energy and resource consumption. It can securely manage energy generation data, energy supplier and demand data records, condition maintaining of the utility, pollution control in smart cities solutions, water management data, and others (Saveen A. Abeyratne and Radmehr P. Monfared 2016).

Blockchain technology has also been used to solve societal challenges such as digital identity solutions to provide significant improvement in terms of security and decentralisation. For instance, blockchain technology can be used to enable voting systems to authenticate the voting process and calculate the result of the elections in real-time (Saveen A. Abeyratne and Radmehr P. Monfared 2016).

On the other hand, blockchain infrastructure can be a critical technology to underpin the further development of other technological solutions such as the Internet of Things (Imbault et al. 2017). Blockchain infrastructure can support the interoperability requirements of sensors for Internet of Things, such as peer-to-peer networking (PPN), distributed file systems and Autonomous Device Coordination (ADC) (Imbault et al. 2017). Blockchain technology and Internet of Things can digitally transform the logical and physical movement and traceability of goods. They also can enable the inter-organisational collaboration in the supply chain management in the manufacturing industry, food industry, and potentially for food donations management, which this latter is the subject of this study.

# 2 Literature Review

This section aims to provide an overview over the existing literature of the research concepts of this study. The literature review includes the following topics: surplus food management, sustainable supply chain practices for product recovery, blockchain properties and their classification, and the state of the art of blockchain technology and Internet of Things in the food supply chain. At the end of this section, the research gaps in the literature are summarised, and the theoretical framework to perform this thesis is introduced.

## 2.1 The entwining challenges of food security and surplus food management

The first recognised crisis that led to severe hunger in many countries was in the early 1970s (Margulis 2013). A shortage of wheat caused panic to the international market and scrambled to secure supply chains (Margulis 2013). Since then, the term food security was incorporated into the international policy to create new instruments to eradicate hunger (Margulis 2013).

The term food security was originated in the World Food Conference in the mid-1970s, which was defined in terms of food supply to ensure its availability and price stability at the national and international level. Food security was defined as the *"Availability at all times of adequate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuations in production and prices"* (FAO 2006).

Nevertheless, the term food security has evolved, reinforcing its multidimensional nature. Nowadays, it includes dimensions of food access, availability, price stability, food use, and recently, the ethical and human rights dimension (FAO 2006; Lambie-Mumford 2016). The term right to food was not a new concept; however, in 1996, it was formally adopted the Right to Adequate food, pointing the way towards the approach of food security based on human rights as an international norm (FAO 2006).

According to (Galli et al. 2018), food insecurity, alternatively named food poverty, also touches on other dimensions such as nutrition insecurity. (Galli et al. 2018) refers to household food poverty either as the inability of people to acquire or consume adequate or sufficient food in socially acceptable forms, or the uncertainty to acquire food because of poverty or low income (Galli et al. 2018).

Parallel to the increased visibility of food insecurity as a global issue, many food poverty initiates have also evolved including large-scale food recovery organisations and networks seeking to reduce and valorise surplus in food systems (Galli et al. 2018). Surplus food consists of finished food products, food ingredients, and partially formulated products that may arise at any stage of the food production and distribution for a variety of reasons (European Commission 2017).

In the last years, the mobilisation of the management of surplus food has been connected with food waste management guidelines and regulations with the dominant vision to recycle, recovery and redistribute materials, shifting towards a more sustainable resolution of environmental, social, and economic impact (Mourad 2016).

Food waste management has shown a significant contribution to sustainable development. Frameworks and concepts of food waste management have been developed based on the notion that ‘waste’ can be a ‘resource’ (Papargyropoulou et al. 2014). This conceptualisation has increased the number of studies in the domains of industrial ecology, circular economy and waste management, addressing food waste through a 'hierarchical' concept often used as the 3Rs: reduce, re-use and recycle (Mourad 2016).

Meanwhile, the 3Rs framework was adopted in many Asian countries including Japan, the waste hierarchy framework was introduced into the European policy in the 1970s, and nowadays it has been widely accepted in other many countries worldwide (Papargyropoulou et al. 2014). The waste hierarchy framework goes from: (1) waste prevention, (2) preparing for re-use, (3) recycling, (4) other recovery (such as Energy recovery), and (5) waste disposal (Official Journal of the European Union 2008). The food waste prevention is the preferable option, ahead of separate collection and different treatment options.

The integrated framework for the management of surplus and waste management across the food supply chain developed by (Papargyropoulou et al. 2014) conceptualises food waste, and it applies the waste hierarchy in the context of food.  It starts from the first priority that is the prevention of the overproduction and oversupply of food beyond human nutritional needs along the supply chain, considering only the production of the necessary amount of food to safeguard food security and for covering the global nutritional needs. It involves that at the stages of consumption and retail is only supplied the necessary food and addresses unsustainable consumption patterns (Papargyropoulou et al. 2014).

Food waste prevention targets the optimisation of processes and systems to avoid the generation of surplus food across the food supply chain. Some methods to prevent food waste have been already discussed in the literature. Methods such as the improvement of agricultural infrastructures, more efficient storage, improve the transportation, distribution techniques and increase knowledge and technical skills (Papargyropoulou et al. 2014); as well as, changing aesthetic criteria on what good fruit and vegetables are in order to modify the social and cultural expectations (Mourad 2016); and others.

Once all the methods for food waste prevention are exhausted, one crucial decision is to identify if the surplus food is fit or not fit anymore for human consumption. If food is still fit for human consumption, it can be redistributed for people affected by poverty through food banks, networks, and others; otherwise, it becomes waste. At that point, it is crucial to identify if the food waste is avoidable or unavoidable for disposal. If it is waste avoidable for disposal, it can be recycled into animal feed or through composting as a second alternative. If the recycling efforts have been exhausted, the following option is to treat food waste with energy recovery such as anaerobic digestion. Finally, waste disposal in landfill is the last option when food waste is unavoidable (Papargyropoulou et al. 2014). Figure 2 illustrates the food waste hierarchy developed by (Papargyropoulou et al. 2014).

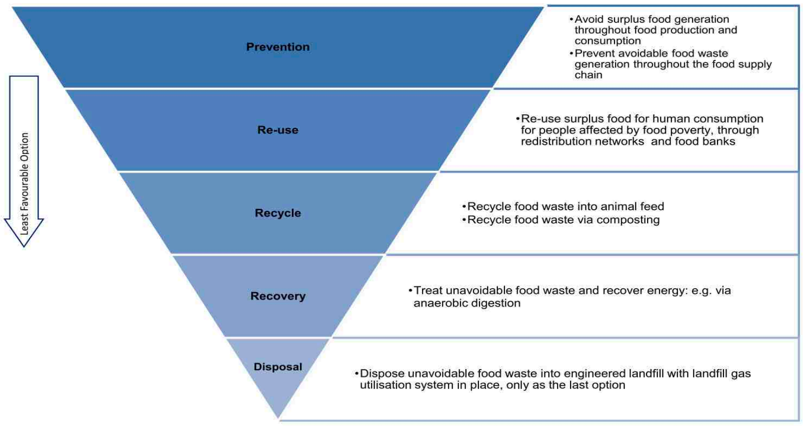


**Figure 2.1** The food waste hierarchy. Source: (Papargyropoulou et al. 2014).

Food loss and food waste can happen at different stages of the supply chain and are caused by different driving forces (Gustavsson et al. 2011). In low-income countries these causes are associated with the technical, financial and managerial limitations in harvesting techniques, infrastructure, packing, storage conditions and transportation; whereas, in medium and high-income countries are connected with the consumer behaviour, inadequate purchase planning and the lack of coordination of the stakeholders during the supply chain (Gustavsson et al. 2011).

Therefore, the developed world plays a significant role to improve the purchase planning and increase the coordination to redistribute the surplus food that is still suitable for human consumption. Surplus food redistribution for a charitable purpose is a well-established practice, particularly in European retail (Hermsdorf et al. 2017). The retail sector generates large amounts of food surpluses in specific and limited locations offering a unique opportunity for the implementation of policies and strategies to limit food waste and surplus food (Albizzati et al. 2019). For instance, in France, all retail outlets larger than 400 square meters are required by law to distribute surplus food that is suitable and safe for human consumption to Charity Organisations (Albizzati et al. 2019). At the same time, in France, retailers can benefit by receiving a tax credit corresponding to up to 60% of the value of the stock value of the foodstuffs, including storage and transportation (Albizzati et al. 2019).

Food rescue programs have been established since the late 1960s with the emergence of Food banks in the United States of America in response as an emergency intervention, while people in need await the support of the welfare state. Food banks are organisations that request, collect, store and redistribute food surpluses to families in poverty or at risk of poverty. Food banks collect products from a variety of sources, including farmers, wholesaler retailers, and others. The delivery of food donated is through charitable human service agencies that serve as front-line organisations (Schneider 2013).

Although food banks have evolved as large professional scale distribution centres, the ethnographic study conducted by (van der Horst et al. 2014) noted that the interactions between receivers with Food banks lead to emotional reactions such as shame and anger, which can be harmful to the self-esteem of receivers.

Besides, the study conducted by (van der Horst et al. 2014) revealed that receivers can have a sense of social status position as a stigma for their situation connected with being lazy, poor, crazy, or socially weak. Another finding in this study is that food banks operate with specific rules of interaction between volunteers that creates a certain sense of distancing. In contrast, some clients in soup kitchens experienced a sense of acceptance and social network owing to the interaction with volunteers (van der Horst et al. 2014).

Currently, the food assistance ecosystem encompasses multiple and diverse range actors such as suppliers, soup kitchens, food pantries, shelters, school nutritional programs, religious organisations, volunteers and anti-hunger advocates (Galli et al. 2018). This diversity of actors operating with private and public resources has led to shaping differentiated initiatives and programs adopting old and new practices and changing the governance process (Galli et al. 2018). For instance, the emergence of operating models driven by social innovation and entrepreneurship have reached beyond a generic provisioning distribution of food to charity organisations.

Social Supermarkets (SSMs) emerged in France in the late 1980s with a similar social orientation than food banks to directly address food poverty with non-marketable food (Schneider et al. 2015). Nevertheless, they do not deliver free food to people in need as food banks but introduced a new monetary contribution system (Caraher and Cavicchi 2014; Schneider et al. 2015).

Social supermarkets are meant for people with low income, unemployed, retired people with a low pension, ex-convicts, all those who cannot afford to buy food in large stores but who are reluctant to benefit from the charity (Caraher and Cavicchi 2014). Social supermarkets provide people with the choice between different products at heavily reduced prices, and the beneficiaries pay them as any customer in a regular store (Caraher and Cavicchi 2014; Holweg and Lienbacher 2011). Nevertheless, this is not the only solidarity action; SSMs also promote the development of a sense of community ownership and mutuality (Caraher and Cavicchi 2014). Social supermarkets are places where people can be listened to and exchange experiences, rebuild their links with society, reinforce their self-esteem, and develop new competencies through complementary activities such as cooking lessons, workshops, and others (Caraher and Cavicchi 2014).

The phenomenon of the social supermarket concept has been studied by using either a single or multiple case study approach. The first-ever book published by (Holweg and Lienbacher 2016) provides a deep understanding of the functions of the social supermarket model, and it analyses the characteristics in different European countries, including Belgium, France and others.

Another study conducted by (EU Fusions Project 2014) noted that the social supermarket concept has a promising potential to complement food aid programs, bringing out sustainability benefits; however, social supermarkets need to optimise their processes and systems to maximise their efficiency to be replicated (EU Fusions Project 2014).

Existing literature connected with social supermarkets describe the functions, operations and the consumers perspective; however, they do not provide details about the information management requirements of social supermarkets to analyse the feasibility of the implementation of new technologies such as blockchain and Internet of Things. One interesting finding of this study conducted by (Holweg and Lienbacher 2016) is that social supermarkets only use administrative software to administer their information requirements such as word, excel, Escarcelle, CCS Group and others.

On the other hand, the study conducted by (Holweg and Lienbacher 2011) identified that one the most critical challenges for surplus food redistribution is the adoption of sustainable supply chain practices to achieve the food recovery and food reallocation between retailers and Charity Organisations, such as Reverse logistics and Closed-loop design.

One general aspect identified in the literature connected with the surplus food redistribution is that there is no systematic data collection and its availability to track their social, economic and environmental impact of the food assistance provided by Charity Organisations. There are some independent studies to assess the social impact on preventing food waste. However, there is not a target within the SDGs framework to measure the social, economic and environmental impact of this effort.

## 2.2 Sustainable supply chain practices underpinning the surplus food management

Supply chain deals with a wide range of issues and several types of decisions that affect operations and long-term development. Aspects such as the definition of the number of locations, the capacity of warehouses, manufacturing plants, the materials flow along with the logistics network, inventory management policies, distribution strategies, integration of the supply chain, procurement strategies and information technology (Georgiadis et al. 2005).

Supply chain in its classical form is a combination of processes to meet customers' demands including the interaction with all possible entities in the chain such as manufacturers, transporters, warehouses, retailers and consumers (Eyob 2007; Govindan et al. 2015). The linear supply chain process from producers to consumers is commonly called *forward logistics* (French and Laforge 2006; Govindan et al. 2015; Krikke et al. 2004; MA et al. 2016).

On the other hand, the material flow that starts inversely from the customers where products are collected and returned to one of the actors of previous or new stages of the supply chain is called *reverse logistics* (Govindan et al. 2015). According to (Rogers and Tibben-lembke 2001), reverse logistics can be defined as *"The process of planning, implementing, and controlling the efficient, cost-effective flow of raw materials, in-process inventory, finished goods, and related information from the point of consumption to the point of origin to recapture or create value or proper disposal"* (Rogers and Tibben-lembke 2001).

According to (Szmelter-Jarosz 2016), reserve logistics comprises four stages of the materials flow: the first stage is the decision about the entry of the product in the reverse flow and the estimation of the value to be recovered. The second stage is the collection for transmission to reverse logistics, followed by the third stage, that is sorting the product and making the decision of the further destination. Finally, the fourth stage involves sending the product to the final destination.

Reverse logistics can follow a centralised or decentralised system. In a centralised system, the recovery centre is the one who makes decisions in the reverse logistics than the place of sale, by contrast, the decentralised system the decisions are made in the place of sale (Szmelter-Jarosz 2016).

The combination of the implementation of forward and reverse logistics in a supply chain resulting in the construction of a closed-loop supply chain (Govindan et al. 2015). (Govindan et al. 2015) defines closed-loop management as *¨the design, control, and operation of a system to maximise value creation over the entire life cycle of a product with the dynamic recovery of value from different types and volumes of returns over time¨* (Govindan et al. 2015).

Figure 2.1 illustrates the generic flow materials for both forward and reverse logistics presenting with solid lines the classical forward logistics and with dashes the reverse logistics. In the return evaluation activity, the decisions on return or reallocation of the products are made (Govindan et al. 2015). The decision of the product destination depends on the value that can be recovered from it (Szmelter-Jarosz 2016).

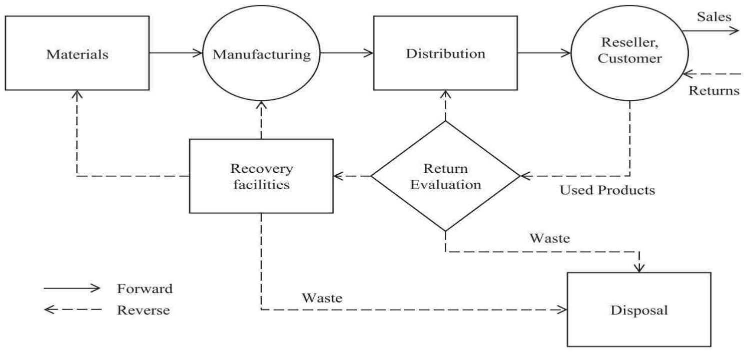


**Figure 2.2** Traditional Closed-Loop Supply Chain (CLSC). Adapted from: (Govindan et al. 2015)

According to (H. Krikke et al. 2001), closed-loop supply management requires the adaptation of business functions such as strategy, marketing, quality management and information systems in view of closing material flows to limit the emission and residual waste. Under closed-loop supply design, there is a higher complexity of the system owing to the number of interactions between good flows, alongside with the uncertainty of the supply side regarding quantity, timing and composition (H. Krikke et al. 2001), the mismatch between supply and demand distinguishing for the push-pull operations nature (H. Krikke et al. 2001), and the sources of raw materials that enter to the reverse logistic are more diverse, and they are at low cost or no cost at all.

The closed-loop design takes into account not only the economic nature of the typical supply chain but also the causes and consequences of activities with social and environmental impact (H. Krikke et al. 2001; Szmelter-Jarosz 2016). Therefore, (H. Krikke et al. 2001) identified a set of principles for the design of a closed-loop supply chain: (1) the design imposes sustainability standards on suppliers including product modularisation and design for recycling practices (H. Krikke et al. 2001). (2) Implementation of accounting systems to determine the full lifecycle costing of the product or service as well as its environmental impact (H. Krikke et al. 2001). (3) Make use of management tools that help companies to identify and select opportunities for improvement, tools such as life cycle analysis, environmental accounting methods, and others (H. Krikke et al. 2001). (4) Manage uncertainty supply and product sorting in a decentralised system to separate valuable items from junk (H. Krikke et al. 2001).

According to (Sgarbossa and Russo 2017), circular models such as the Closed-loop Supply Chain design comprises networks of business that generate economic value via product recovery and the continuous exchange of resources enabled by the implementation of innovative logistics and supply chain ecosystems. Particularly for the recovery of food resources from waste is necessary to consider additional configurations to the classical food supply chain. These configurations will influence the flow of food waste that is the output from the network nodes, and introduce new nodes connected with the existing nodes in the food forward logistics (Sgarbossa and Russo 2017). Five typical areas comprise the food supply chain: (1) Farmers, (2) Manufacturer/Processor, (3) Distribution/Wholesaler, (4) Retailers and (5) Consumers (Regattieri et al. 2007).

Figure 2.3 illustrates how the food resources recovered by a new section of the supply chain could be used either in the primary supply chain, or surplus food can be either redistributed to the community or redistributed to other supply chain networks (Sgarbossa and Russo 2017). The recovery of food waste and surplus food for conversion into new resources in the food supply chain represents a closed-loop approach. This approach requires further evaluation in terms of sustainability, the value of investment of new actors in the supply chain and measures the environmental and social impact of this model (Sgarbossa and Russo 2017).

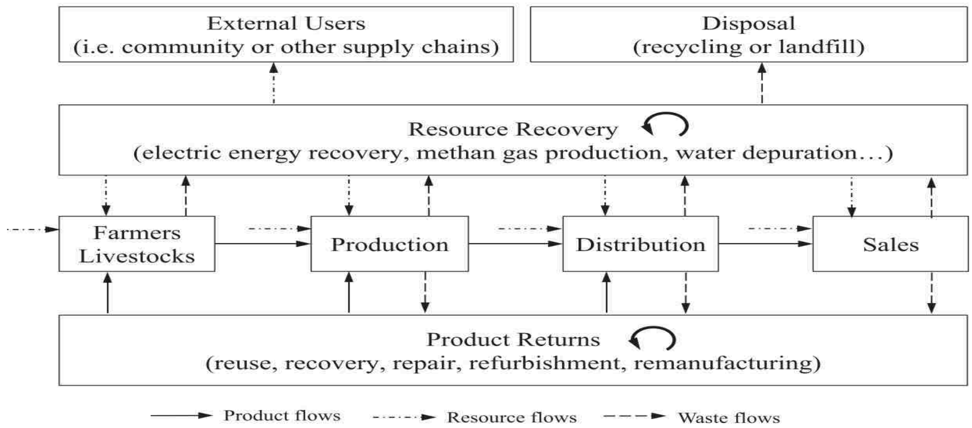


**Figure 2.3** Closing new loops in the food supply chain. Source: (Sgarbossa and Russo 2017).

One vital aspect to consider in the food industry is that it deals with safety issues due to the short shelf life of food products, which has a profound ramification on the design of the supply chain. The food supply chain needs to provide the certainty that perishable products are moved to the marketplace to avoid deteriorations, and at the same time, to provide certainty to the buyer concerning product quality, safety and reliability. These aspects lead to the need for constant deliveries, through dedicated nodes of transportation, efficient storage and refrigeration facilities (Georgiadis et al. 2005). Food quality is determined by time and environmental conditions that may influence the type of packing, the availability of temperature-controlled package, way of loading, transportation and warehouses (Accorsi et al. 2016).

Furthermore, proper monitoring and response to food safety issues require the capacity to trace lots across the supply chain from food processors to retailers and also the ability to trace back to the supplying farm (Georgiadis et al. 2005). In the event of foodborne disease outbreaks and incidents, a traceback investigation needs to be conducted to define and document the production and distribution chain and the source of a product that has been implicated in a foodborne disease investigation (Aung and Chang 2014).

According to (Regattieri et al. 2007), a food traceability system is fundamentally based on four main pillars: (1) product identification, (2) data to trace, (3) product routing and (4) traceability tools. The product identification involves recording the physical characteristics of the foodstuffs such as volume, weight, dimensions, packing and length of the life cycle (Regattieri et al. 2007). With regards to data tracing, it involves recording the constant check and automatic alarms across the supply chain, including product number, confidentiality level, and others (Regattieri et al. 2007).

Product routing is the third pillar that relates to recording lead times, production cycle, movement, storage activities and any other information of the process that have a direct impact with traceability (Regattieri et al. 2007). The fourth pillar is the definition and implementation of traceability tools. According to (Accorsi et al. 2016), an effective traceability system is not only a useful tool to manage food quality and safety risks but also to enhance the development of an effective supply chain.

The studies conducted by (Aung and Chang 2014; Regattieri et al. 2007) identified four main technological innovations that meet the specifications of the four pillars suggested by (Regattieri et al. 2007). These four technologies are (1) alphanumeric codes that consist of a label with a sequence of number and letter of various sizes, (2) bar codes that encode alphanumeric characters and vertical bars and are optically machine-readable, (3) Radio Frequency Identification systems (RFID), which are tagged objects to identify and track objects using radio waves, and (4) Wireless Network Sensors (WNS) that collect sensing data from environmental and physical conditions of objects (Aung and Chang 2014).

Barcoding has become an essential tool in all industries, including the food sector (Attaran 2007). Nevertheless, this tool is not useful when it requires monitoring environmental conditions such as temperature, dirt or hazardous contamination. In this case, RFID technology is often preferred. RFID is one of the leading technologies enabling Internet of Things. RFID uses radio waves to capture data from tags; therefore, they do not require labels. RFID is comprised of three main components: (1) RFID tags that are chips embedded in the product, pallet or case, and send information about the specific unit; (2) readers that are frequency transmitters and receivers administered by a microprocessor or digital signal processor that communicates with the tag; (3) the computer that gathers, interprets and stores data from tags through cable or wireless (Attaran 2007).

According to the study conducted by (Accorsi et al. 2016), it analysed and developed scientific propositions for the implementation of RFID using closed-loop supply design on a case study for dairy products in Italy. He proposed the implementation of RFID tools for real-time monitoring and an *ex-post* monitoring system. Real-time monitoring allows for data gathering related to the conservation of the products in real-time such as time, temperature, and humidity, which facilitate the decisions in run time to correct, improve or modify the supply chain design. On the other hand, the ex-post monitoring system consists of inserting data loggers within the primary packing of the products, which at the end of the distribution chain the data gathered by the data loggers are collected and analysed. This process allows for identifying the most critical steps in the food distribution and supports the operational decisions to improve the food quality and food safety (Accorsi et al. 2016).

Some studies have also raised concerns regarding the potential threat of security and privacy risks in particular when the devices are not under the control of only one actor or a closed manufacturing environment (Lee and Kim 2006; Weis 2003). Some aspects, such as vulnerabilities to physical attacks, spoofing, traffic analysis or denial of service, are potential threats to the unprotected tags (Weis 2003). (Weis 2003) proposed several actions to avoid these threats, such as hash lock, asymmetric key agreement, security agents, among others. Blockchain properties can offer certain benefits to solve some of these concerns, which are described in the section of applicability of blockchain and Internet of things in the food supply chain of this chapter.

## 2.3 Properties of blockchain technology

### 2.3.1 Blockchain components

The concept of blockchain was originated in late 2008 when an anonymous group with the pseudonym of 'Satoshi Nakamoto' published a paper in a cryptography mail group entitle ¨Bitcoin - A peer-to-peer electronic cash system¨ (Yuan and Wang 2018). The described system called Bitcoin was launched one year later as the first digital currency system (Ølnes et al. 2017).

Blockchain is a list of records that are continuously recorded, linked and secured using cryptography (Wang et al. 2019). These records are commonly called blocks. Blockchain adopts the Peer-to-Peer (P2) protocol, which shares resources that are directly accessible by other peers without passing intermediary entities (Wang et al. 2019). The elimination of a central third-party administrator provides the benefit that participants of the blockchain network can independently verify that the information that they see is consistent with the data of every other participant. Therefore, any alteration of the data, tampered by a malicious actor, can be instantly detected and rejected by participants of the network (Rauchs and Hileman 2017). A peer-to-peer protocol can also tolerate a single point of failure in the network (Wang et al. 2019).

The agreement between participants of the blockchain network over the state of data is made through a consensus mechanism (Rauchs and Hileman 2017). Every transaction entered into the peer-to-peer network is first validated by the nodes; if the nodes agree on its legitimacy, they confirm the transaction, which is recorded in a new block. (Bano et al. 2017; Ølnes et al. 2017). The new block is added to the previous chain of blocks, maintaining a shared and agreed-upon of the view on the blockchain network with timestamps (Ølnes et al. 2017). The process of appending new blocks to the blockchain data structure is called mining. A blockchain network relies on miners to aggregate and append the new blocks in the blockchain network. (Xu et al. 2017).

The consensus mechanism ensures common and unambiguous ordering of transactions and blocks. This consensus mechanism also guarantees data integrity and consistency, along with the geographically distributed nodes of the blockchain (Wang et al. 2019). The combination of consensus mechanism with a specific data structure enables to solve both aspects of the 'double-spending' problem and Byzantine Generals Problem (Mingxiao et al. 2017; Rauchs and Hileman 2017). The 'double-spending' problem prevents users from duplicating and spending the same digital file twice through the verification of the transactions by many distributed nodes together (Mingxiao et al. 2017; Rauchs and Hileman 2017). This blockchain property facilitates the transfer of digital assets without needing a central authority (Rauchs and Hileman 2017).

On the other hand, there is a potential risk in distributed systems of misinformation or miscommunication between different nodes either accidentally or deliberately (Lamport et al. 1982). This misalignment in distributed systems is known as the Byzantine Generals problem (Lamport et al. 1982). Blockchain needs to deal with this issue autonomously through the design of the corresponding consensus algorithm (Mingxiao et al. 2017).

The key innovation of Bitcoin was to achieve the consensus among an open and decentralised group of nodes based on proof-of-work (PoW). Proof of work is a consensus mechanism where all nodes attempt to find the solution to a hash puzzle, where the winning node adds the next block to the blockchain network (Bano et al. 2017).

By design, blockchain is a decentralised, replicated, immutable and tamper-evident log data that cannot be deleted. Blockchain also offers auditability since anyone can read data from the blockchain network and verify its correctness (Bano et al. 2017; Zheng et al. 2017).

According to studies performed by the University of Berkeley, blockchain technology can be useful to solve three particular business requirements: (1) create a self-sovereign network when there is no need of a central authority, (2) streamline business processes across multiple entities to achieve horizontal integration, and (3) solving point of failures under a distributed system design (University of California Berkeley, 2019).

Although blockchain technology has enormous potential in the construction of decentralised systems, some studies have identified that blockchain still faces two main challenges: scalability and security (Bano et al. 2017; Xu et al. 2017; Zheng et al. 2017). Firstly, bitcoin size is limited to 1 MB, and a block is mined every 10 minutes. Additionally, the bitcoin network is restricted to 7 transactions per second, not being capable of dealing with high-frequency trading (Xu et al. 2017; Zheng et al. 2017).

Some users need to maintain a large blockchain that represents larger storage space and slower propagation in the network, leading to centralisation gradually. Consequently, the trade-off between block size and security is still a challenge (Xu et al. 2017; Zheng et al. 2017). Secondly, the setting of privacy is limited since there are not privileged users. Every participant of the blockchain network can access all the information and validate new transactions (Xu et al. 2017). Table 2.1 summarises the key components of a blockchain network.

| Component | Description |
|---|---|
| Cryptography | Use of myriad of cryptography techniques including cryptography one-to-one function, Merkle trees and public key infrastructure (private-public key pairs) |
| P2P Network | Network for peer discovery and data sharing in a peer-to-peer fashion |
| Consensus mechanism | The algorithm that determines the ordering of transactions in an adversarial environment (for instance, assuming that every participant is honest) |
| Ledger | List of transaction bundled together in cryptographically linked blocks |
| Validity rules | A common set of the network (for instance: what transactions are considered valid, how the ledger is updated and others). |

**Table 2.1** Five key components of a blockchain. Source: (Rauchs and Hileman 2017)

### 2.3.2 Blockchain and Distributed Ledger Technologies

The fast-growing trend of blockchain has attracted significant interest from governments, financial institutions, high-tech companies, as well as the capital markets (Yuan and Wang 2018). Blockchain networks hold the promise of reducing the 'trust gap' providing verifiable systems made by each participant, improving the accountability and dis-incentivising misbehaviour via public auditability (Rauchs and Hileman 2017).

The first blockchain networks were based on the architecture of bitcoin, where all transactions sent across the system are arrayed into a new block. This new block references the preceding block forming a cryptographically chain linked transaction arrays. However, new systems referred to as blockchains emerged, which do not share the same features used by cryptocurrencies systems (Rauchs and Hileman 2017). For instance, some systems do not reach consensus on the state of the global ledger, they rely on the state of sub-ledger or channels, but they still use some of the same cryptographic primitives. The development of these new systems loosely built on the original concept resulted in the emergence of a new generic term called Distributed Ledger Technology (DLT). DLT refers to distributed systems or distributed databases where systems reduce the need for trust or incorporate validators in the network (Rauchs and Hileman 2017).

Although the architecture design of these new systems is not equal to the first blockchain networks, a study conducted in 2017 showed that blockchain technology and DLT in practice are mistakenly used interchangeably, being the term blockchain the one that is commonly referred to both architectures (Rauchs and Hileman 2017). In order to create a link with the literature available, it will be used the term blockchain in this study to refer to both blockchain and distributed ledger technologies. Nevertheless, the taxonomy proposed by (Xu et al. 2017) is used to classify and to identify the properties of each of the blockchain frameworks. Blockchain taxonomies allow an architect to explore the conceptual design space and establish rigorous comparison and evaluation of different options (Xu et al. 2017). Likewise, in this study, the classification used in practice by McKinsey is also referenced for the permission classification of the blockchain frameworks (Carson et al. 2018).

### 2.3.3 Blockchain taxonomy

The blockchain taxonomy developed by (Xu et al. 2017) captures the major architectural characteristics to assess the impact of the design decisions. This taxonomy considers three main aspects to classify and evaluate the blockchain architecture design: (1) decentralisation, (2) storage and computation, and (3) blockchain configuration.

Decentralisation devolves responsibility and capability from a central authority. While a centralised system, all users rely on a central authority to mediate transactions, in a fully decentralised system is entirely open without needing a central authority, such as Bitcoin and Ethereum blockchains. In a permissionless public blockchain, new users can join the network, validate transactions and mine blocks (Xu et al. 2017).

There are plenty of possibilities between centralisation and decentralisation. The most common options for partial decentralisation are related to permission and verification (Xu et al. 2017). Some blockchain networks may require one or more authorities that act as a gate of participation, leading to a partially decentralised system. This decentralisation might include permission to join the network, permission to initiate transactions or permission to mine. This blockchain architecture design is known as permissioned, such as Ripple and Eris blockchain networks (Xu et al. 2017).

Some permissioned networks could implement the code of public blockchains and restrict or grant access by using the network settings. On the other hand, permission information can be recorded on-chain and off-chain. Permissioned blockchains may provide better control than permissionless frameworks in particular to control the access of off-chain information.

Other factors that can also influence the decision of the selection of a blockchain framework are the transaction processing rate, cost, reversibility, finality and the flexibility to modify and optimise the network rules. Another characteristic that may also influence the suitability of permissioned blockchain is the size of the network (Xu et al. 2017).

In terms of verification, blockchain networks may require the verification of some type of information from external systems. To achieve that, a verifier role can be introduced to check the state of external data. The verifier is a third trusted party that can be implemented in a server outside of the blockchain with the permission to sign transactions by using a key pair on-demand. The instance of a verifier in Bitcoin is called oracle (Xu et al. 2017).

The verifier can be implemented inside of the blockchain network as a smart contract with the external state being injected into the verifier periodically via oracle. Nevertheless, a central verifier can represent a potential single point of failure; therefore, a distributed verifier can be implemented instead. This distributed verifier consists of several verifiers that also provides the same functionality of checking states of external systems (Xu et al. 2017).

Additionally, the blockchain network may require having an entity to resolve disputes or check the external status, and for that purpose, it can be set as an arbitrator. This arbitrator may be either a human with certain account privileges to sign the transaction after validation or an automated arbitrator that validates the transactions based on information obtained from external systems (Xu et al. 2017).

Figure 2.2 summarises the characteristics of blockchain frameworks based on the reading, writing and committing permission as well as several practices regarding the deployment of the infrastructure and the scalability level identified in practice based on the study conducted by McKinsey and Company.

| | **Permissionless** | **Permissioned** |
|---|---|---|
| **Public** | ▪ Anyone can join, read, write and commit<br>▪ Hosted on public servers<br>▪ Anonymous, highly resilient<br>▪ Low scalability | ▪ Anyone can join and read<br>▪ Only authorized and known participants can write and commit<br>▪ Medium scalability |
| **Private** | ▪ Only authorized participants can join, read and write<br>▪ Hosted on private servers<br>▪ High scalability | ▪ Only authorized participants can join and read<br>▪ Only the network operator can write and commit<br>▪ Very high scalability |

**Table 2.2** Blockchain architectures based on read, write and commit permissions granted to the participants. Source: (Carson et al. 2018).

Concerning storage and computation, as it was mentioned before the data storage available and the amount of computational power remains limited. In a fully decentralised system, it may represent a high infrastructure investment with a different kind of cost models than conventional software systems. Therefore, the main design decision in implementing blockchain is to choose the data and computation power that be placed on-chain and what should be kept off-chain (Xu et al. 2017).

One common practice in the design of the blockchain is to store only meta-data, critical data and hashes of the raw data on-chain and keep all raw data off-chain. The off-chain data can be stored in a private cloud of the customer's infrastructure or on public storage provided by a third party or network. The flexibility of using cloud computing to store data depends on the type of implementation. Some peer-to-peer data storage are specially designed to be blockchain-friendly such as InterPlanetary File System (IPFS) (Xu et al. 2017).

One crucial decision is the scope of the implementation. Most cryptocurrency systems use public blockchain that can be accessed by anyone on the Internet. Public blockchain frameworks offer better information transparency and auditability but sacrifice performance and have a specific different cost model. A consortium blockchain is used across multiple organisations, where pre-authorised nodes control the consensus process. In a private blockchain, write permission is under the control of one specific organisation; therefore this is the most flexible configuration because the network is governed and hosted by a single organisation (Xu et al. 2017).

On the other hand, the choice of consensus protocol determines the level of security and scalability. Usually, the consensus mechanism is fixed for a particular blockchain. However, there are modular architectures that allow for the pluggable implementation of various consensus protocols, such as Hyperledger (Xu et al. 2017).

There are several types of consensus mechanisms nowadays that support different blockchain frameworks. Table 2.4 provides a general description of the main consensus mechanisms and blockchain frameworks that were identified in the literature.

| Consensus mechanism | Brief description | Blockchain framework |
|---|---|---|
| Proof of Work (PoW) | When the transaction is initiated, miners try to solve the puzzle to verify it | Bitcoin, Ethereum |
| Proof of Stake (PoS) | The user who spends more becomes a validator to create a block and it also can be designated as a witness | PPCoin, NXT |
| Delegated Proof of Stake (DPoS) | Under a voting system, stakeholders can vote for a few delegates who will be responsible for securing the network | BitShares, Lisk |
| Proof of Elapsed Time (POET) | Each participating node is required to wait for a chosen time period assigned randomly and the first one to complete the designated time wins the new block | Hyperledger Sawtooth lake |
| Practical Byzantine Fault Tolerance (PBFT) | The transaction is initiated by a node to a leader node, who broadcasts the request to the backup nodes, and they send the reply to the node that initiated the transaction. | Hyperledger Fabric |

**Table 2.3** Consensus mechanisms on blockchain. Extract taken from source: (Gol 2019).

Table 2.3 shows the relationship between consensus mechanisms and blockchain frameworks. The scope of the study is not to analyse the technical capabilities and limitation of each consensus mechanism.

### 2.3.4 Smart contracts

Smart contracts are computer protocols that facilitate, verify and enforce digitally the contracts made between two or more parties on blockchain. Smart contracts are regularly deployed on and secured by blockchain (Wang et al. 2019). Their main characteristics are that they are recorded and verified on the blockchain, making them tamper-resistant. Smart contracts execution is enforced among the trustless and anonymous individual nodes without any centralised authority (Wang et al. 2019).

Since smart contracts are scripts stored on the blockchain, they act as intelligent agents that may have their own digital assets and transfer them when certain predefined conditions are triggered (Wang et al. 2019). They are executed independently and automatically in a prescribed manner on every node in the network based on the data included in the triggering transaction (Christidis and Devetsikiotis 2016).

The distinguishing structure and flow management characteristics of smart contracts allow for identifying what digital asset or digital product is ‘owned’ or transferred by and to a particular actor. Granting permission to actors to enter new information in the product profile, or initiating a new trade with other actors of the network through smart contract agreements and consensus (Saberi et al. 2019).

Ethereum framework was the first platform to support advanced and customised smart contracts with the support of the Turing-complete virtual machine called Ethereum Virtual Machine (EVM). EVM is a runtime environment where everyone of the Ethereum network runs and executes the instructions given, this means, that in every node on the network, there is a virtual machine (VM) running and the blockchain network acts as a distributed VM (Christidis and Devetsikiotis 2016).

Ethereum is the most popular development framework for smart contracts, and these can be used to design and develop various decentralised applications (DApps) including applications for digital rights management, crowdfunding, supply chain management, and others (Wang et al. 2019). Smart contracts governance and process rules in a blockchain-based supply chain can be managed by certifiers, which allows for enabling trustworthiness of the network (Saberi et al. 2019).

There are currently some high-level programming languages that can be used to write smart contracts such as Solidity or Serpent for Ethereum (Wang et al. 2019). On the other hand, smart contracts can also be developed by using Go, JavaScript or Java for other blockchain frameworks such as Hyperledger Fabric (Zafar et al. 2018).

Although smart contracts have been adopted and used to solve different use cases, they still face some challenges. A well-known event in June 2016, a decentralised investor-directed venture capital secured by Ethereum blockchain was attacked by exploiting a smart contract bug called 'recursive call', draining more than $50 million of Ether. A hard fork of the Ethereum was implemented to claw back the funds from the attack; however, the hard fork was controversial since it violated the principle of code by law of blockchain. Besides this security problem, it has arisen several concerns regarding their legal context (Wang et al. 2019).

## 2.4 Applicability of blockchain and Internet of Things in the food supply chain

In response to the food contamination scandals around the globe, it emerged several and differentiated strategies for tackling food security in the supply chain using blockchain technology (Kamath 2018). In 2016, the first-ever paper that proposed a conceptual framework for the implementation of an agri-food supply chain system using blockchain technology and Internet of Things was published by (Tian 2016). This framework aimed at establishing an agri-food supply chain traceability system for helping Chinese agri-food markets to enhance their food safety and quality, as well as to reduce the food losses during the logistics process (Tian 2016).

The agri-food supply chain traceability system proposed by (Tian 2016) relies on RFID technology to achieve data acquisition, circulation and data sharing along all the stages of the agri-food supply chain. Also, the traceability system proposed the use of blockchain technology to ensure that the information shared and published in the traceability system is reliable and authentic (Tian 2016).

One particular feature of the conceptual framework is to cover not only each enterprise in the agri-food supply chain but also includes the compulsory checks of food safety and food security done by third-party regulators. Besides, at the same time, enabling an alerting system that in case an accident happens, emergency measures can be taken immediately to prevent the spreading of the hazard (Tian 2016).

According to (Tian 2016), together blockchain technology and RFID can enable a decentralised traceability system, which can realise securely and transparent the identification, inquiry, tracking, monitoring and tracing of the information along the agri-food supply chain. Besides, the implementation of complementary technologies is suggested to achieve the real-time tracking and monitoring of foodstuffs across the agri-food supply chain, such as WSN, GPS, GIS and others. For instance, GIS can be used together with RFID technologies to monitor the production of the plants, while GPS can be used to make the vehicle positioning and to optimise their route for distribution. Figure 4.2 described the conceptual framework proposed by (Tian 2016).

There are three main benefits of the implementation of RFID and blockchain technology in the agri-food supply chain identified in the study conducted by (Tian 2016): (1) open and transparency data along the supply chain including the food supervision made by authorities, (2) increase the neutrality, reliability and security of data in a decentralised structure, and (3) prevent the data manipulation. All of these factors guarantee food safety and quality.

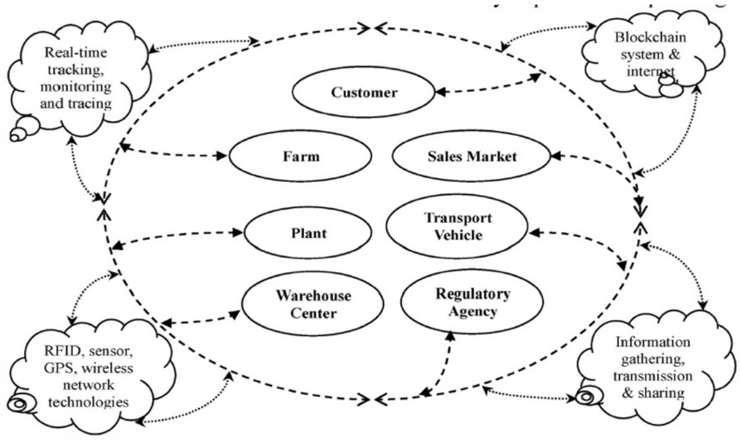


**Figure 2.4** Conceptual framework proposed for an agri-food supply chain traceability system based on RFID and blockchain technology. Source: (Tian 2016).

On the other hand, according to (Tian 2016), the two disadvantages of the agri-food supply chain traceability system based on RFID and blockchain technology are: (1) the high cost of the implementation of RFID tags in every product as well as the computational requirements to enable a blockchain network. However, some practices for cost reduction were identified, such as the use of tags in pallet, packing-case and containers. (2) the obstacle of performance and scalability under a full decentralised system (Tian 2016), as it was explained in the blockchain components section of this chapter.

The proposition of using RIFD technologies for implementing a traceability system in the agri-food supply chain proposed by (Tian 2016) is backed up by a previous study conducted by (Zhao et al. 2015). The study of (Zhao et al. 2015) emphasised the need to track the temperature fluctuations to ensure food safety and food quality from the field along the supply chain and in processing environments. (Zhao et al. 2015) introduced an architecture integrated into three layers: sensing, communication and applications layers.

The sensor layer is designed to monitor the conditions of the crops and livestock on farms as well as in the supply chain with different automatic identification and capture technologies. For instance, to identify swine and cattle and high-value meats and fruits can be used RFID tags, while for low-cost fruits can be tracked using 1-D and 2-D bar codes. Wireless sensor networks can monitor humidity, carbon dioxide, temperature and other environmental conditions in the field (Zhao et al. 2015). The communication layer is designed to allow different stakeholders to access authorised data across the supply chain. It was set up an architecture based on Object Name Services (ONS) so all data to be captured and stored on the web.

Finally, the application layer provides the functionalities to build applications and services on top of the Internet of Things infrastructure to support the development of applications and services that can be used for the different stakeholders in the supply chain including farmers, retailers, government analysts and consumers (Zhao et al. 2015).

On the other hand, in 2017, IBM signed off a collaboration agreement with ten food producers and retailers to deal with the most urgent issues in the global food supply chain, including Walmart, Nestlé, Unilever, McCormick, Dole, Discoll's, and others. This initiative seeks to help retailers to identify sources of contaminations through the application of blockchain technology.

IBM's Food Trust system is a cloud-based solution that stores the data of about one million of food items, which is shared across the supply chain on the IBM blockchain platform using Hyperledger Fabric framework supported by Linux Foundation (Wolfson 2018). Currently, there are more than 350,000 data transactions on the IBM Food Trust platform. The items comprise a different type of foodstuffs, including vegetables, spices, fruits, meat and more. IBM notes that the use of blockchain technology can reduce the average product return by up to 80% (Wolfson 2018).

Carrefour is one of the exemplary use cases on IBM's Food Trust blockchain. Nowadays, any customer can go into a Carrefour store and scan a QR (Quick Response) code with his phone using the carrefour application and knows all the traceability information of the product. The major achievement was to be able to enhance the visibility along the supply chain and also increase consumer trust and loyalty in brands (Wolfson 2019).

### 2.5 Theoretical framework

Blockchain, as an emerging paradigm of collaborative business networks, requires the use of an engineering framework that assures the sustainability of the application and particularly of the network partnerships. The active participation and incentives to run nodes in the network need to be equally distributed to create a sustainable network that justifies the implementation of a blockchain network instead of a centralised system. Sustainability of the partner network is decisive to maintain the network viability; otherwise, the participation will be limited to only data exchanges, which may become in a deserted network (Osterland and Thomas 2018).

Incentives for network participation, business models and operational processes are vital on the selection and implementation of options for the blockchain platform (Osterland and Thomas 2018). Therefore, it is needed to use a theoretical framework that can guide in the assessment of the blockchain potential for the use case of surplus food redistribution while identifying the advantages and incentives for sustainable participation of the actors in the blockchain network.

Therefore, the integrated approach of the adapted framework of Engineering sustainable blockchain applications proposed by (Osterland and Thomas 2018) and the criteria of blockchain selection proposed by (Wust and Gervais 2018) are used to conduct this study. These elements guided the formulation of the research propositions, data gathering and case study analysis. In this section, these elements are described detailing its applicability and scope for this thesis.

### 2.5.1 Engineering sustainable blockchain applications

The analysis of the case has been conducted by using an adapted version of the engineering framework proposed by (Osterland and Thomas 2018), called engineering sustainable blockchain canvas. This engineering framework was adopted from the business model canvas, which is a strategic management tool to describe how an organisation creates, delivers and captures value (Osterwalder and Pigneur 2010). The original conceptualisation includes three main aspects: (1) how the components and functions of an organisation are integrated to deliver value to the customer, (2) how these functions are interconnected along with the stakeholder networks and its supply chain, and (3) how the organisation generates value through those connections (Osterwalder and Pigneur 2010).

Blockchain sustainability canvas extends the original business model structuring in four main sections: incentives for fair change, innovation for networking, process optimisation, and finances. For this study, the framework has been adapted, considering only the three first areas, excluding finances, since the investment assessment requires data that is not publicly available (Osterland and Thomas 2018).

The adapted canvas is organised in three areas. The upper left area covers the identification of the network participants as well as the advantages and disadvantages of participation. The resulting aspects of both sides can be invaluable elements in identifying weaknesses of a blockchain network and inputs for process optimisation. The scope of the analysis of the use case does not consider the evaluation using the rating weight method of the incentives against each participant of the network due to the time restrictions to conduct this study (Osterland and Thomas 2018).

The upper centre helps in analysing the application of existing business processes in the use of blockchain. The 'trust enabler' box identifies how blockchain can provide trust in existing defective processes or how these processes can replace the existing resource of trust that leads to the elimination of intermediaries.

Change of governance covers the potential change of the process governance by adopting blockchain, for instance, the automation of business rules, validations and others, via automation made by smart contracts. The section Business Processes describe the existing processes that can be used in the blockchain network and side channels represents the alternative communication channel besides blockchain technology (Osterland and Thomas 2018).

The upper right area covers the question of what processes can be re-engineered after the benchmarking of the existing process concerning the applicability and performance expected from the blockchain adoption. Figure 2.5 shows the structure of the blockchain sustainability canvas adapted from (Osterland and Thomas 2018).

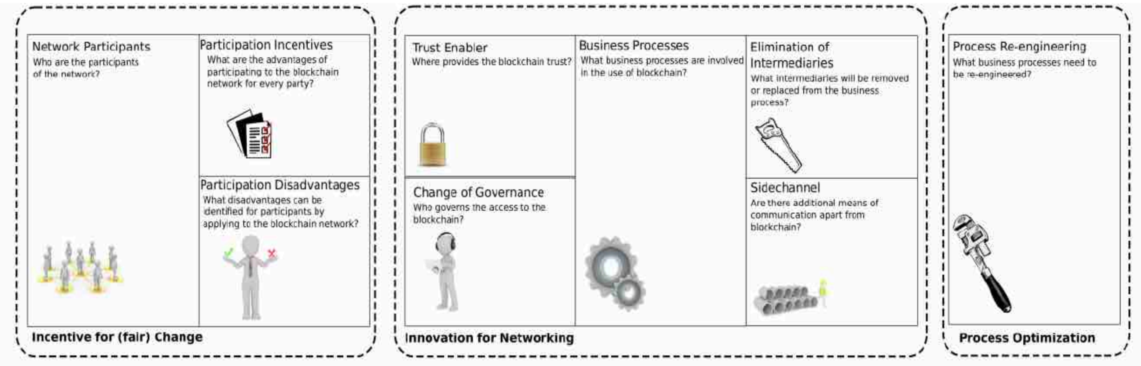


**Figure 2.5** Blockchain Sustainability Canvas. Adapted from: (Osterland and Thomas 2018).

Several studies have followed adapted models from business canvas to determine factors such as: how to create company value from Research and Development, model competitive advantage, output and province the operational model, support planning from the business scenario to design a business target or roadmapping the business product (Abe et al. 2009). The limitation of the business model canvas is that it limits the judge the choice of alternative technologies (Toro-Jarrín et al. 2016).

Blockchain model canvas has been used as a business blueprint of the social supermarkets model for gathering empirical data from blockchain experts' consultations. Blockchain experts need to gain a deep understanding of the case to confirm the blockchain potential, provide recommendations for tools selection, and the identification of incentives for sustainable participation on blockchain technology and Internet of Things.

### 2.5.2 Criteria for blockchain technology selection

The structured methodology proposed by (Wust and Gervais 2018) is used in this study to assess the technical solution to meet the information management requirements of social supermarkets within the European context. The decision-making process for the selection of the most suitable technology consists of several verifications through a workflow.

The first step in the workflow defines if the data generated along the process needs to be stored in a database or does not require to be stored at all. The second step identifies if there is one or multiple writers either in the database or in the repository where the data is stored (Wust and Gervais 2018).

The third step is to define if a trusted third party is available (TTP) considering two scenarios of this. The first scenario is that the trusted third party is always online, writing operations that can be delegated to it and if it can operate as a verifier for state transactions. The second scenario is if the trusted third party usually is offline, and it can function as a certified authority of a permissioned blockchain, where all the participants of the network are known. If the writers are unknown to the participants, a permissionless blockchain is the most suitable option, such as Bitcoin or Ethereum (Wust and Gervais 2018).

If all writers trust each other, a database with shared write access is the best solution. Contrary, if the writers do not trust each other using a permissioned blockchain is the best option. Depending on if the public verifiability is necessary, anyone can be allowed to read the state (public permissioned blockchain), or there may be restrictions for the readers, a private permissioned blockchain is the best option (Wust and Gervais 2018). Figure 2.6 illustrates the flow chart with the steps to assess if a blockchain solution is suitable for a specific problem. Please refer to Table 2.3 to differentiate between permisionless and permissions blockchain, as well as the public or private verifiability.

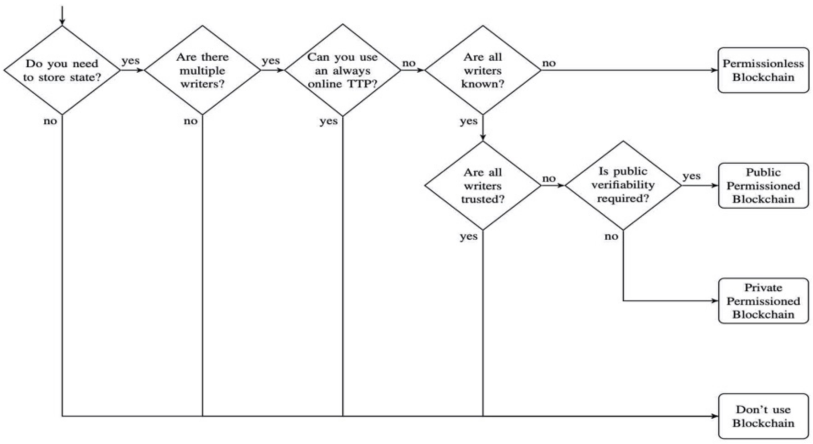


**Figure 2.6** Flow chart to determine if blockchain is the appropriate solution. Source: (Wust and Gervais 2018).

## 2.6 Summary

Existing literature noted that food poverty initiatives have emerged to valorise and redistribute surplus in the food systems and to address food insecurity for people in poverty. The efforts of surplus food redistribution have been connected with the development of food waste management policies in many countries, which seek to bring social, economic and environmental benefits.

The retail sector generates a significant volume of food surpluses in specific and limited locations, offering the unique opportunity to implement strategies to limit food waste and enable the surplus food redistribution. The concept of social supermarkets driven by social innovation has shown to be an effective mechanism to redistribute food in the European context, at the same time, that they support the implementation of social programs with a wide-community focus.

Although social supermarkets have shown potential in the study funded by the European Commission named Fusions, however they still face different challenges to increase their operational efficiency to be replicated in other EU countries. Existing literature connected with social supermarkets describe functions, operations and the consumers perspective; however, they do not give details on the information management requirements of social supermarkets to analyse the feasibility of the implementation of new technologies such as blockchain and Internet of Things. Therefore, there is a need to gain a deep understanding of how components and functions of the social supermarkets model delivers value to consumers, how these are interconnected with the stakeholders' network and how they create value through these connections to assess the blockchain and Internet of Things potential.

From the supply chain perspective, reverse logistics and closed-loop design support the product recovery of the primary food supply chain, allowing for either the reallocation of food surpluses to other supply chains, or for its redistribution to communities, or waste disposal. The implementation of effective traceability systems is relevant in the food supply chain to provide certainty for food quality, safety and reliability.

Radio Frequency Identification systems have shown advantages to identify and track objects using radio waves. RFID technologies can be implemented to achieve the real-time monitoring of the conservation of the foodstuffs. Furthermore, RFID can also be applied for the ex-post monitoring system to assess the performance of the supply chain and to develop corrective actions without needing a huge infrastructure investment, resulting in a cost-effective tool for supply chain design and planning.

Blockchain technology and RFID systems have been already implemented in agri-food markets to improve the food safety and quality of foodstuffs. A decentralised traceability system has been proposed to achieve data acquisition, circulation and data sharing with all the participants of the network by (Tian 2016). The main features of the implementation are: (1) the alerts system to notify in case an accident or contamination happens to all the participants of the network, (2) incorporating the compulsory checks for food safety and food security in the systems and (3) track and monitor the conditions of food with RFID technologies.

Several blockchain frameworks can meet these requirements, such as Hyperledger Fabric. However, there is not any use case to identify the benefits and potential to adopt and implement blockchain technology and Internet of Things for surplus food redistribution – food donation process. On the other hand, it has identified some blockchain implementation issues connected with scalability and performance, depending on the decentralisation required and consensus mechanism implemented.

In light of the above, it is needed to analyse the current challenges and operating model of social supermarkets, including its information management requirements to define if blockchain can meet those requirements to build a collaborative ecosystem and support the sustainable supply practices for food recovery.

# 3 Methodology

This research aims to provide a guide for the adoption and implementation of blockchain technology and Internet of Things to increase the operational efficiency of the surplus food redistribution through a collaborative and less fragmented ecosystem to enable the UN Zero Hunger goal.

The term of operational efficiency is used here to refer to the capability of delivering products and services using best practices and making most of the available resources and at the same time ensuring the high quality of the products and services. The primary consideration for this study is that surplus food redistribution requires to comply with the same requirements of food safety and food quality as the regular food supply chain, as well as the implementation of push and pull strategies for product recovery and reallocation of foodstuffs in the supply chain.

This study is performed in three main phases. The first phase aims to gain a deep understanding of the actors, relationships and information management requirements of the operating model of social supermarkets to determine the level of process optimisation and information flow that can be achieved by implementing blockchain and Internet of Things. The second phase involves collecting empirical data with expert's consultation to first validate the case study and uncover the challenges for the surplus food redistribution between retailers and social supermarkets. As a result of this phase, a business blueprint of the operating model of social supermarkets was created to assess the blockchain potential and finally to identify tools, practices and develop recommendations for its implementation.

According to (Rowley 2002), there are three factors to determine the best research methodology: the type of questions to be answered, the control over behavioural events and the degree of focus on contemporary events rather than historical events. This research involves answering 'how' questions that support more detailed investigations, the triangulation of different primary and secondary sources such as documents, artefacts and semi-structured interviews, as well as the study of a contemporary event rather than a historical one. Therefore, it was identified that the most suitable methodology to conduct this study was the case study research approach.

This research is interdisciplinary in nature. A qualitative exploratory research is conducted using a holistic single case study research in software engineering. Case study research in software engineering is an empirical method to investigate a contemporary software engineering phenomenon within its real context, and to answer questions related to computing concepts, such as methodologies, software life cycle engineering, information technology usage and operation in a specific context (Runeson et al. 2012).

## 3.1 Research questions

This study was designed as a holistic single case study focusing on the core feature of the applicability of blockchain technology and Internet of Things for the food donation process between retailers and social supermarkets. The holistic feature of the study implies that the analysis will be based on ¨the case¨, and therefore, this will not be divided into smaller sub-units of analysis (Yin 2018). The study will answer the following research question:

RQ: How can blockchain technology and Internet of Things enable the UN Zero Hunger Goal by supporting the surplus food redistribution through Social Supermarkets?

Three sub research questions support this main research question. Each sub research question maintains a link between the main research question, propositions and the protocol questions. This link established correct operational measures of the concepts studied in the research (Rowley 2002). Furthermore, this link also generates a chain of evidence to satisfy one of the principles for data collection needed to observe in the case study design (Rowley 2002). The three sub research questions are described below:

SQ1: How can the operating model of the Austrian social supermarket concept contribute to the achievement of the UN Zero Hunger goal?

SQ2: How can blockchain and Internet of Things increase the operational efficiency of the Austrian social supermarket?

SQ3: How to implement a blockchain-based solution using Internet of Things to increase the operational efficiency of the Austrian social supermarkets to enable the UN Zero Hunger goal?

The objective of the first sub research question aims to analyse and to create a business blueprint of the operating model of a representative case of the concept of social supermarket in Europe, followed by the analysis of what characteristics contribute to the achievement of the Zero Hunger goal. The second sub research question targets to identify the main challenges for surplus food redistribution and how the adoption of blockchain and Internet of Things can increase the operational efficiency of the Austrian social supermarket model. The last sub research question targets to identify tools, practices and develop recommendations to support a push-pull strategy with a blockchain-based solution and Internet of Things.

This research was conducted following a deductive positivist research approach. Following the steps to perform this study are illustrated in Figure 3.1

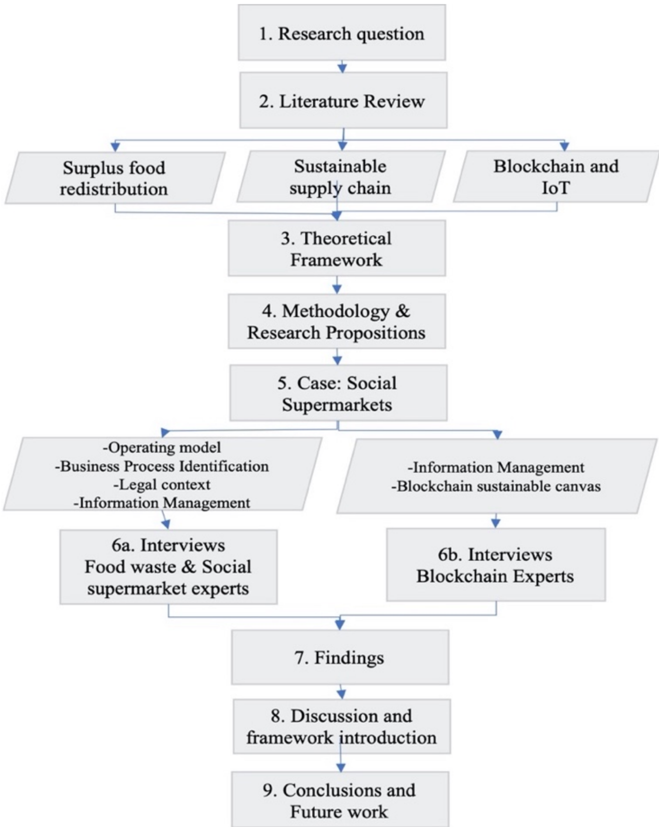


**Figure 3.1** Steps of the research process. Source: (The Author)

This study started with a review of the existing literature to identify the opportunities and challenges to enable the Zero Hunger goal. As a result of this review, the research questions and the concepts of this study were defined. The second step consisted of conducting an in-depth analysis of the research concepts of the research, including the topics of surplus food redistribution within the European context, sustainable supply chain management for food recovery and food reallocation of foodstuffs, blockchain properties and the potential implementation of blockchain and Internet of Things in the food supply chain.

As a result of the previous step, gaps in the literature were identified, and the theoretical framework was selected. The theoretical framework guided the analysis of the case study and to assess the blockchain potential. It was selected two structured methodologies; the first one is the adapted version of the framework proposed by (Osterland and Thomas 2018) to guide the structure and analysis of the case study to create a blueprint of the operating model of the social supermarket concept. And the second one is a structured methodology proposed by (Wust and Gervais 2018) to assess the blockchain potential and support the selection of the most suitable blockchain framework.

The fourth step consisted of the definition of the methodology to conduct this study. During this step, the sub research questions, propositions, data collection methods and data analysis techniques were defined. The research propositions were deduced logically from the gaps in the literature and the theoretical framework selected. From the sub research questions, the interview guide and questionnaires were formulated for the empirical data collection, creating a link between research questions, interview guide and questionnaires.

The study of the Austrian social supermarket was performed in the fifth step. This analysis was conducted by using a document analysis technique. The analysis encompassed the identification of the relationship using a graphical representation of the operating model, as well as the business processes identification and business modelling using BPMN, the simplified representation of the sources flows in the food supply chain, the legal context and identifying the information management requirements. As part of the study of the case, it was analysed how the operating model of the social supermarket captures and delivers value by using the engineering framework for blockchain called blockchain sustainability canvas proposed by (Osterwalder and Pigneur 2010). Finally in this step, the first assessment of the blockchain potential was performed by using the structured methodology of (Wust and Gervais 2018), which also supports identifying what blockchain framework is suitable for the food donation chain.

The outputs of the analysis of the case provided two different interconnected units of study, one unit of analysis concerning the operating model and information management requirements of the social supermarket model, which were validated and enriched with experts' consultations in the field of food waste, retailing and social supermarkets. The second unit of analysis relates to the assessment of blockchain and Internet of Things potential and the identification of practices and tools for their adoption and implementation. The data gathering for this unit of analysis was performed by conducting semi-structured interviews to experts.

The empirical data gathering from both groups of experts was conducted by performing individual semi-structured interviews. An interview guide was created to define the themes connected with the research questions. The interview guide is described in Appendix B. Besides, two questionnaires were designed, one per each target group, one questionnaire for the sustainability and social supermarket experts, which is contained in appendix D; and, the second one questionnaire was designed for collecting data from blockchain experts' consultations, which is described in Appendix E.

The selection of the interviewees was performed considering their area of specialisation, relevant experience in the field. Particularly in the case of blockchain experts, it was selected experts who had previous experience in the implementation of blockchain and Internet of Things in the food supply chain. Appendix C describes the list of interviewees who participated in the research. All the interviews were recorded, transcribed, coded and analysed by conducting a thematic content analysis using NVivo software.

The seventh step involved the analysis and reporting of findings from experts' consultations following the guide of the themes contained in appendix B. The eight step of this study encompassed the discussion of results, and it introduced the conceptual design of a decentralised digital marketplace based on blockchain and Internet of Things for surplus food redistribution. Finally, the last step involves summarising critically the outcome of the research, describes the limitations and provides recommendations for future research work.

## 3.2 Propositions

Propositions in case study research relate to those predictions that could be deduced logically from theory (Runeson et al. 2012). These propositions can be judged as true or false when these are validated with different data sources (Runeson et al. 2012). The research propositions were motivated from each sub research question and formulated as outputs of the study rather than elements of the research approach. The validation of the propositions was done by consulting experts and are discussed in chapter 6. Following the research propositions are described:

**Proposition 1:** IF blockchain can support the functions of the operating model of social supermarkets THEN a decentralised ecosystem can be implemented to address the inter-organisational collaboration for the surplus food redistribution via social supermarkets.

**Proposition 2:** IF blockchain and Internet of Things are a suitable solution for the food donation chain THEN the requirements of transparency, traceability, auditability and data security can be achieved.

**Proposition 3:** IF the data of the conditions of the foodstuff can be digitally available using blockchain and Internet of Things THEN they can support the decision-making process for re-use, reallocate and redistribute foodstuffs.

**Proposition 4:** IF blockchain technology and Internet of Things can facilitate the pull and push strategies to match the offer and demand for food donations, THEN the operational efficiency of the food donation chain can increase.

## 3.3 Case and subject selection

As a result of the literature review, it is evident that developed countries play a significant role to fight against hunger, poverty and waste by redistributing surplus food to people in need. The social supermarket concept in Europe has shown to be an excellent intermediary tool to achieve these goals. Its operating model goes beyond a generic provisioning distribution of food to charity organisations

(Galli et al. 2018), touching different dimensions: It is socially inclusive, has a wide-community focus, supports social integration and reduces long-term unemployment (Holweg and Lienbacher 2016). These characteristics are highly relevant for the achievement of the UN Sustainable Goals and other initiatives as the Europe 2020 targets (Holweg and Lienbacher 2016), and the European Green deal because of their sustainability benefits.

Therefore, it is crucial to gain a deep understanding of its operating model to identify what aspects of the processes, stakeholders' relationships, information flow and logistics can be optimised to increase its operational efficiency by implementing blockchain and Internet of Things. Prior studies have revealed, however, that there are different operating models depending on their workforce organisation, beneficiaries, target group, type and layout, sourcing and fundraising, type of donations/contributions and incentives (Defourny and Borzaga 2018; Holweg, Lienbacher, and Peter Schnedlitz 2010; Klindžić et al. 2016; Maric et al. 2015; Schneider et al. 2015).

Therefore, the *most similar approach* was used to identify the one that is broadly representative and allows for providing a basis for strong generalisation (Seawnght and Gerring 2008). According to (Seawnght and Gerring 2008), the most similar method begins by identifying a set of variables, verifying the scores and analysing the differences in the control group.

Based on the results of the assessment of the multiple case study approach of social supermarkets in six European countries conducted by (Holweg and Lienbacher 2016), where it was assessed the key distinguishing features of social supermarkets such as social integration, prevention of food waste, reduction of long-term employment, customer satisfaction and revenue per hour.

For this study, some of these key characteristics were contrasted to determine that the Austrian social supermarket is the most similar case in the European Union. The Austrian model reached the highest rank for providing the best social integration to its customers. Additionally, the Austrian social supermarket model ranked second place in the prevention of food waste, third place to reduce long-term unemployment, third in customer satisfaction and second place in revenue per hour. Therefore, the Austrian social supermarket can provide a high generalisation to perform this study. Table 3.1 shows the ranking resulted from the study of (Holweg and Lienbacher 2016) considered for the case study selection.

| | France | Austria | Switzerland | Belgium | Luxembourg | Romania |
|---|---|---|---|---|---|---|
| - Social integration | 1.10/3.00 | 1.38/3.00 | 1.00/3.00 | 1.10/3.00 | 1.00/3.00 | 1.00/3.00 |
| - Prevention of food waste | 2.44/3.00 | 1.58/3.00 | 2.00/3.00 | 2.80/3.00 | 1.88/3.00 | 2.00/3.00 |
| - Reduction of long-term unemployment | 2.05/3.00 | 2.11/3.00 | 3.00/3.00 | 2.00/3.00 | 2.50/3.00 | 0.00/3.00 |
| - Customer satisfaction | 1.9/3.00 | 1.9/3.00 | 2.0/3.00 | 2.2/3.00 | 1.7/3.00 | 2.7/3.00 |
| - Revenue per hour in Euro | 63.4 | 79.3 | 176.7 | 59.3 | 40.6 | 20.3 |

**Table 3.1** Social supermarkets by rank. Source: (Holweg and Lienbacher 2016)

### 3.4 Data collection methods

**Search process.** The search process was performed using the best practices of (Webster and Watson 2002) for identifying the relevant literature connected with the concepts with the research. It was followed by applying a structured approach to define and classify the source material using a concept-centric approach.

The concept-centric approach was conducted by using a go backward strategy utilising the search engines of Limo of KU Leuven and Google scholar to determine the relevant articles based on the number of citations. Complementary, a go-forward strategy was done by performing systematic searches via Web of Science.

Both strategies allowed for creating a compendium of literature including books, handbooks, journal articles, peer-reviewed journals, conference proceedings, regulations, artefacts, reports issued by organisations such as United Nations, FAO, OECD, World Bank; as well as, reports published by practitioners and consultancy firms such as KPMG, McKinsey, Deloitte, Ernst and Young, and others. The searches were performed, considering the main research concepts. Appendix A contains an extract of the concept matrix of the literature review.

**Document analysis.** Document analysis technique is a procedure for reviewing and evaluating printed and electronic material (Bowen 2009). Document analysis requires that data is examined and interpreted to bring out meaning, understanding and develop empirical knowledge (Bowen 2009). This technique was used to collect and analyse the existing secondary sources connected with the Austrian social supermarket using a systems engineering approach.

Systems engineering discipline has used a structured systematic approach to manage the development of products and processes. This approach is also used to guide the development of information systems from the understanding the business needs until the implementation of the systems (Samaras and Horst 2005). For this study, the first stage of the requirements definition is performed to identify the needs of the users, actors, relationships and processes of the Austrian social supermarket to develop an alternative system concept design based on the properties of blockchain and Internet of Things. Complementary tools for the analysis of the case were used, such as the Signavio application for the business process modelling using BPMN notation 2.0.

The analysis of the case was conducted following an adapted version of the engineering framework proposed by (Osterland and Thomas 2018), called engineering sustainable blockchain canvas. This engineering framework was adopted from the business model canvas, which is a strategic management tool to describe how an organisation creates, delivers and captures value (Osterwalder and Pigneur 2010). The result of the analysis provided a business model blueprint of the Austrian social supermarket model, which also guided to the analysis of the reformulation of governance, process re-engineering and incentives for participation in the blockchain network.

The sources used to conduct this analysis included books, handbooks, journal articles, conference proceedings, peer-reviewed journals, websites, GitHub, and others. The new data collected was validated and triangulated with empirical data obtained from experts' consultations of food waste, retailing and social supermarkets.

**Semi-structured interviews.** The interview is one of the most common methods used in case studies for either primary data collection or validation of other kinds of data (Runeson et al. 2012; Yin 2018). Semi-structured interviews resemble guided conversations to explain how qualitatively the interviewee experiences the phenomenon. (Runeson et al. 2012; Yin 2018).

For this study, six semi-structured interviews were performed to gain a better understanding of the context surrounding the concepts of the research. The semi-structured interviews were conducted via Skype with a minimum duration of 40 minutes and up to 120 minutes. An interview guide was designed, maintaining the connection with the research questions and research propositions of the research to increase the level of reliability of the study. Besides, two questionnaires were formulated considering the area of specialisation of the interviewees, which are described in appendices D and E. The questionnaires included open questions giving the flexibility to explore additional issues raised in the conversation.

The first questionnaire aimed to gather data regarding the frameworks and practices for surplus food valorisation and redistribution, current challenges of retailers and social supermarkets in the food donation chain, as well as the validation of the operating model of social supermarkets in Austria. On the other hand, the second questionnaire targeted to collect data regarding the aspects considered for selecting a blockchain framework, assess the blockchain potential and identify what blockchain frameworks are suitable for the food donation chain. Additionally, this questionnaire aimed to identify the tools, practices, incentives for participation and technological components to meet the information management requirements and address the challenges of the surplus food redistribution between social supermarkets and retailers.

The selection of the experts was based on their area of specialisation and relevant experience in each domain. The interviewees of the fist experts' group have more than fourteen years of experience in the fields of food waste management, retailing and social supermarkets in Europe. In addition to their practical knowledge, both experts have worked as researchers in several projects connected with social supermarkets and gathered data directly in the field in the retail sector and social supermarkets.

The experts of the second target group have proved experience in the engineering lifecycle and in the strategy design for implementing blockchain-based and Internet of Things solutions in the food supply chain. One expert is specialised in topics related to process mining on blockchain. Before the interviews taking place, the summary of the case was provided to the interviewees, the questionnaire described in appendix E and the blockchain sustainability canvas described in appendix H.

All the interviews were recorded, transcribed from audio recordings to text, and coded using NVivo software to perform a thematic content analysis. The results of the thematic content analysis and its data triangulation with secondary sources are presented in section 5.

## 3.5 Data analysis methods

**Thematic content analysis**. Thematic content analysis is a method used to identify patterns, organise and present the data in detail (Runeson et al. 2012). All the semi-structured interviews were recorded, transcribed, coded and analysed by using NVivo software. The codification was consistently performed based on the themes of the interview guide contained in appendix F, which are linked with the research questions and research propositions.

## 3.6 Validity procedure

A case study research design presents logic statements that are linked between the data collected and the conclusions to be drawn to answer the research questions (Rowley 2002). These statements should be consistent and show a level of validity to denote the trustworthiness of the results, and besides to identify to what extent these results are not biased by the subjectivity of the researchers' point of view (Runeson et al. 2012). According to (Rowley 2002; Runeson et al. 2012; Yin 2018), there are four tests to examine the quality of the research: construct validity, internal validity, external validity and reliability.

### 3.6.1 Construct validity

Construct validity is a test to identify correct operational measures to unify and to have a common understanding of the concepts studied between the researcher and the interviewees. This test also ensures that the research questions, concepts, propositions and the questionnaire design for data gathering remain consistent for increasing the level of reliability. For this study, two tactics were applied to test the construct validity of the research.

The first tactic was the triangulation of different data sources, including secondary and primary qualitative data sources. These triangulations allowed for providing an analytical generalisation of the concepts and theory building. A systems engineering perspective was used to guide in the requirements definition of the case. The second tactic used was the creation and maintenance of a chain of evidence using a mind map model, which detailed where the study's findings came from and how these findings were linked to the search questions and propositions.

### 3.6.2 Internal validity

Internal validity test deals with the evidence for 'why' and 'how' relationships to build the internal validity for the research. For this reason, the study was conducted following a deductive approach. The research propositions were formulated from existing literature, including peer-reviewed journals, institutional reports and conference proceedings, which increase the rigour and reliability of the research.

### 3.6.3 External validity

The analytical generalisation of this study was achieved by comparing the theory with conflicting literature to develop the framework and draw the conclusions. While the comparison of related literature improved the construction of definitions of the study, the comparison with conflicting literature raised the theoretical level of the study.

### 3.6.4 Reliability

The reliability test ensures the correctness and replication of the research protocol. The correctness and replication can be achieved with thorough documentation procedures and appropriate record-keeping (Rowley 2002). For this study, three tactics were implemented: (1) documenting in detail the research process, (2) maintaining a chain of evidence using a mind map scheme, and (3) conducting thematic content analysis using NVivo software to code, visualise and analyse the inputs gained from individual semi-structured interviews.

# 4 The Case: Social Supermarkets in Austria

This section aims to provide a deep understanding of the functions of the Austrian social supermarkets and how its operating model can contribute to the achievement of the UN Zero Hunger goal. It analyses what aspects of their processes, stakeholders' relationships, information flow and logistics can be optimised to increase the operational efficiency of the Austrian social supermarket model by implementing blockchain and Internet of Things.

This analysis provides a new perspective of the Austrian social supermarket model by using a systems engineering approach. This analysis is conducted by using a content analysis technique of secondary sources, including books, handbooks, journal articles, websites, GitHub, peer-reviewed journals, websites, conference proceedings, directives and reports from the Austrian Government, European Commission, the Austrian Institute of Ecology, SOMA Österreich, OECD and EU Fusions project.

The result of this analysis provides a blueprint of the operating model in a blockchain sustainability canvas of the Austrian social supermarket model following the framework proposed by (Osterwalder and Pigneur 2010), which can be used to assess the blockchain potential. The initial assessment of the blockchain potential is performed by using the structured methodology of (Wust and Gervais 2018) considering aspects of participants, permissions and verifiability. Then through experts' consultations have been analysed the benefits and technological components in Section 5.

## 4.1 Case description

Social Supermarkets (SSMs) emerged in France in the late 1980s with a similar social orientation than food banks to directly address food poverty with non-marketable food (Schneider et al. 2015). Nevertheless, they do not deliver free food to people in need as food banks but introduced a new monetary contribution system (Caraher and Cavicchi 2014; Schneider et al. 2015).

Social supermarkets are meant for people with low income, unemployed, retired people with a low pension, ex-convicts, all those who cannot afford to buy food in large stores but who are reluctant to benefit from the charity (Caraher and Cavicchi 2014). Social supermarkets provide people with the choice between different products at heavily reduced prices, and the beneficiaries pay them as any customer in a regular store (Caraher and Cavicchi 2014; Holweg and Lienbacher 2011). Nevertheless, this is not the only solidarity action; SSMs also promote the development of a sense of community ownership and mutuality (Caraher and Cavicchi 2014). Social supermarkets are places where people can be listened to and exchange experiences, rebuild their links with society, reinforce their self-esteem, and develop new competencies through complementary activities such as cooking lessons, workshops, and others (Caraher and Cavicchi 2014).

Social supermarkets are usually recognised as organisations driven by a social mission and consequently as social enterprises (Defourny and Borzaga 2018; Holweg, Lienbacher, and Peter Schnedlitz 2010; Klindžić et al. 2016; Maric et al. 2015; Schneider et al. 2015). They use their business and marketing capacities to create profits, and then these profits are reinvested to achieve social goals for a specific geographical location (Defourny and Borzaga 2018).

The social supermarket vision is to create 'social value' from surplus food to fight against poverty and food waste (Holweg and Lienbacher 2011). Simultaneously, social supermarkets also meet economic and environmental goals, on one side SSMs enable to save money to their members and create new jobs opportunities; and, on the other hand, allow for the reduction of food waste in the supply chain by redistributing surplus food (Defourny and Borzaga 2018).

Social supermarkets have been intensively developed since 2008 as a response to the economic crisis across Europe (Knezevic et al. 2017). Croatia, Austria, France, Belgium, Greece, the United Kingdom, Italy, Germany and Switzerland are some of the European countries where the social enterprise model has been implemented. However, several studies have identified that the operating model of social supermarkets can vary depending on its development level, type of partnerships for the surplus food supply, fundraising activities, legislation and incentives (Defourny and Borzaga 2018; Knezevic et al. 2017; Schneider et al. 2015). Even so, some studies have identified distinctive characteristics of the social supermarket in Europe. Table 4.1. describes the typical attributes of social supermarkets in six European countries: The United Kingdom, Austria, Croatia, France, Switzerland and Germany.

| **Social Supermarkets in Europe** | |
|---|---|
| **Characteristics** | **Description** |
| Organisation type | • Non-profit organization. Social enterprises |
| Beneficiaries | • Consumers at risk of poverty or from low-income groups<br>• Mostly controlled access (membership or identification card) |
| Benefits | • Members pay reduced prices<br>• Prices: From 10% to 30% of the actual value of the products in the market<br>• Poverty prevention<br>• Prevention of food waste through surplus food redistribution |
| Products | • Mostly food and non-food consumables (except alcohol and cigarettes) |
| Workforce Organization | • Mixed. Work with volunteers and long-term unemployed people who are hard to place, including ex-convicts, disable people and others. (approximately from 20 regular to 400 occasional volunteers) |
| Size | • Conventional area is in average 90 sq. meters and largest up to 1,000 sq. meters |
| Sourcing | • Food contributions from retailers, local charity events and food manufacturers<br>• Food acquisition to fill the surplus food supply<br>• Funding sources (private contributions): Annual fundraising initiatives, Charitable Organizations, and Government subsidies<br>• Private companies and individuals: vehicles and cooling storage area |
| Social support | • Coffee shops, training programs, personal development and cooking classes |
| Incentives | • Taxes incentives (for some countries) and governmental subsidies |

| Characteristics | Description |
|---|---|
| Authorities | • Coordination with local social welfare offices and local employment service for users' registration. |
| Inter-organisational relationships | • Business to Business(B2B): Business to Non-profit, Non-profit to Non-profit<br>• Business to Government (B2G): Government to Non-profit and Government to Business<br>• Business to Consumer (B2C): Business to Consumers |
| Regulations | • No specific law with respect to the liability of social organisations<br>• There are guidelines at National and European Level for food redistribution |

**Table 4.1** Common characteristics of social supermarkets in Europe. Source: (The Author).

### 4.2 Subject description

Austria is a landlocked country situated in Central Europe, with nearly 8.7 million citizens (AMS Österreich 2017). According to studies of the Organisation for Economic Cooperation and Development (OECD), Austria is one of the wealthiest countries in the region, having the second-lowest regional disparities in GDP average. In the last decade, its GDP growth was above the OECD average (OECD 2020a). However, Austria showed in 2017 that 9.4% of its population lived in poverty (OECD 2020b) and reached 8% of unemployment (OECD 2020a).

Notably, the youth population is the most affected. Vienna has reached 10% of the youth unemployment population and 9.1% of Austrian children live in a household with a disposable income of less than an average salary in Austria (OECD 2020a). Furthermore, according to a study conducted by Statistics Austria, 21,567 of homeless people were registered in 2017 (Wiener Tafel n.d.).

One strategy adopted in Austria to alleviate hunger and poverty was the implementation of social supermarkets under the umbrella of inter alia SOMA. The first SOMA was established 20 years ago in Linz. The name of ¨SOMA¨ is the abbreviation of ¨Sozialmarkt¨ that means ¨social supermarket¨ (Schneider et al. 2015). SOMA was expanded as a franchise-kind form, and the name was registered as a trademark (Schneider et al. 2015).

SOMA is nowadays the main actor of the solidarity grocery stores in Austria, which comprises a network of 37 social supermarkets along with Austria. SOMA network supports nearly 100,000 people in a situation of economic and social fragility (SOMA n.d.). In addition to SOMA network, some independent social supermarkets were created with similar characteristics, such as Vinzimarkt, Sozialmarkt, Barbara Laden, TiSo Markt, Laube, Der Korb, Krautund Rüben and Sozialladen (Schneider 2013). In 2015, 80 social supermarkets were operating nationwide (Schneider et al. 2015).

SOMA aims to provide an integrated approach to develop a new form of food aid, capable of combining choice, freshness, quality and respect for habits in a retail-like environment. The vision of the founders of SOMA was (1) to prevent consumable food and household products from turning out into waste, (2) help people who are financially at risk of poverty, and (3) support the reintegration of unemployed Austrian residents into society (Holweg, Lienbacher, and Zinn 2010).

SOMA assists the affiliated social supermarkets for organisational matters, facilitates closer cooperation between social supermarkets to perform joint logistics, and helps them to connect with multiple stakeholders in the supply chain. (Holweg, Lienbacher, and Zinn 2010; Schneider et al. 2015). SOMA also provides the infrastructure to its affiliated organisations, such as warehouse, cooling facilities, and others (Schneider et al. 2015).

### 4.2.1 Actors

The EU guidelines on food donation and previous studies on social supermarkets have identified several actors involved in the food donation/acceptance process. These actors represent individuals, organisations or entities that interact with each other during the execution of the process. Following it is described the actors involved in the food donation process of social supermarkets in Austria:

‘**Donor’ organisations**. These organisations are food business operators that provide surplus food from each stage of the supply chain, for instance: food processing and manufacturing companies, retailers, catering, restaurants and hospitality sectors (European Commission 2017).

‘**Receivers’ organisations**. These are all organisations involved in the collection and redistribution of surplus food, which are classified as 'back-line' or 'front-line' organisations, or even one organisation can operate fulfilling both functions. These are non-profit organisations (European Commission 2017).

**‘Back-line’ organisations** are those organisations that collect, transport, sort, store and redistribute surplus food from donors' organisations in the supply chain (European Commission 2017). These organisations serve a network of affiliated charitable organisations, such as food banks and SOMA social supermarkets (European Commission 2017).

Besides, Food banks also play the role of back-line organisations in the operating model of social supermarkets when they transfer food donated from their warehouse to them (Schneider et al. 2015). The food transfer between food banks and social supermarkets establishes an emerging relationship identified as non-profit to non-profit relationship. On the other hand, independent social supermarkets that are not part of the SOMA network can play both roles as back-line and front-line organisations (Schneider et al. 2015).

**‘Front-line’ organisations** receive the surplus food donated from 'back-line' organisations or directly from donor organisations in the food supply chain (European Commission 2017). Social supermarkets as front-line organisations deliver the food donated to the ‘consumers’ (beneficiaries) in different forms: in a retail-like environment, as food packages through mobile supermarkets or prepared food via coffee shops (Holweg and Lienbacher 2011; Schneider et al. 2015).

**'Facilitator' organisations** enable the coordination for food redistribution acting as an intermediary between donors and receiver organisations (European Commission 2017). Facilitator organisations might provide services to enable partnerships and match the supply and potential demand for food (European Commission 2017). SOMA as a network play the role as facilitator organisation by performing joint logistics for the transportation, collection and storage of foodstuffs of multiple social supermarkets that are affiliated to its network (Schneider et al. 2015).

This role also relates to organisations that use technological platforms or other digital tools to follow their respective obligations under EU food law (European Commission 2017). At the very beginning, when social supermarkets emerged in Austria there was the initiative to create an online platform to facilitate the donation process; however, it was not implemented at that time because of political reasons. Furthermore, there is not any platform at the European level as it happens in the United States of America.

**SOMA customers** are people with low income and registered as a consumer in any social supermarket affiliated to the SOMA network. SOMA customers can acquire foods in SOMA supermarkets, food prepared in the coffee shops or buy donated food in packages via mobile social supermarkets. For the registration, they need to prove their residence in Austria and provide supporting documentation for their application declaring their income and stating their dietary requirements – if it is applicable (SOMA n.d.).

**Private donors** are individuals who provide food directly to social supermarkets on an ad hoc basis at the community, or other charity events organised by churches, schools or city fairs (European Commission 2017). Private donors occasionally provide food, and therefore, they are excluded from obligations to the General Food Law as donor organisations concerning occasional handling, preparation, storage, and serving of food (European Commission 2017). There is only a guidance regarding the implementation of provisions of the regulation on hygiene food. (European Commission 2017).

**Public Employment Service in Austria,** better known as Arbeitsmarktservice, is the governmental office responsible for consultation, job referral and unemployment services for people who are residing in Austria (AMS Österreich 2017). Public Employment Services coordinates with social supermarkets, the registry of unemployed people as members of social supermarkets (Schneider et al. 2015).

**Federal Social Welfare Office in Austria** (Bundessozialamt BASB), is the governmental agency responsible for maintaining and improving the quality of life of residents in Austria. This organisation is responsible for coordinating the provision of health services and social welfare through municipal institutions. Local social welfare in Austria coordinates the registry of beneficiaries in social supermarkets, conducts analyses and keeps statistics (Schneider et al. 2015).

**Other Charitable organisations** are non-profit organisations that can support logistics, donate food or provide financial assistance to help the social supermarkets' operation (Schneider et al. 2015).

#### 4.2.2 Operating model

The Austrian social supermarket model has shown a community-wide strategy that aims to address the core causes of food insecurity and hunger in Austria. Its operating model covers five main factors: funding sources, donor partnerships, workforce, delivery methods and logistic process. Figure 4.1 in Appendix F illustrates a simplified representation of the Austrian social supermarket model.

As far as funding sources concern, the dominant funding sources of social supermarkets in Austria are donations. SSMs are non-profit organisations driven by social entrepreneurs, who plan, organise, and manage the donations and government subsidies to provide social benefits to specific local communities. Start-up costs are unique investments made by participating communities or other donors (Schneider et al. 2015).

In terms of donor partnerships, donations have become the instrument to help corporations to achieve their Corporate Social Responsibility and to be benefited from tax subsidies (Holweg and Lienbacher 2011). Private companies, charitable organisations and individuals make in-kind and cash donations, being retailers and manufacturers the major contributors to food donations (Meissner and Schneider 2011).

In-kind donations can be made either regularly or occasionally. The donations received from retailers and manufacturers are typically made on a regular basis. For that, they sign a food donation agreement with social supermarkets to specify aspects concerning product type, estimated frequency, cooling requirements, transportation, storage specifications, and legal liability. These agreements are formulated following the Austrian legislation for food hygiene and food safety in place and EU guidelines on food donation (Meissner and Schneider 2011).

On the other hand, occasional donations made by individuals, churches, or charity events do not need any written agreement; however, they also need to follow the Austrian food hygiene and safety regulations. Furthermore, some services and equipment can be donated such as transportation, storage, cooling systems, and others (Meissner and Schneider 2011)

Concerning the workforce, mostly volunteers and employees support the activities involved in the back-line and front-line in the surplus food redistribution process. Some employees are part of social aid programs, which are sponsored and managed by the Public Employment Office (AMS) and the Federal Social Welfare Office in Austria. These social programs consist of providing a grant to unemployed people who are hard-to-place to help them to integrate into the labour market (Holweg, Lienbacher, and Zinn 2010; Meissner and Schneider 2011).

These grants have a length of a maximum of 12 months, which are managed through social supermarkets. Social supermarkets act as the employer, and they report the performance of the employees to the Austrian government agencies. Under these programs are also included additional support such as training, counselling and expert guidance (Meissner and Schneider 2011).

The Austrian social supermarkets model involves three mechanisms to deliver social support to the people in need: (1) trough small retailers (SSMs), selling the products donated at heavily reduced prices with a sales area of 90 square meters approximately (Schneider et al. 2015), (2) via mobile social supermarkets that sell foodstuffs and goods in remote locations at a reduced price (Meissner and Schneider 2011; Schneider et al. 2015), and (3) provide prepared food through social coffee shops (Meissner and Schneider 2011; Schneider et al. 2015).

The concept of mobile social supermarkets was created to reach locations where there exists low population density, and it is not suitable to establish a fixed social supermarket (Schneider 2013). Mobile social supermarkets prepare food packages that are delivered by bus in specific stops across different regions (Schneider 2013). In 2005, mobile supermarkets operated in the region of Vorarlberg, which is situated in the northern part of Lower Austria (Schneider 2013). In 2011, it was counted that around 29 stations already operated in other regions such as Salzburg, Lower and Upper Austria and Styria (Meissner and Schneider 2011).

Social coffee shops were implemented not only to provide cheap meals and food but also to offer a place for meeting people under the same conditions or find new friends since the facilities are open to everyone (Schneider 2013). The coffee shops were also a place where beneficiaries can find useful information and professional assistance as counselling services from social workers (Schneider 2013).

For these three delivery mechanisms, SOMA set the following principles: (1) all goods received are offered via social supermarkets to only beneficiaries at symbolic prices or free of charge, (2) all donated goods are free of charge by the partners, alcohol and cigarettes are not trade, (3) the beneficiaries are seen as customers and not as 'receivers' of goods, (4) all social supermarkets are non-profit organisations, (5) profits should be reinvested in social projects, and (6) purchases are recorded and limited to personal needs of the beneficiaries (SOMA n.d.).

The customers' registration process is handled using two different ways, one is through the own social supermarket process, and the second method is to be registered in coordination with the local social welfare office (Schneider et al. 2015). To be able to buy foodstuffs in social supermarkets, customers need to apply for a pass or a card that allows them to access any distribution method of SOMA (Weichselbaum 2009). A close examination of family or individual circumstances is performed, including income assessment, to obtain the pass (Weichselbaum 2009). People with income considered to be at or below the poverty line are eligible to shop in SOMA social supermarkets (Weichselbaum 2009). The card is used as personal identification and is valid for one year, after which customers need to reapply (Weichselbaum 2009).

Customers who benefit from social supermarkets are families with several children, those who receive welfare benefits, the employed, retired people, homeless people, students, teenagers with meagre income or no income, as well as single parents (Weichselbaum 2009).

Social supermarkets set an expenditure limit per week in order to avoid abuse of the market system, such as bulk purchasing (Weichselbaum 2009). Furthermore, social supermarkets monitor and analyse the needs of their customer on an annual basis (Schneider et al. 2015).

### 4.2.3 Logistics process

From a supply chain point of view, the core process of social supermarkets as a distribution network is logistics. Social supermarkets act as food storage and distribution depots for small retailers, in a similar way as retail distribution centres service of large stores. Social supermarkets receive food donations of surplus food. Then they distribute the food donated, either as an independent social supermarkets serving as both back-line and front-line or through a network of social supermarkets such as SOMA (Schneider et al. 2015; SOMA n.d.)

Social supermarkets collect, transport, store, process and ship food out to the community. With the help of employers and volunteers, the warehouse operation inspects, sorts, packages and stores the foodstuffs in preparation for distribution to social supermarkets or directly to the community through coffee shops or mobile supermarkets (Meissner and Schneider 2011; SOMA n.d.)

The food collection and transportation are usually the responsibility of social supermarkets; nonetheless, in some cases, retailers or private companies can offer this service as well as a donation (Schneider et al. 2015). SOMA network can conduct joint logistics via its redistribution centres (Meissner and Schneider 2011). Trucks are utilised to pick up loads from various processing and retailers’ warehouses within 48 hours and stored in one of the two intermediate warehouses of SOMA network (Meissner and Schneider 2011). Inspection, sorting and packaging activities take place in social supermarkets’ warehouses.

During the sorting activity, the essential aspects to help to judge the products' status are: 'sell by' and 'best before date' (Defourny and Borzaga 2018). 'Sell by' refers to the last date the product should be sold, for instance, on fresh bakery products. 'Best before date' relates to the approximate time in which the product will be available at the highest quality.

In addition, a set of guidelines for sorting food was developed by The Austrian Institute of Ecology and ECR Austria working group 'Social Sustainability'. These guidelines define specific criteria for the selection of foodstuffs for human consumption including (1) foods arising from the overproduction of regularly available goods, (2) when shelf life is too short for a retailer, exceeds promotional period or exceeds the minimum storage life, products from trade presentations, for instance, products for display, promotional events and others that were not delivered, (3) products produced in foreign countries that meet Austrian food law requirements however they cannot be sold in large stores, (4) food products that have a wrong year, product specifications in a foreign language, loose labels, no labels or incorrect description of ingredients, and others. (Meissner and Schneider 2011).

After sorting and packaging activities, food is stored using cooling systems and then distributed to social supermarkets. The delivery to the branches takes place via a list of redistribution defined by each SOMA social supermarket (Meissner and Schneider 2011).

Figure 4.2 in Appendix F illustrates the simplified resource flow in the food donation chain**.** This figure depicts three specific streams: (1) when food banks may distribute surplus food from retailers and manufacturers to social supermarkets, (2) a joint logistic process carried out through social supermarkets networks such as SOMA, and (3) surplus food redistribution performed directly by independent social supermarkets as well as their possible interaction with joint logistics warehouses.

Based on the resource flow in the food donation chain, it shows the following aspects: (1) there is a high degree of uncertainty of surplus food supply concerning volumes, quality and timing, (2) there is not a coupled operation between the quantity of surplus food and the food demand owing to the lack of data available from both social supermarkets and donors, (3) There may be numerous of donor organisations involved in the food donation chain, (4) they may also be a high number of social supermarkets involved in joint logistics, (5) there are guidelines for waste management (not enforced by law) at the Austrian and European level with particular focus on generating environmental benefits, (6) there may be more than one intermediate distribution centre before shipping the goods to social supermarkets. Currently, there is not any quantitative study to show the benefits of the implementation of the material flow for food donation considering these aspects.

### 4.2.4 Business Processes Identification

Based on the analysis of the literature, it has been identified six main processes that support the operation of social supermarkets: (1) Customers registration (described in section 4.2.2), (2) Administering of social programs for unemployed people in coordination with Governmental agencies (described in section 4.2.2), (3) Sorting food process (described in section 4.2.3), (4) Registry and report of donors for a tax deduction (described in section 4.2.5), (5) Surplus food redistribution from regular donors, and, (6) Surplus food redistribution from occasional donors

For this study, these processes can be classified as core and support processes. Core processes are those that add or deliver direct value to end consumers, while support processes are those that enable the execution of core processes. According to this classification, two core processes add direct value for alleviating hunger, which is the redistribution of surplus food for both occasional and regular food donations.

The redistribution of surplus food process from regular food donations involve the following activities: (1) Retailers identified surplus food that is close to 'by best before date' or 'sell by', (2) Sorting food is performed to classify goods for human consumption or non-food items for distribution at retailer warehouse, (3) Donors advise its intention to donate products to social supermarkets, (4) Reach an agreement with the donor, particularly on how the products will be delivered and what are the benefits of the donor will have, (5) Sign a food donation agreement including a waiver legal liability provided by social supermarkets, (6) Collect the goods at the donors' warehouse, (7) Register the food and non-food donated, including the description of the donor, address, products type and other specifications, (8) Transport and deliver the food to the SOMA warehouse or a logistics company in case of joint logistics, (9) The distribution centre receives and store the foods, (10) Sorting food takes place at SOMA warehouse, (11) Packing and labelling of goods identified for human consumption are performed, (12) Ship to either social supermarkets, social coffee shops or mobile supermarkets, (13) Update inventory at the points of sale, (14) Notify that food is ready to purchase of the products available to customers, and (15) Customers buy food at reduced prices (Meissner and Schneider 2011). Figure 4.3 in Appendix F illustrates the core business process of surplus food distribution for regular donations.

The difference between occasional and regular donations relies on that in the case of the sporadic food donation process is not required to reach a food donation agreement between the parties. In contrast, in the regular donation, it is compulsory.

### 4.2.5 Legal Context

At the Austrian level, there is no specific legislation or guidelines for the food donation process; nonetheless, the main piece of law that regulates the obligations for collection, processing and transportation of waste is the Austrian Waste Management Act 2002. The Waste Management Act lays down the principles for: waste prevention, preparation for reuse, recycling, other utilisation, and waste disposal (Landesgesetzblättern der Länder 2002). The Waste Management Act also establishes the creation of a waste management plan that includes obligations and initiatives to promote the reallocation of foodstuffs suitable for human consumption (Landesgesetzblättern der Länder 2002).

The Austrian Waste Management Plan 2011 contains several measures to limit food waste including the development of incentives systems for surplus food redistribution, the clarification of the legal situation regarding any claims for damages when the food is donated. Besides, it contains the development of standards that provide a better understanding of donors on how the foodstuffs are handled in the food donation process. (Bundesministerium für Land- und Forstwirtschaft 2011).

Additionally, the Food Safety legislation and Consumer Protection Act define applicable rules in particular for food handling in adherence with the General Food Law (Federal Law Gazette No 13/2006) (European Commission 2019).

Under the General Food Law, any organisation that receives surplus food, including Charitable or redistribution organisations are considered food business operators. Food business operators have the responsibility for ensuring the requirements of food law and food control, for instance: refuse products proposed that could represent a risk for the final consumers, the implementation of Hazard Analysis and Critical Control Point Principles (HACCP), and other measurements (European Commission 2017).

Social supermarkets, as food business operators, are also responsible for providing accurate information to the consumers regarding the date of minimum durability of the 'best before' or 'use by' date, name of food, the official language of the country where the food is from, any special storage conditions and other specifications (European Commission 2017).

Article 17.1 of the General Food Law establishes the guidelines and responsibilities in the agri-food chain in the event of a food safety concern (European Commission 2017). Public health authorities will investigate the whole supply chain on a case-by-case basis to identify the origin and cause of the problem and then determine the liability of a given food business operator(s) (European Commission 2017). In terms of legal liability of the food donated, SOMA social supermarket provides a waiver of legal liability to all donors when the products are transferred to them (Schneider et al. 2015).

Social supermarkets also need to observe the traceability requirements and notify unsafe food according to Article 19 of the General Food Law (European Commission 2017). Food donors and food business operators are required to implement a traceability system that identifies whether the food has been placed either on the market or if it has been made available free of charge (European

Commission 2017). Donors are required to keep records for a minimum of 5 years, while social supermarkets only from 2 to 5 years (European Commission 2017).

On the other hand, at the European level, the EU guideline on food donation seeks to address the legal and operational barriers for donors and receivers to the distribution of food for human consumption, as well as to support the current efforts, at both national and European levels, as well as to promote balanced diets for all European citizens in particular for children (European Commission 2017).

This guideline facilitates compliance of relevant requirements to food safety, food hygiene, traceability, VAT, primary responsibility and legal liability applicable to non-for-profit food redistribution activities, including social supermarkets (European Commission 2017). Moreover, it promotes conventional interpretation by regulatory authorities in the EU Member States of the European Union (European Commission 2017). Most of these initiatives are still being under development.

According to the Value Added Tax (VAT) directive, the foodstuffs donated to the poor, little or no VAT is paid; however, there are exceptions for products that are standard rated such as chocolate biscuits, crisps, and others (European Commission 2017).

Companies operating in Austria and the public can deduct up to 10% of last year's taxable income (European Fundraising Association 2018). Charities Organisations are enforced by law to identify and to formally report their donors to the Authorities for the tax deduction (European Fundraising Association 2018). Notably, the tax incentives in Austria are less than the deduction allowed in Germany and France, companies in these countries can deduct up to 20% of their annual taxable income (European Fundraising Association 2018).

### 4.2.6 Information Management

This section describes the essential requirements to capture, store, share and manage information across the food donation chain and also the data that supports the activities of the operating model of social supermarkets in Austria. These requirements were gathered from the existing literature, the Austria Waste Management Plan, EU guidelines on food donation and General Food Law.

#### 4.2.6.1 Users profile

One essential requirement of the social supermarket operating model is to register, assess and create a consumer's profile. The consumer profile contains the demographic data, income and dietary information. Social supermarkets firstly register and evaluate the information of applicants to determine if the person is suitable to become a consumer. Whether the person fits the requirements, a unique identification customer number is assigned. It is issued a pass or a card, which will identify the customer and to grant him access to social supermarkets. The customer circumstances are evaluated on an annual basis. The registration can be done either directly with the social supermarket, through the Local Social Welfare Office or the Public Employment Service Office (Meissner and Schneider 2011).

Additionally, social supermarkets need to register, track and report who employees are part of the social integration programs of the Public Employment Service Office. Social supermarkets capture and share information regarding grants, duration and employee performance with the Public Employment Service Office. The length of each employment contract and the amount of the grant are decided and sponsored by the Public Employment Service Office (Meissner and Schneider 2011).

#### 4.2.6.2 Management of food donation agreements

According to the General Food Law regulation, food business processors need to identify, register and report any person from whom they have received food, food-producing animals or any substance intended to be incorporated into a portion of food. Social supermarkets should have in place systems and procedures to identify the business to which their products have been supplied (European Parliament 2002).

Besides, social supermarkets are required to identify private donors by name and date of birth as well as to report donations to the Authorities for a tax deduction (European Fundraising Association 2018).

#### 4.2.6.3 Traceability

Food business processors are required by law to implement the procedures and systems to record, trace and store information regarding products supplied and suppliers. This information must be available for the corresponding authorities on demand. Food should be adequately labelled or identified to facilitate its traceability (European Parliament 2002).

The information required for traceability must contain at least the supplier name, address of the supplier, identification of products supplied, date, time of the transaction, volume or quantity. Traceability obligations are applicable for all the actors in the supply chain, in particular, the 'one step back' and 'one step forward'. Social supermarkets are only required to record the information of 'one step back' (European Commission 2017).

#### 4.2.6.4 Alert system

According to Article 19 of the General Food Law, social supermarkets, as food business operators are required to withdraw, recall or notify unsafe food. Social supermarkets are obliged to initiate the procedures to remove the food from the market and to inform competent authorities. In case the products have reached to the consumers, they need to notify them as well (European Parliament 2002).

#### 4.2.6.5 Auditability and Accountability

Social supermarkets are required to store the information related to donors (suppliers), products, volumes and quantity from two to five years and make it available to the competent authorities on demand (European Commission 2017; European Parliament 2002). Social supermarkets also are required to submit a formal report to the Tax authorities, detailing the donors and the food or goods donated (European Fundraising Association 2018).

#### 4.2.6.6 Transparency

Social supermarkets need to ensure the maximum transparency to donors that the products donated will no longer enter the market to be re-sellable or that additional cost will be incurred (Meissner and Schneider 2011).

#### 4.2.6.7 Inter-organizational Collaboration

Another essential requirement is to have a convenient and flexible platform to easily engage with a multi-stakeholder network (Knezevic et al. 2017), as well as share timely information considering these three types of relationships: 1) Business to Business (B2B). For surplus redistribution Social supermarkets establish 'business' relationships with retailers and food manufacturers, as well as the relationship with other Charity organisations such as Food banks (Non-profit to Non-profit relationship), 2) Business to Consumer (B2C). Social supermarkets serve as the provider to the final consumer of the food redistributed, and, 3) Government to Business (G2B). Social supermarkets support the implementation and performance of social reintegration programs (Holweg and Lienbacher 2011).

#### 4.2.6.8 Flexibility and interoperability

The adoption of sustainable practices in the food supply chain requires the flexibility and adaptability of current logistics practices to ensure timely data sharing in the food donation process (Holweg, Lienbacher, and Zinn 2010).

#### 4.2.6.9 Data Security

Another vital requirement is to secure customer, employees and donors’ sensitive data. Social supermarkets procedures for data privacy and data security need to be in compliance with the General Data Protection Regulation in place.

### 4.2.7 Impact on sustainability

Surplus food redistribution is one of the best solutions to alleviate hunger and achieve the integration of environmental sustainability with economic benefits (Schneider 2013). Unfortunately, there are limited studies to assess the environmental impact of surplus food redistribution of social supermarkets since there is no data available on how much food is donated since most of this data is considered confidential for many Charity Organisations (Schneider 2013).

A study conducted in SOMA of Hilfswerk investigated the approximate amount of food recovered in order to determine the amount of carbon dioxides that could be eliminated by redistributing surplus food in one year. During 2011, the daily visits of approximately 240 customers were recorded, where it was identified that around 525 tonnes of food could be recovered within one year. The food counted had the following distribution: vegetables (198 tonnes), bread (101 tonnes), fruits (70 tonnes), soft drinks (57 tonnes) and yoghurt products (53 tonnes), as well as other products, accounted each for less than 24 tonnes a year (Schneider 2013).

Considering only the 76% by mass of the business volume to calculate the CO2 equivalents, it was counted for 202 tonnes of CO2 during production and processing, which represents the amount of carbon dioxide emissions that could be eliminated by only one SOMA supermarket in one year (Schneider 2013).

## 4.3 Identification of blockchain frameworks suitable for the food donation process

Following the structured methodology proposed by (Wust and Gervais 2018), in this section, it is analysed the blockchain properties of several blockchain frameworks in order to determine which best fit the requirements of the food donation chain of social supermarkets. This analysis was performed by conducting document analysis, which is further enriched with experts' consultations. The selection process is comprised of three steps: (1) identification of the existing blockchain frameworks and key properties, (2) categorisation of the blockchain frameworks based on their properties and adaptation of the methodology taking into account this classification, and (3) assess the requirements of the food donation chain following the flow chart to determine the blockchain frameworks that best meet these requirements.

Firstly, the identification of the existing blockchain technologies was made by researching academic papers, websites and GitHub of each platform. The data gathered of the current architectures include the following characteristics: name of the blockchain architecture, name of the maintainer, the type of permission of the blockchain, type of consensus, whether these architectures are smart contacts and IoT supported. Appendix G contains a list of blockchain frameworks. Sources: (BitcoinCore n.d.; Corda n.d.; Enterprise Ethereum Alliance n.d.; Ethereum n.d.; Hyperledger Fabric n.d.; Hyperledger

Iroha n.d.; Hyperledger Sawtooth n.d.; Kadena n.d.; Multichain n.d.; Open Chain n.d.; Quorum n.d.; Ripple Inc n.d.; Tendermint n.d.; Vos et al. 2018).

As a result of this research, it has been identified a list of thirteen blockchain frameworks. Most of these frameworks are open-source software and available for further development and customisation. These frameworks are usually supported by communities composed of adopters, innovators, developers and business. Some blockchain frameworks have been developed in alliance with software or hardware manufacturers such as IBM, Intel, SAP or consortiums such as Linux Foundation.

It has been identified that three out of thirteen blockchain frameworks support smart contracts and Internet of things and also have met requirements in the supply chain. These three architectures are Enterprise Ethereum, Hyperledger Sawtooth Lake and Hyperledger Fabric. On the other hand, Quorum and Ripple support smart contracts with some implementations of supply chain use cases; however, they have not implemented integrating Internet of Things. Finally, Tendermint is a middleware that shows potential for the interoperability of multiple blockchain networks.

Secondly, the categorisation of the blockchain frameworks was following the methodology of (Wust and Gervais 2018) taking into account the following properties of blockchain technology: permission (please refer to Table 2.3), public verifiability, transparency, trusted third party and trust level on the network.

Based on the findings obtained from the first step, the flowchart to determine what blockchain framework is suitable for this specific use case has been updated considering the following classification: Permisionless Bitcoin and Ethereum, Public permissionless - Enterprise Ethereum and Hyperledger, and Private permissionless: Multichain. Figure 4.4 illustrates the flow chart updated, incorporating this classification.

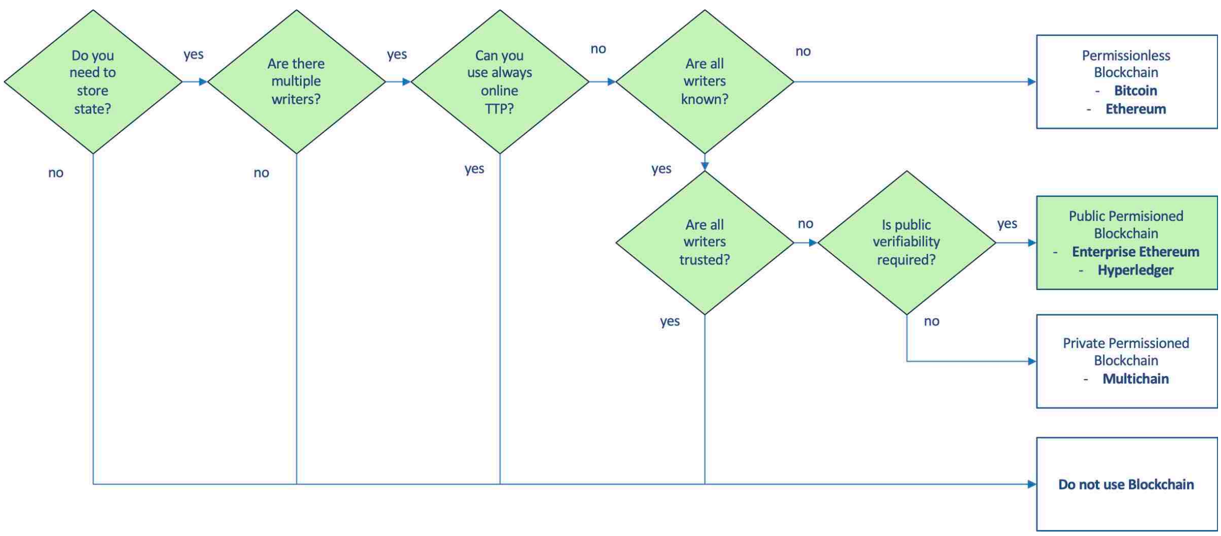


**Figure 4.1** Flow chart to determine if blockchain is an appropriate technology for the food donation chain. Adapted from: (Wust and Gervais 2018).

Finally, the assessment of the blockchain enterprises architectures was conducted by answering the questions of the flow chart as follows:

**Do you need to store state?** Yes. The food donation process requires to register the states of the transaction of the foodstuffs trading as well as meet the requirements of traceability, auditability, and social programs administration.

**Are there multiple writers?** Yes. The social supermarket model involves the interaction of numerous stakeholders, including donors, facilitators, back-line organisations, front-line organisations and government agencies as well as other charities organisations such as Food Banks.

**Can you always use online Trusted Third Party (TTP)?** No. The trusted third party can function as a certificate authority in the setting of permissioned blockchain since all the writers should be known. Also, it was identified that the food donation process requires the implementation of smart contracts, which does not need a TTP to operate.

**Are all the writers known?** Yes. It is needed to record who is providing the food and who is receiving it; therefore, all users need to be known.

**Are all the writers trusted?** No. It is necessary to have a central unity that grants or revokes access, read and write the system.

**Is public verifiability required?** Yes. The food donation process needs to provide transparency, auditability and accountability. For that, it is necessary to allow anyone to verify the correctness of the state of the system.

Figure 4.4. illustrate the flow chart to determine the blockchain architecture based on the social supermarket requirements. It indicates with green the answers recorded and the result. The result of this assessment indicates that Enterprise Ethereum, Hyperledger Fabric and Hyperledger Sawtooth are the most suitable blockchain enterprise architectures to meet social supermarket requirements. Besides, performing cross-referencing with the list of enterprise blockchain architectures of Appendix G confirms that these enterprise architectures support smart contracts, which are an indispensable feature for the implementation of trading and transfer of foodstuffs, as well as their interconnectivity with Internet of Things.

## 4.4 Blockchain sustainability canvas for food donation

In the previous sections of this chapter, the social supermarket model in Austria was analysed holistically detailing its information management requirements. The requirements definition allowed for the identification of candidate enterprise architectures for implementing Blockchain and Internet of Things. This section aims to provide a further analysis concerning the identification of particular advantages and incentives for sustainable participation in a peer-to-peer network (incentives assurance). It identifies any possible change in the governance structure and the roles of the stakeholders in the network (partnership network), opportunities to add new services among the stakeholders (network experience), and it identifies any potential opportunities of business process re-engineering (Osterland and Thomas 2018).

Appendix H contains the analysis of the use case of social supermarkets using the blockchain sustainable canvas, which is also described below:

**The incentive for fair change section** identifies the network participants and describes the advantages and disadvantages of participating in the network. The participants in the network of social supermarkets are donors, facilitators, back-line operators, social supermarkets and government agencies. Concerning the advantages of participation, it has been identified that the following properties bring significant advantages in the food donation chain: trading for food donation agreements management, traceability of foodstuffs, transparency and the implementation of performance indicators for food waste prevention, surplus food redistribution and sustainability impact. On the other hand, the disadvantages for participating in the network rely on the side of the retailers who might need to increase the workforce and thus increase their operational costs to process regular food donations.

**The innovation for the networking section** identifies five aspects. The first aspect is to identify the business process that is suitable to be performed in the network. A platform can support five out of six processes of the operating model of social supermarkets: customers registration, regular and occasional surplus food distribution, social programs management and register and report of tax deduction. The sorting process cannot be automated since this is a manual process.

The second aspect relates to how trustiness can be enabled in the blockchain network. As all actors should be known in the network to increase the trust of the network. Alongside, to have validators that grant or revoke access to the network, for this specific case, social supermarkets should be the entity that plays this role.

The third aspect is the identification of the elimination of intermediaries in the current process. SOMA coordinates joint logistics which involves performing numerous administrative activities. With the implementation of a blockchain network where all actors can collaborate simultaneously, the centralised administrative burden can be reduced.

The fourth aspect is to identify the side channels to establish the coordination apart from blockchain, which possibly is email and manual data registration along the process. The fifth aspect is the actors who govern access to the blockchain network. For this use case, SOMA will be the entity which governs access to the network. On the other hand, the process flow would be automatically managed by deploying smart contracts.

**The process optimisation section** identifies the opportunities for re-engineering existing business processes. There are three potential processes optimisation, which are: online transparency for donor organisations in order to track that the food donated is for the exclusive use of social supermarkets, physical traceability of foodstuffs using RFID technology and sensors for Internet of Things, and make public the demands and offers of food donations among the stakeholders so as they can define a distribution plan based on their capacities and local communities requirements.

### 4.5 Summary

In this chapter, it was analysed the benefits of implementing blockchain and Internet of Things in the food donation process by conducting document analysis. Firstly, the case of social supermarkets was introduced and analysed using a system engineering perspective for requirements definition. It was identified and analysed the operating model of social supermarkets in Austria, including the identification of actors, business processes, logistics, legal context, information management requirements and their impact on sustainability.

Social supermarkets are driven by social innovation following a wider-community strategy, support the implementation of social programs in coordination with government agencies and promote social inclusion. The actors involved in the social supermarket model include organisations, individuals and government agencies. It has been identified six processes, being two core processes that generate value to alleviate hunger and poverty and the four processes supporting the execution of them. Most of the information management requirements are enforced by national laws and EU guidelines for food safety, food hygiene and food donation. These requirements involve users profile management, trading (food donation agreements), traceability, alert system, auditability and accountability, transparency, inter-organisational collaboration, flexibility, interoperability and data security.

Following the structured methodology of (Wust and Gervais 2018), it was identified candidate blockchain frameworks that could meet the social supermarket requirements. These frameworks have the following properties: all are public permissioned architectures, are supported by smart contracts and support the interoperability with RFID technologies and Internet of Things. Finally, it was analysed the impact of the implementation of blockchain technology and Internet of Things in the food donation process by using an engineering framework adopted from the business model canvas. This analysis particularly identified the potential changes in governance, elimination of intermediaries, process re-engineering as well as analysed the advantages and disadvantages of the actors using a blockchain-based supply chain platform with Internet of things. The result of this work allows for providing a deep understanding of the social supermarket model, requirements definition and the selection of the most suitable blockchain architectures for the surplus food redistribution.

# 5 Findings

This section presents the findings obtained from experts' consultations. The empirical data was gathered by conducting semi-structured interviews via Skype with a minimum duration of 40 minutes and up to 120 minutes. An interview guide was designed maintaining the connection with the research questions and research propositions of the research to increase the level of reliability of the study, which is described in Appendix B. Besides, two questionnaires were formulated considering the area of specialisation of the interviewees, which are described in appendices D and E.

The first questionnaire aimed to gather data regarding the frameworks and practices for surplus food valorisation, current challenges of retailers and social supermarkets in the food donation chain, as well as the operating model of social supermarkets in Austria. The experts of this target group have more than fourteen years of experience in the fields of food waste management, retailing and social supermarkets in Europe. In addition to their practical knowledge, both experts have worked as researchers in several projects connected with social supermarkets and gathered data directly in the field in the retail sector and social supermarkets, including activities in the food donation process ranging from products collection to delivery of foodstuffs to people in need. The empirical data obtained from the interviews and the data gathered by conducting a document analysis of section 4 were triangulated to provide a generalisation of the concepts and theory building. This triangulation involved the analysis of the operating model, resources flow in the food donation chain, business process identification and information management requirements. The result of this analysis provides a deep understanding of the social supermarket from a systems engineering perspective, which then it was used to validate the blockchain and Internet of Things potential.

The second questionnaire targeted to collect data regarding aspects considered for selecting a blockchain framework, identify the blockchain frameworks suitable for the food supply chain as well as the incentives for participation. The experts of this target group have proved experience in the engineering lifecycle and in the strategy design for implementing blockchain-based and Internet of Things based solutions in the food supply chain. One expert is specialised in topics related to process mining on blockchain. Before the interviews taking place, a summary of the case study, the questionnaire described in appendix E and the blockchain sustainability canvas described in appendix H were provided to the interviewees.

All the interviews were recorded, transcribed from audio recordings to text, and coded using NVivo software to perform thematic content analysis. The results of the thematic content analysis and its data triangulation with secondary sources are presented in this section.

## 5.1 Concepts and frameworks for surplus food management

The results confirm that the current legislation on food waste management in the European Union is the most important mechanism of reporting and measuring the food waste amounts, jointly with the waste framework directive revised in 2018 (Food waste and SSMs expert, 2020).

> ¨*There have been many different definitions of food waste, and still, there are many definitions, but now it is possible to refer to one definition in the European Union*¨ (Food waste and SSMs expert, 2020).

Both experts confirmed that the waste hierarchy is an essential part of policy development and mechanism for surplus food redistribution since it defines the actions starting from food prevention, then re-use, recycling and use for animal feed and so on (Food waste and SSMs expert, 2020).

The waste hierarchy application facilitates the incentives for food donation, which is the second effort after the waste prevention measurements (Food waste and SSMs expert, 2020). A relevant finding is that the Corporate Responsibility argument plays a vital role in the retail sector to facilitate surplus food redistribution as well. (Retailing and SSMs expert, 2020).

The result of the analysis of the interviews confirmed that there are two critical activities in practice during the food donation process that are not standardised:  the food sorting process and the index for measuring the sustainability impact resulted from the surplus food redistribution (Retailing and SSMs expert, 2020).

The sorting process in the food donation chain relates to the identification of the products that are declared unsellable but still fit for human consumption. There are several causes of surplus food, including an oversupply of products that cannot be returned to the supplier, products that are closed to their 'best before date', and any legal or commercial reasons not to sell them in the traditional supermarkets. According to (Food waste and SSMs expert, 2020), in Austria, there is one guideline that deals with the legal aspects of the food donation from companies, not only retailers but companies in general, and there is another one for practical issues.

The practical guide was developed in Austria by social organisations in coordination with the ECR group (Efficient Consumer Response), which is an International workgroup with the goal of improving the supply chains and increasing the value for consumers in the whole system (Retailing and SSMs expert, 2020).

This practical guide identifies and classifies by groups of food products which are fit for human consumption to be donated. This guideline usually is attached to the food donation agreements signed between donors and charities organisations. However, this guideline is still subject to the interpretation of the stores' managers of the retailers as well as the managers of the social supermarket (Food waste and SSMs expert, 2020).

> ¨*The retailers cooperate with different types of social organisations, they have on Monday this organisation, which will take the surpluses today, they have to sort it according to their requirements, and tomorrow another organisation will come, and they have other requirements*¨(Food waste and SSMs expert, 2020).

These situations seem to impact logistics planning, and the workforce demands on the retail side to handle the food surpluses in both distribution centres and outlets.

On the other hand, the results of the interviews provide evidence that there is a lack of an index for measuring the sustainability impact of the surplus food donation. (Food waste and SSMs expert, 2020), emphasised that it is a methodological issue because it is difficult to collect data of surplus food redistribution at large-scale for the whole country because of the great diversity of Charity organisations (Food waste and SSMs expert, 2020).

According to (Food waste and SSMs expert, 2020), there are some socio-economic studies that have measured the surplus food redistribution impact; however, there is not an agreed methodology to measure it at large-scale. The only methodological framework available to measure the environmental impact is the life cycle assessment. Likewise, (Retailing and social supermarkets expert, 2020) confirmed that there was a pilot project to estimate how much food waste was prevented by a social supermarket; however, the study is not representative to measure the social impact of social supermarkets since all they are different in terms sizes and capacity of the volume.

### 5.2 Drivers and challenges in the food donation between retailers and social supermarkets

The results of the analysis concerned the drivers and challenges for the food donation via social supermarkets go beyond the existing literature, uncovering logistical, infrastructure and behavioural factors that have a significant impact in the operational efficiency in the food donation process.

Five drivers have been identified as the main reasons why retailers are motivated to donate surplus food. The first one is the Corporate Social Responsibility (CSR) argument in the retail sector (Retailing and SSMs expert, 2020). Corporate Social Responsibility, which relates to establishing voluntary measurements and initiatives to support the environmental protection, the wellbeing of employees and generates social benefit, which includes strategies to reduce the shrinkage rate by limiting food waste.

The second driver is the brand image of the retailers to build a good reputation in the eyes of consumers, stakeholders, employees and society in general (Food waste and SSMs expert, 2020). The third driver is the moral and ethical considerations of the stores' managers of the retailers. In individual researches performed by the experts revealed that managers of the outlets feel bad if they need to waste food, which is still fit for human consumption (Food waste and social supermarkets expert, 2020; Retailing and social supermarkets expert, 2020). There is a moral burden because they cannot make their decision with autonomy and independence to limit food waste (Retailing and SSMs expert, 2020).

The fourth benefit is the monetary gain obtained from the food donation, which is clearly defined in some countries where there exist tax incentives such as France (Food waste and SSMs expert, 2020). However, both experts emphasised that most of the companies do not know how to measure the economic benefit generated from food donations since they do not register the food donated (Food waste and SSMs expert, 2020; Retailing and SSMs expert, 2020). One aspect to be considered as part of the measurement of the economic benefit is the reduction of disposal cost of food waste. It is crucial to mention that not all countries have these types of incentives. Nowadays, retailers in some countries need to pay for donating food (Food waste and SSMs expert, 2020).

The fifth driver is the legal context of some countries, where there are tax incentives such as France; however, some countries need to pay taxes if they waste food, and they do not pay taxes if they donate food. By contrast, Austria is not interested if retailers throw away food in the residual bin or the aerobin or if the food is given to social organisations (Food waste and SSMs expert, 2020). This contextual factor per each country can incentivise or can be a barrier for food donations.

As it was previously identified in the literature, the food donation process is more fragmented and less structured than the typical supply chain, involving the participation of multiple stakeholders including donors, charities, organisations, private companies and government agencies. In this section, it is described as the challenges identified on both sides, including the retailers and social supermarkets perspectives.

One first aspect highlighted by (Retailing and SSMs expert, 2020) is that:

> *¨Retailers are doing a fantastic job in terms of efficiency. Their shrinkage rate is one, two, three per cent far below of the waste rates of households, or other parts of other stakeholders' groups in the supply chain, but the issue is that the volume which accumulates in the retail store is quite significant and therefore the pressure comes to¨* (Retailing and SSMs expert, 2020).

Although retailers have improved the operational efficiency regarding the implementation of food prevention and redistribution measurements, still, they face several challenges in the food donation process. The first challenge for retailers is to set up an official process to agree on the terms of the legal liability of foodstuffs.

> *¨First you need to set up an official process to pass on the products from the store to a charity, that has to do with liability, and its legal responsibility can only be given by the headquarter of*

*the chain and not by the store manager that the liability goes either from the retailer to the social supermarket or the food bank* (Retailing and SSMs expert, 2020).

The headquarters of retailers are responsible for formally setting up this process. At the same time, stores' managers are responsible for the implementation of the procedures at the operational level for the food donation process.

The second challenge for supermarkets and retail stores is that they need to implement structured processes. Furthermore, they need to have enough workforce available to remove the items from the shelf, check the expiration date, register the products that are not sold, sorting the food products that are suitable for human consumption, and follow the frameworks and external conditions for waste management (Food waste and SSMs expert, 2020). As retailers are short on human resources to perform these activities, it is easier for some of them to throw away into the waste containers than implement and execute this structured process on a regular basis (Retailing and SSMs expert, 2020).

Retailers expect that the food donation process is performed without any complexity. However, the ‘professional’ handling on the side of social supermarkets is considered the third challenge for retailers. This topic involves two aspects; the first one is that each charity organisation applies different criteria for the food sorting process as well as various policies to accept the food donated

> ¨ *if a social organisation leaves something at the supermarket, people (from retailers) would think okay, they do not need it*¨ (Food waste and SSMs expert, 2020).

The second aspect is the difference in working style.

> ¨*Sometimes it is difficult because volunteers of Charity organisations have a different business understanding being in the non-profit sector in comparison to efficiency driving profit organisation* ¨ (Retailing and SSMs expert, 2020).

One shared challenge for retailers and social supermarkets is to process and handle donations of a large volume of food. On the retailers' side, it is required to have efficient coordination and collaboration of multiple stakeholders. On the other hand, on the side of social supermarkets, they need to make available the infrastructure, transportation, cooling systems, storage and human resources to handle this, being joint logistics a critical factor in achieving that.

> ¨*I think one of the problems for most of the organisations is if a company offers 20 tons of peeled carrots frozen, and so, this is an amount that a single organisation cannot handle. So, they need to cooperate with others to share the products and to be able to accept this offer from the company. Because if you reject the offer, the company will think, okay, it is so difficult for us to ask this organisation every time, we have products because they are not able to take it over. So, after three or four times, the company will not call the organisation again. I think this process took some time to be recognised that cooperation is a benefit for all stakeholders. For*

*example, if you take Unilever, they have different production sites and huge portfolios. So, they have enough for every organisation, so it is not necessary to compete with each other. Cooperation is the key topic ¨* (Food waste and SSMs expert, 2020).

Another shared challenge for both retailers and social supermarkets is trust and data security, since

*¨Companies want to keep the number of people low and or keep who knows about surpluses in detail¨* (Food waste and SSMs expert, 2020).

Even when it has not institutionalised any reporting mechanism in the food donation process, there is a considerable step for retailers to commit their surpluses and start reporting data voluntarily to the Chamber of Commerce in Austria *(*Food waste and SSMs expert, 2020).

On the other hand, concerning the challenges faced by social supermarkets, as it has been already mentioned before, the lack of infrastructures such as transportation, cooling systems and human resources available for handling donation of large volume is a huge challenge. Another aspect is the timely coordination to perform joint logistics with multiple organisations including social supermarkets networks like SOMA, Food banks and also charity organisations of other European member states that may have available the infrastructure required to handle donations of large volume. This latter may involve performing cross-border food donations (Food waste and SSMs expert, 2020).

According to (Food waste and SSMs expert, 2020), the United Nations Economic Commission in Geneva, the division responsible for trade and market standards for vegetables and fruits, is looking for companies that are interested in supporting cross-border food donations at regional level under a concept of the marketplace; however,

*¨I think the time is not ready to cooperate for the implementation of a regional or a European platform of surpluses. Perhaps things will develop now with the crisis in another way and faster, in a positive way, but I have no idea how long it takes to implement such a marketplace¨* (Food waste and SSMs expert, 2020).

Another relevant challenge is the fluctuations in the availability of surpluses since they change every day

*¨fluctuations in availability is a challenge because sometimes retail stores have products, and sometimes they do not, and you need to balance out the demand across the various suppliers from retail organisations as well as the industry¨* (Retailing and SSMs expert, 2020).

A critical aspect that social supermarkets had to deal with at the very beginning of the food donations is the low quality of food donated, which they needed to sort it out and stamp at their own cost of disposal waste (Retailing and SSMs expert, 2020).

On the other hand, volunteer handling is a complex task for social supermarkets. There are three main aspects connected with this topic; the first aspect is the complexity of handling more than twenty (20) volunteers per store (Retailing and SSMs expert, 2020). The second aspect is that some volunteers are elderly people and who cannot physically handle heavy loads of food. Even though there are young volunteers, their time availability is not the same. Furthermore, the last aspect is the personal relationship between the staff members of social supermarkets and retailers that can positively or negatively affect the operational efficiency in the food donation process. The manager of social supermarkets is the main responsible for addressing these challenges, which is difficult to train, as well as replace him, since managers are old and experienced people in the food donation process (Food waste and SSMs expert, 2020).

It is important to note that volunteer handling is not only a challenge for social supermarkets but also for food banks, in which the European Federation of the Food Banks (FEBA) are still developing solutions to cope with these problems (Food waste and SSMs expert, 2020). The last challenge identified for social supermarkets is to build an excellent collaborative environment with Government authorities to facilitate the regular food safety and food quality checks, especially for products that have reached the ‘best before date’ (Food waste and SSMs expert, 2020). Figure 5.1. summarises the drivers and challenges for surplus valorisation and redistribution between retailers and social supermarkets presented above.

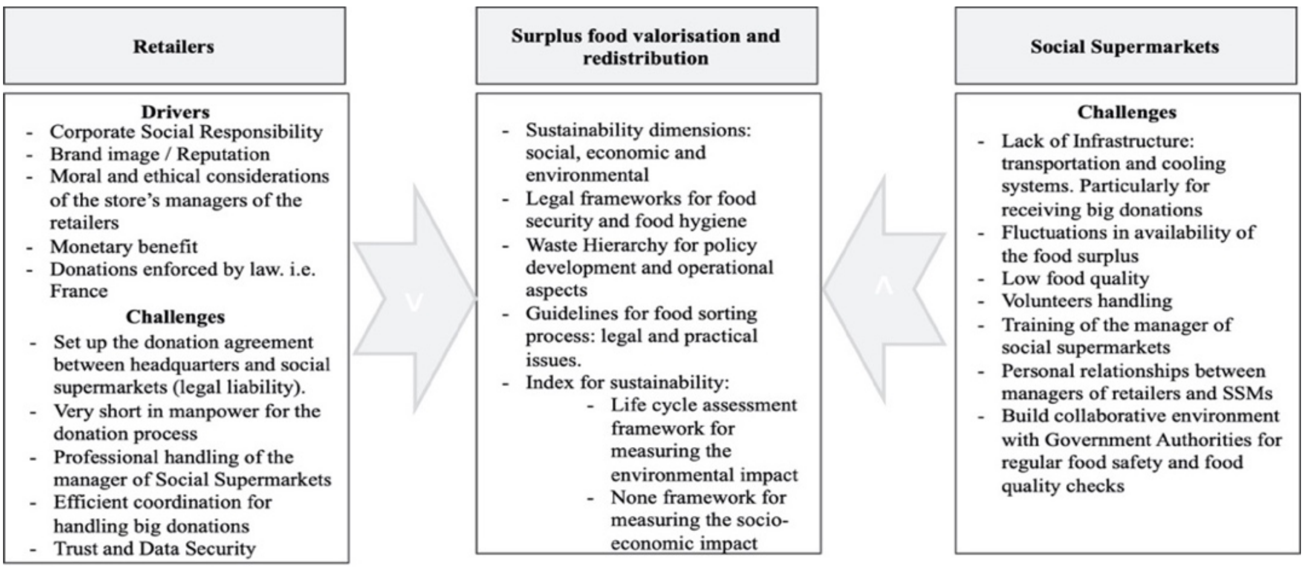


**Figure 5.1** Drivers and challenges for surplus food valorisation and redistribution between retailers and social supermarkets. Source: The Author

## 5.3 Case study validation: Social Supermarkets in Austria

This section presents the findings regarding the validation of the case study of social supermarkets, mainly four aspects: Operating model, sources flow in the food donation process (logistics), business process identification and information management requirements. The basis of the analysis is made based on the material produced in section 4 by conducting content analysis and using a systems engineering perspective. This material was provided to the experts before the interview took place, and it was verified during the interview.

**Operating model of Social Supermarkets in Austria.** Concerning the operating model, there is a universal agreement of both experts that the elements and their relationships of the simplified representation proposed of the operating model of the Austrian social supermarket, presented in section 4.2.2 in Appendix F, are consistent with their observations in the field. Experts provided some recommendations that are described below, and it was also updated the simplified representation of the operating model of social supermarkets in Austria illustrated in Figure 5.2

- Include the participation of the Government Authorities. Government authorities create the law and also conduct regular checks for food quality and food safety. Government authorities play an essential role also in the cooperation between donors and social supermarkets (Food waste and SSMs expert, 2020).
- There are many types of social organisations in Austria, which ranges from associations (called Verein in German), social organisations, professional social organisations and the so-called socio-economic companies. These socio-economic companies follow a model implemented that is partially funded by the Public Employment Service in Austria (AMS). Therefore, apart from taxes and food safety checks, AMS partially funded a socio-economic model (Food waste and SSMs expert, 2020; Retailing and SSMs expert, 2020).
- Include the participation of Agricultural organisations such as farmers as donor organisations, since they also donate fruits and vegetables to social supermarkets (Food waste and SSMs expert, 2020).
- Change the name from fixed social supermarkets to the stationary social supermarket. This change can provide a better interpretation of the social supermarket outlets (Retailing and SSMs expert, 2020).
- Social programs and coffee shops should be integrated as part of the stationary social supermarket since these services are provided as part of this delivery mechanism (Retailing and SSMs expert, 2020).

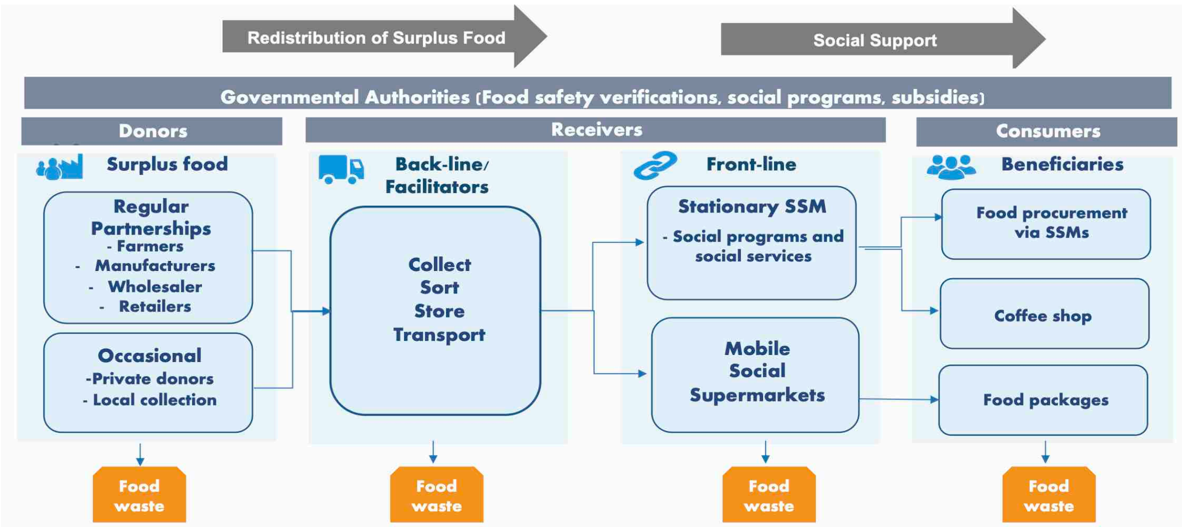


**Figure 5.2** Updated simplified representation of the Austrian social supermarket model. Source: (The Author).

**Source flow in the food donation chain of Social Supermarkets**. The findings confirmed that the three resource flows identified in section 4.2.3 in Appendix F for the food donation chain reflect the observations made in the field by the experts. Furthermore, according to (Retailing and SSMs, 2020), a fourth resource flow exists when the surplus food redistribution is done between the food banks and the SOMA social supermarket network as part of the cooperation established between them.

> *¨I think this was one of the main reasons to install an umbrella organisation for the food banks and the social supermarkets to have close cooperation and to exchange in both directions¨* (Food waste and SSMs expert, 2020).

The four resource flows are described below, and Figure 5.3 has been updated based on the findings. The four resource flows are (1) the distribution of the surplus food from retailers, wholesaler, processing and manufacturing companies to food banks, and then food banks redistribute it to the social supermarket network in Austria – SOMA, which this latter can redistribute the food either to individual social supermarkets or the warehouses of social supermarkets (2) Redistribution of surplus food from retailers, wholesaler, processing and manufacturing companies to individual social supermarkets, which redistribute the food donation through the different delivery methods. It may also involve the interaction with joint logistics in both directions, either to distribute food to the SOMA warehouse and receive food from them. (3) the third resource flow relates to the surplus food redistribution through the joint logistics performed by the network of social supermarkets SOMA, which redistribute the food donated either to individual social supermarkets or transfer it to the warehouse of food banks. (4) Food banks can also receive food donated from joint logistics performed by the SOMA network of social supermarkets. This transfer of products can be done due to limitations of infrastructure or to satisfy the needs of other social organisations (Food waste and SSMs expert, 2020).

On the other hand, reverse logistics has been implemented in trials. Retailers collect food close to the 'best before date' from the outlets by themselves, and social supermarkets can collect surpluses in the central warehouse or head offices, this aspect simplifies and increases the effectiveness of social supermarkets for managing the surpluses. However, it requires additional research in practice to confirm if it is still in place on a regular scheme (Food waste and SSMs expert, 2020).

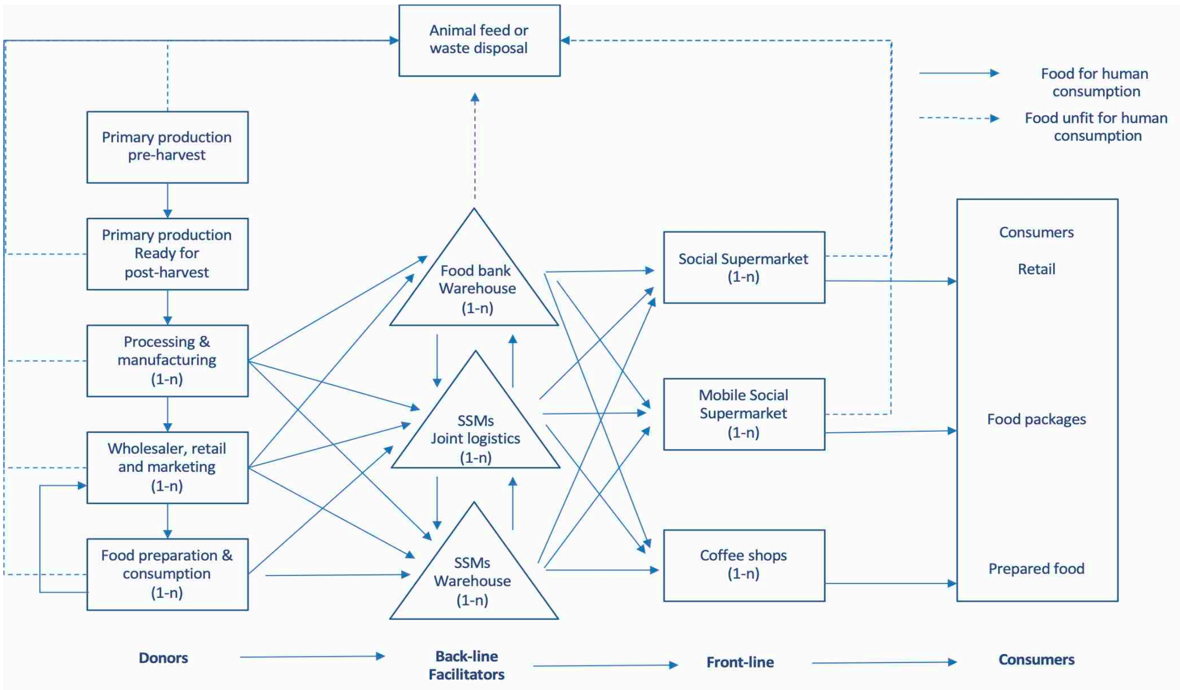


**Figure 5.3** Updated simplified resource flow in the food donation chain of Social Supermarkets in Austria. (The Author).

**Business Process Identification of Social Supermarkets in Austria.** The results of the analysis of activities, sequence and actors of the business process identification showed that the diagram of section 4.2.4 in Appendix F depicts the observations in the field made by the experts. Furthermore, some considerations need to be included based on the legislation of waste management of Austria that is also connected with surplus food redistribution. The findings are described below, and Figure 5.4 illustrates the high-level business process identification diagram updated.

- Include the participation of Government agencies with retailers, SOMA network and social supermarkets (Food waste and SSMs expert, 2020).
- Three activities are related to the interaction with government agencies: (1) From 2020 companies within the European member states need to report their food waste voluntarily to the European Commission, (2) There are food safety checks for authorities regularly to ensure the food quality of the food donated. (3) Social supermarkets need to establish close cooperation with AMS in

Austria to report the employees' performance of people hired under the social programs (Food waste and SSMs expert, 2020; Retailing and SSMs expert, 2020).

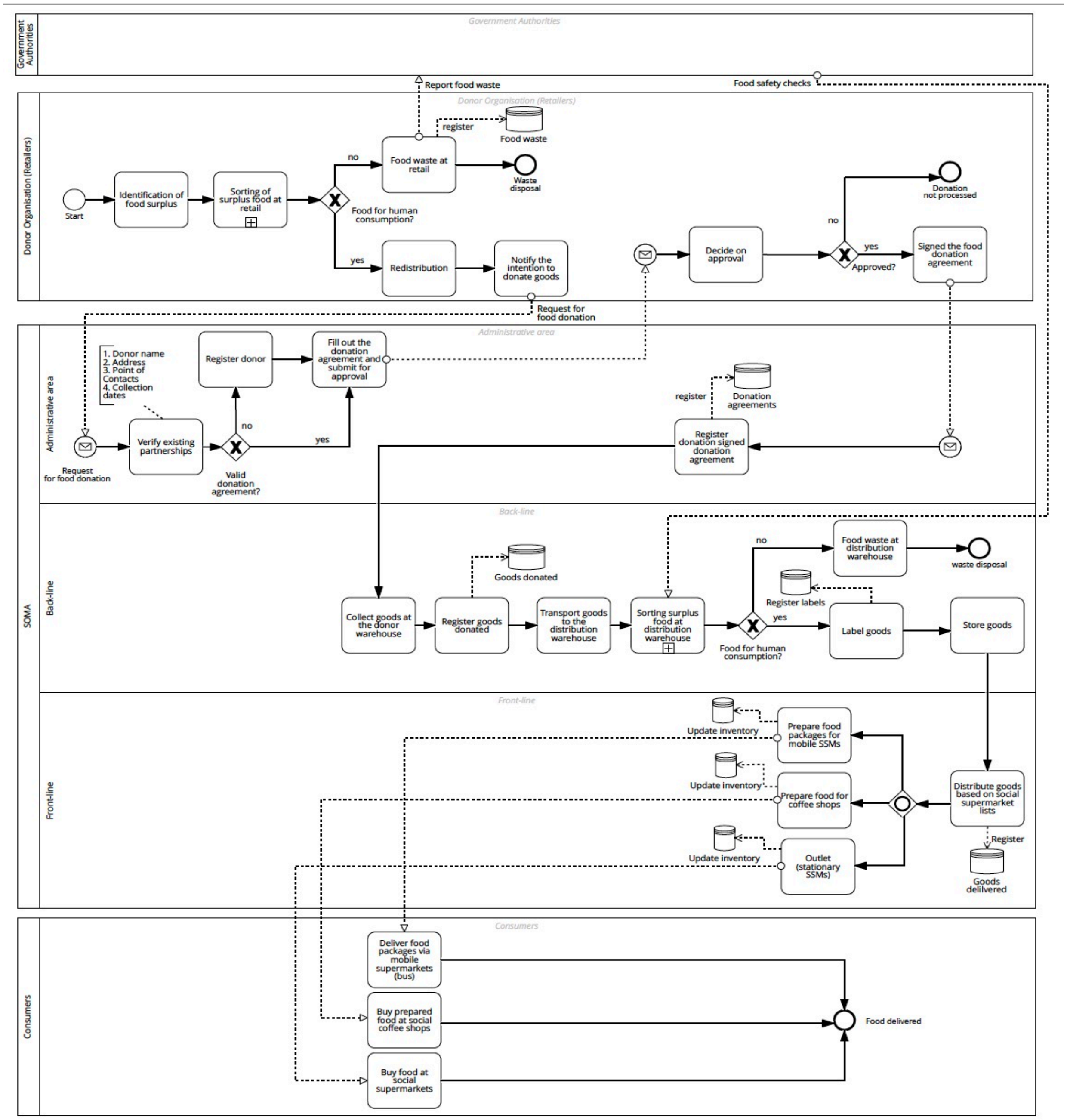

**Figure 5.4** Updated Business Process Identification of surplus food redistribution from retailers to Social Supermarkets in Austria. Source: (The Author).

**Information Management requirements of Social Supermarkets in Austria.** Experts confirmed that the seven information management requirements in the food donation chain identified in section 4.2.6 are consistent with the observations made by the experts in the field. Two additional requirements were identified; the first one is related to recording and managing the information flow of the logistic process in addition to the food donation agreements (Food waste and SSMs expert, 2020). The second requirement is related to recording and managing all the information concerned with the marketing efforts of social supermarkets (Retailing and SSMs expert, 2020).

### 5.4 Assessment of blockchain and IoT potential for surplus food redistribution through social supermarkets

The following sections present the findings obtained from blockchain experts' consultations to assess the blockchain and IoT potential in the food donation chain. Four aspects were studied (1) the general and technical considerations for selecting a blockchain framework, (2) what blockchain frameworks are suitable for the food donation chain, (3) the identification of tool and practices for implementing blockchain and Internet of Things based solution and (4) the identification of incentives for participation in the blockchain network.

**General considerations for selecting blockchain frameworks.** There are many and multiple frameworks to implement a blockchain network as it was identified in section 4 and described in appendix G**.** There is already a proven methodological framework to assess the general suitability of blockchain potential as the method proposed by (Wust and Gervais 2018). Furthermore, there is already a taxonomy to identify and classify the use of the frameworks considering aspects such as permission and validation to provide guidelines in the blockchain selection, as it has been described in section 2.3.3.

Nevertheless, the assessments and the selection of the blockchain framework depends on the functional and technical requirements of each use case; therefore, this should be conducted on a case by case basis (CTO Blockchain expert, 2020). However, it has been identified some general aspects for selecting a blockchain framework. The first aspect is the level of maturity of the framework.

> *¨if it comes to developing new applications on top of a blockchain; it should be at least fairly stable as a release because otherwise, it becomes hard to follow the development¨ (*Process mining on blockchain expert, 2020).

The second aspect is connected to the support model. Many blockchain enterprise frameworks are open source software, which have been supported by companies such as IBM, Linux Foundation and others. These companies not only support the further software development but also provide a cross-industry collaboration, which can enable the further technology roadmapping of the technology adding features to meet new and diverse functional requirements (Blockchain consultant, 2020).

The third aspect is community development. Blockchain has been developed from developers to developers; therefore, the peer-to-peer production is one of the distinguishing features of the blockchain ecosystem to support the further software development and also to cope with issues that could arise during the implementation (Blockchain consultant, 2020).

Lastly, the fourth aspect is the ease of use of the framework for software development purposes. As the framework provides an easy guide for implementation, it will work as an accelerator (Blockchain consultant, 2020).

> *¨You do not need to reinvent the wheel; you can just start using it to build your own product from prebuilt tools¨* (Blockchain consultant, 2020).

On the other hand, six initial definitions for selecting the blockchain enterprise framework have been identified:

- Actors. It is essential to identify who are the actors or players and what their participation is in the network (CTO Blockchain expert, 2020)
- Primary consensus method. The permissions of the actors to write, read and to validate data in the network (CTO Blockchain expert, 2020).
- The number of transactions. The number of transactions will determine the scalability choice for the blockchain implementation since some consensus mechanisms support a limited number of transactions. It is important also to identify if the blockchain framework offers pluggable choices. Some blockchain frameworks can operate with only one or with different consensus mechanisms; therefore, this option opens the possibility to select the one that best meets the functional requirements of the use case (CTO Blockchain expert, 2020; Blockchain consultant, 2020).
- Definition of the assets. It is important to define what type of products and type of transactions will be executed in the blockchain. The assets are understood as digital twins of the physical products used in real life (IBM Senior Architect, 2020; Process mining on blockchain expert, 2020)
- Access policies and access control. This aspect relates to the level of complexity to grant or deny access in the network (CTO Blockchain expert, 2020; Blockchain consultant, 2020)
- Data security. A critical aspect for the data transmission is the selection of the cryptographic algorithm, and encryption techniques, such as ECASD, EAS-256, SHA-1 bit-160 and others (Blockchain consultant, 2020).

**Suitable blockchain frameworks in the food donation chain.** After reviewing the information management requirements of social supermarkets, blockchain experts confirmed that blockchain technology can meet the requirements of the Austrian social supermarket model. Additionally, they confirm that blockchain potentially can also increase the operational efficiency of the food donation not only between retailers and social supermarkets but also of all the donor organisations involved in the food supply chain. It has been identified four public permissioned blockchain frameworks that can meet those requirements, which are: (1) Hyperledger Sawtooth, (2) R3 Corda, (3) Enterprise Ethereum and (4) Hyperledger Fabric, According to (CTO Blockchain expert, 2020), Hyperledger Sawtooth has some interesting implementations to achieve the traceability and monitoring in the food supply chain; however, Hyperledger Fabric can meet the requirements in the food supply chain straightforwardly. On the other hand, according to (Blockchain consultant, 2020), the product called blockprovenance of R3 Corda can be useful for the food donation process since it has been implemented in use cases also connected with transparency and food traceability, as well as the permissioned version of Ethereum.

All experts identified Hyperledger Fabric as the leading player in the market of blockchain for the food supply chain. According to (IBM Senior Architect, 2020), IBM designed and developed Hyperledger Fabric, which was made available to the technology community as an open-source project under the consortium named Linux Foundation. IBM has built on the top of the blockchain infrastructure Administrative Management Systems to manage the blockchain network since it is not an easy task. Currently, IBM has an extensive software portfolio to meet different requirements such as Tradelens to enable the tracking of the global shipping supply chain, food provenance, real-time monitoring and others.

According to the (IBM Senior Architect, 2020), two products can be useful for the food donation chain: IBM Food Trust and Fresh Insights.

> *¨IBM Food Trust is a blockchain-based solution, which its primary goal is to provide traceability in all the stages of the food supply chain, including production, storage and processing of the foodstuffs. The main idea behind this technological solution is that you search for the provenance of the product and you can see the complete tracing of the product along with all the supply chain stages, from harvest to the shelf in the supermarket. This functionality includes the traceability not only of individual products but also the combination of foodstuffs when they are processed. For instance, some lots of carrots can be delivered in the supermarket, whereas others were provided to produce other products like salads, etcetera. So, with only the product code or lot number, you can identify where the products came from¨* (IBM Senior Architect, 2020).

IBM food trust can support the food traceability and also ensure the food safety and food quality of the food donated.

> *¨It used to take a lot of time, and it was difficult to identify the causes of foodborne disease outbreaks. Thus, when you had a myriad of lots of food, the only possible option was to destroy all the lots of the products since there was not any way to know where the contamination occurred. Nowadays, you can identify any contaminated product with only get a complete tracing of the product in the blockchain in a couple of seconds. You can get the historical data, and you can see what other lots in your inventory belong to the lot contaminated, so you can*

> *first identify where the contamination occurred and second to define what products you need to destroy or to remove from the supply chain¨* (IBM Senior Architect, 2020).

IBM Food Trust has been evolving, and now the data already collected from different actors in the food supply chain can be exploited with a data analytics software called IBM Fresh Insights. IBM Fresh Insights could support the automation of the decision-making process for the logistics in the surplus food redistribution (IBM Senior Architect, 2020).

> *¨Fresh Insights allows you to monitor the freshness of the food products and to share it with other actors in the supply chain. For instance, if you are a food processor who needs to know the freshness of the food products, and you can identify what is close to the expiration date, then you can reallocate the product to limit food waste. At the same time, you can automate the logistics decision making processes ¨* (IBM Senior Architect, 2020).

Other functionalities that can be added on top of the blockchain, such as the interoperability with GS1, RFID technologies and Internet of Things. Hyperledger Fabric now is compatible with all these technologies since it was designed following international standards.

> *¨For instance, there are already some international standards for labelling and traceability of different products in the food supply chain, such as bar codes, lots identifiers and other things. GS1 and RFID technologies shared the same standards. GS1 serves as a method of product identification and RFID supports the automation of the existing functionality in blockchain; however, RFID is not essential, with only a bar code of the product can be traced¨* (IBM Senior Architect, 2020).

The interoperability between blockchain and Internet of Things has shown a significant value-added for the monitoring and tracking of the environmental conditions of the foodstuffs along all the stages of the supply chain. What is more, the implementation of both technologies can bridge the trust gap among the participants in the food donation chain.

> *¨There are sensors to measure the temperature, humidity and carbon dioxide. The advantage is that sensors are already used in the food supply chains. The data (collected from sensors) has a huge value for the industry. The issue arises on how to trust the data collected. When you own the sensors, you obviously believe in the data gathered, but what happens when the data needs to be shared and used by other participants in the food supply chain - who probably do not trust you? Therefore, the idea to store the data in the blockchain is to give them 'the word honour', since the data is immutable and secure in the blockchain¨* (IBM Senior Architect, 2020).

Another relevant finding is that the data contained in the blockchain is now used also to simplify and to reduce the costs of other industries that support the food supply chain, such as the insurance industry. Nowadays, with the data recorded and retrieved from the blockchain, it is possible to define parameters under which the lots of products can be insured. If the data collected indicates that the products are under these parameters, the insurance company can reduce the administrative burden for inspections when an incident occurs (IBM Senior Architect, 2020).

> ¨*The advantage is that if we are reading this information entirely from the blockchain and controlled by a smart contract, what may end up happening is that the moment these thresholds are exceeded without the need for an adjuster, the insurance company already has evidence that the threshold has been exceeded, and then the payment of a claim can be automated. There, what you have, it is a mechanism for insurance claims that is much cheaper and much more agile*¨ (IBM Senior Architect, 2020).

Even though IBM Food trust shows excellent potential in the food donation chain, one expert raised the concern of the implications of storing the data of stakeholders with a third party.

> ¨*it could be perhaps better to try another framework that is not necessarily backed by specific this type of Industries just because of the clear concerns with the access of data. So, maybe there are certain things that people do not want to share with the owners. Because, you know, it is hard also to convince the stakeholders that they are using a platform which is from external vendors where data will not be ever read*¨ *(*Process mining on blockchain expert, 2020).

### 5.5 Tools and practices for implementing a blockchain and IoT based solution for the food donation chain

The results of the findings showed that there are five technological components to meet the information management requirements of the social supermarket: (1) blockchain technology, (2) Internet of Things, (3) Analytics, (4) IPFS for management of off-chain data and (5) Software development.

**Blockchain properties.** The findings revealed that public permissioned blockchain frameworks can meet some requirements of social supermarkets by themselves such as (1) Inter-organisational collaboration, which can be achieved by implementing a peer-to-peer network (Blockchain consultant, 2020). (2) Management of trading and transfer of the foodstuffs for the food donation agreements, which can be achieved by implementing smart contracts. The business process rules can be implemented by using smart contracts or with the main properties of the blockchain framework. Smart contracts also can be used to register the state of the transactions along the supply chain (CTO Blockchain expert). Smart contracts can be developed using Goland, Java or JavaScript (CTO Blockchain expert; IBM Senior Architect, 2020; Blockchain consultant, 2020). (3) The data can be transmitted and stored securely by implementing cryptography algorithms to guarantee that the information is immutable. Furthermore, the implementation of validators along the food donation chain can be executed by using consensus mechanisms, which ensures the trustiness in the network (CTO Blockchain expert; IBM Senior Architect, 2020; Blockchain consultant, 2020; Process mining on blockchain expert, 2020). (4) Transparency, since all the data is recorded in sequential order as it is updated. The last block in the chain contains all the information recorded. The data access can be granted or denied according to the access policies agreed by the participants (Blockchain consultant, 2020).

**Business Process Modelling and Monitoring.** The results showed that the requirements definition and the translation of those functional requirements into code is still the responsibility of the technical team. There exists the technical feasibility to create an API and to integrate it with a BPMN software to provide a graphical representation to orchestrate a process diagram, however it is not available at the moment (IBM Senior Architect, 2020). Some experts mentioned that the UML notation for business process modelling is frequently used (CTO Blockchain expert; Blockchain consultant, 2020).

One novel finding is there are a couple of software available that follow a Model-Driven Engineering approach (MDE) for the development of smart contracts, which implement a full-blown business process, ranging from the inception to the end *(*Process mining on blockchain expert, 2020).

> *¨The good thing about them is that you do not need to know a coding language by heart, as solidity. It is enough to know how to model the process in graphical languages such as BPMN, and this can allow the users to directly create code that is already doing what the process model is dictating one by one. It does reduce the risk of putting mistakes or false. As you know, overlooked bugs and the like, plus of course with some optimisation and perhaps making code as if it was meant to be read and written by humans, you know may undergo¨ (*Process mining on blockchain expert, 2020).

Lorikeet and Caterpillar are the tools for blockchain business process execution and asset management that have adopted the so-called MDE. Caterpillar is fully open source, while Lorikeet is a product of 61 CSIRO, which is a Research Institute *(*Process mining on blockchain expert, 2020). Additionally, Caterpillar in the last version provides the functionality of role-based access control to be handled on the fly, which adds flexibility to resources allocation in the business process.

> *¨you have to transport the goods from A to B, but then, the one who will be in charge of carrying out the transportation may not be known in advance. So, in that case, one has to really create a sort of auction and check who is available at the moment and who can actually take care of this task and assign it to them, it is a runtime feature¨ (*Process mining on blockchain expert, 2020)

**Blockchain and Internet of Things.** Blockchain is not mature enough to meet the following requirements by itself: traceability, alerting system and to record all the information flow of logistics. Therefore, there some additional mechanisms should be implemented along with blockchain technology. (Blockchain consultant, 2020; IBM Senior Architect, 2020; CTO Blockchain expert, 2020). Mechanisms such as GS1 to facilitate the identification of the products, RFID technologies for automating and recording as well as to monitor the resources flows, and sensors to monitor and control environmental conditions such as temperature, humidity and carbon dioxide of the foodstuffs to ensure the food quality and food safety (IBM Senior Architect, 2020; CTO Blockchain expert, 2020). One significant benefit that blockchain can bring to the traceability requirements is that not only provide one up and one down visibility but also to achieve from going from upstream to downstream in the supply chain (Blockchain consultant, 2020).

**Blockchain Analytics.** The retrieval and processing of the combined on-chain and off-chain data via an analytics software in the food donation chain can enable the auditability, traceability and alerting system (Blockchain consultant, 2020; IBM Senior Architect, 2020). The correlation between the physical conditions of the foodstuffs versus the data recorded on-chain can trigger notifications for reallocation and redistribution of the products when they are close to the 'best before date' or when the products are declared unsellable. This aspect can support supply chain planning and monitoring, including reserve logistics and closed-loop supply chain design (IBM Senior Architect, 2020).

**Front-end applications.** The enterprise blockchain frameworks usually provide a Software Development Kit (SDK) to support the development and interoperability between the blockchain network and the front-end applications, including decentralised applications -Dapps (CTO Blockchain expert, 2020). Some open-source projects provide the code of prebuilt decentralised applications that can be customised according to the specific needs of the project. The programming languages frequently used are Angular.js and Node.js (Blockchain consultant, 2020).

**On-chain versus Off-chain data**. One important finding related to scalability and performance of the blockchain is the definition of which data should be stored on-chain or off-chain. All experts consider that only the critical data or pointers should be stored in the blockchain. The recommendation for storing off-chain data is to implement an InterPlanetary File System (IPFS), which can be paired with the blockchain network. IPFS only should be implemented when the information needs to be shared with the blockchain participants. Otherwise, a local system can be implemented and make it interoperable with blockchain.

**Interoperability.** Based on the results, it is evident that the interoperability among the different technological components is vital to support the operating model of social supermarkets. All experts shared the same opinion that there is a lack of standards in the industry for blockchain. The conventional method used to achieve interoperability with external systems, including Internet of

Things, compatible blockchain networks and non-compatible blockchain networks is via REST and JSON APIs. There are emerging frameworks focused on achieving interoperability among different blockchain networks such as ChainLink, Tendermit, and Holochain. Each of these frameworks offers different architecture and approaches. However, there is not any use case of reference for the food supply chain. Table 5.1 summarises the information management requirements and describes the technology component that meets each specification.

| # | Requirement | Description | Component |
|---|---|---|---|
| 1 | Employees register | Social supermarkets need to register, track and report who employees are part of the social integration programs of the Public Employment Service Office | Off-chain data |
| 2 | Consumer profile | The consumer profile contains the demographic data, income and dietary information. | Off-chain data |
| 3 | Traceability | Traceability obligations are applicable for all the actors in the supply c 'one step back' and 'one step forward'. In addition, tit is required investigation when a food contamination is identified | Blockchain<br>Smart Contracts<br>Internet of Things<br>Analytics |
| 4 | Management of food donation agreements | Food business processors need to identify, register and report any person from whom they have received food, food-producing animals or any substance intended to be incorporated into a portion of food. | Blockchain<br>Smart Contracts |
| 5 | Alerting system | Food business operators are required to withdraw, recall or notify unsafe food. Social supermarkets are obliged to initiate the procedures to remove the food from the market and to inform to competent authorities | Blockchain<br>Internet of Things<br>Analytics |
| 6 | Auditability and Accountability | Social supermarkets are required to store the information related to donors (suppliers), products, volumes and quantity from two to five years and make it available to the competent authorities on demand | Blockchain<br>Analytics |
| 7 | Transparency | Social supermarkets need to ensure the maximum transparency to donors that the products donated will no longer enter the market to be re-sellable or that additional cost will be incurred | Blockchain |
| 8 | Inter-organisational collaboration | Facilitate the engagement of multiple stakeholders including B2B, B2C, B2G and Non-profit to non-profit organisations | Blockchain |
| 9 | Flexibility design | The adoption of sustainable practices in the food supply chain requires the flexibility and adaptability of current logistics practices to ensure timely data sharing in the food donation process | Blockchain<br>Smart Contracts |
| 10 | Data Security | Social supermarkets procedures for data privacy and data security need to be in compliance with the General Data Protection Regulation in place. | Blockchain |
| 11 | Interoperability | Achieve the interoperability with external systems to retrieve and update data off-chain and also with external systems. | Software development |
| 12 | Logistics information | Record and update information regarding the logistics such as transportation company, collection dates, locations, and any information related to the collection and delivery of the food donated. | Blockchain<br>Smart Contracts<br>Internet of Things |
| 13 | Marketing Information | Manage the information regarding the marketing campaigns performed to donors. | Off-chain data |

**Table 5.1** Common characteristics of social supermarkets in Europe. Source: (The Author).

## 5.6 Incentives for participation

The incentives for participation in the blockchain relate to the costs and benefits of choices participants can make, which are of high importance to enable a sustainable blockchain implementation. According to (IBM Senior Architect, 2020), there may exist good incentives for retailers to achieve economic benefit from tax incentives, altruism, but there may also exist some perverse incentives. For instance, some perverse incentives can be donating food that is not fit for human consumption anymore, reporting more than the actual food donated to claim higher taxes incentives, or for money laundering.

To fight against these perverse incentives, Authorities need to implement mechanisms to monitor and control any potential fraud. For instance, Authorities can request a certified receipt issued by receivers' organisations, which will be valid for tax claims. These control mechanisms are costly for all the participants involved in the food donation since it consists of the cost of implementing structured processes on the side of the donors, monitoring costs for Authorities, and cost of accomplishment for retailers when they are enforced by law to donate food (IBM Senior Architect, 2020).

The digital transformation of the food donation chain can reduce these three type of costs. For instance, when a smart contract with sensors can collect the data of the products closed to their 'best before date' and send an automatic notification to retailers. They can decide at the end of the day where to reallocate or redistribute the foodstuffs; the automated notification to charities organisations to receive the products; the automatic generation of the digital food donation receipts; and then, sending these digital receipts to Tax Authorities for processing the tax claims. With these automated actions, it is possible to prevent robbery, fraud but most importantly reduce the transaction costs for all the participants in the network (IBM Senior Architect, 2020).

When the obligations and costs are balanced out for all participants, it is possible to implement economic models to provide benefits for those who generate the data and charges for those who retrieve the data for tracing the food provenance. For instance, IBM Food Trust grants free access to those participants who generate data as a benefit to them and they obtain in exchange a certification of the conditions of their products. On the other hand, those who need to trace the provenance of products, they need to pay for that service. The final goal is to define an economic model that provides a balanced benefit for all the participants in the network (IBM Senior Architect, 2020).

# 6 Discussion

The basic premise of this research was to explore how blockchain technology and Internet of Things can increase the operational efficiency of the surplus food redistribution through a collaborative and less fragmented ecosystem to enable the UN Zero Hunger goal.

Blockchain has been in the market for more than thirteen years, reaching a certain level of maturity, evolving in different data structures, and nowadays, it is applicable for many and various use cases. (Kumar and Mallick 2018). Blockchain has been a revolutionary technology because it has shifted from traditional systems that secure and control transactions with a central authority to a decentralised governance method that allows for redefining the business rules under a collaborative network structure (Saveen A. Abeyratne and Radmehr P. Monfared 2016).

Existing literature review has identified the existence of different types of networks based on the permission and decentralisation level ranging from public networks accessible to everyone to permissioned networks with restricted access and validated by a group of participants of the network (Carson et al. 2018). Additionally, to the network structure, the data is recorded and replicated to all the nodes of the network, which is not like the traditional database structure. A blockchain data structure is a distributed repository, which has been created by design to be immutable and record data comprehensively.

Another property of the blockchain network is that all transactions are broadcasted across the network providing access only to the participants involved in each transaction, and the authorisation of the transaction can be done by the person who solves a cryptographic puzzle. This cryptographic puzzle is replicated to all nodes with the access rights, and all participants can validate the correctness of the data. When the puzzle is solved, it is creating a new block in the network which is signed cryptographically, and it is stored securely to become immutable and tamper-evident data log (Bano et al. 2017; Zheng et al. 2017).

Therefore, the network and data become secure and reliable. On top of that network can be created and developed intelligent agents into the transactions that support the business rules of the participants of the network (Wang et al. 2019). Smart contracts can create services to perform business functions, transfer of digital assets, and to support the communication with the external world of the blockchain (Saberi et al. 2019).

The main benefits of the blockchain properties are the building consensus in the network, the creation of the digital twins as a copy of the real world, for instance, a lot of food, etc., recording of the transactions comprehensively, and its potential to automate processes.

The emergence of new blockchain database structures open different ways of storing and representing data such as R3 Corda, Hyperledger and bring other possibilities to meet specific requirements of trading, tracking and different consensus mechanisms. Therefore, the identification and assessment of the use case are relevant to determine the potential of blockchain and the benefits obtained from its adoption. For this study, the preliminary analysis of the case of the Austrian social supermarkets shed light on the actors, their relationships among them, information flow and information management requirements.

The output of the analysis of the case was initially assessed by using the framework proposed by (Bano et al. 2017; Zheng et al. 2017) to assess the blockchain potential and to identify the blockchain framework suitable for the food donation chain based on permissions, writers and verifiability. However, the analysis of the case of social supermarkets not only considers the potential of data storage and accessibility, but it also analyses the complete technological solution for the process of regular food donation between retailers and social supermarkets.

The results revealed that the most suitable framework for the food donation chain is a public permissioned blockchain. A public permissioned blockchain allows the participants to be known to achieve the traceability of the foodstuffs. Moreover, it allows for data verifiability by the public and government authorities, as well as it provides transparency among actors,

The five technological components identified in this study to meet the information management requirements of the social supermarket are: (1) a public permissioned blockchain framework, (2) sensors for Internet of Things, (3) Inter-Planetary File Systems to pair the on-chain and off-chain data to provide large scalability and performance of the implementation, (4) software development to develop the front-end applications and achieve the interoperability with external systems and (5) analytics to support the operational and strategic decision making for product recovery and food reallocation.

This study confirms that blockchain and Internet of Things can increase the visibility capabilities in the food supply chain to achieve food safety and food quality, which is also a requirement in the food donation chain. Sensors for Internet of things are already widely used in the food industry, which capture the environmental conditions of the food, such as temperature, humidity and carbon dioxide. This data is captured by sensors and send it to the blockchain network where it is securely stored and shared.

The mechanism to capture the sensors data is through the use of oracles and smart contracts. Smart contracts can contain specific predefined parameters of the ideal conditions of food to be saleable, and if the foodstuffs exceed or are below of these parameters can notify the participants of the network in the form of alerts. Additionally, in the case of foodborne disease outbreak and incidents, it can notify automatically to all participants as well.

This results of this study confirm that blockchain and Internet of things can meet the four pillars identified by (Regattieri et al. 2007) for building a sound traceability system. They enable product identification by using R1 and RFID tags to support their automation. They can trace the data across the supply chain sequentially and securely. Additionally, they can achieve the product rooting by scaling up the implementation of a real-monitoring system using Wireless Network Sensors (WNS). As well as, they can achieve not only one and up visibility in the supply chain, but also, they can go from upstream and downstream visibility in the supply chain.

On the other hand, the results of this study confirmed that the implementation of a public permissioned framework can enable the transparency, accountability and auditability required in the food donation chain since the state of the transactions is recorded and available to be verified by all the participants in the network. There are additional control mechanisms in blockchain to ensure that the information collected from external sources are reliable by implementing verifier roles and arbitrators. Verifier roles can check the correctness of the external data, and arbitrators can be humans with specific privileges to sign the transactions after validation. These mechanisms can prevent data manipulation and also disincentive misbehaviour of the participants in the network.

Smart contracts are pieces of code. Therefore, they are developed and implemented based on the business rules defined by the users. Smart contracts are the technological components in the blockchain that also enables the design and implementation of inter-organisational business processes. As smart contracts are running in each node of the network, they enable the streamline of the business process across different organisational entities or actors.

One interesting finding of the research is that there are a couple of tools to model the business process and create code to develop smart contracts. These tools are Caterpillar and Lorikeet. These tools use a Model-Driven Engineering approach to implement a full-blown process that provides high flexibility for the implementation of a role-based design. The business rules definition is still on the side of the business; therefore there is a lot of previous work to do in order to identify the activities, sequence, actors and business rules of the existing processes or the desired behaviour of the process in more detail than the provided in this study.

Smart contracts can also enable the management of food donation agreements. The findings confirm that smart contracts can identify and control who actor owns the digital twin of the foodstuffs and how they can be transferred to another actor. The distinguishing characteristic of the transaction recorded in the blockchain is that they are supported by cryptographic digital signatures, which can be used to create and sign food donations agreements digitally. Additionally, to the automation of the food donation agreements, it is also feasible to automate the report of donors to government activities and receipts for donors of the food donation (donation slips).

As all the transactions are cryptographically signed, it is required to implement an Identity Management System either the one available in some of the blockchain frameworks or another one that allows for granting, denying or revoking access to read or write transactions in the blockchain.

Another relevant aspect for the design and implementation of a blockchain network for the food donation chain is that only the data registry of the transactions can be stored on-chain. Therefore, it requires the implementation of off-chain store systems that need to be paired with the blockchain network such as Inter-Planetary File System. This implementation will reach a higher performance level of the network and higher scalability.

This study revealed that Blockchain Analytics is the key component of the solution proposed to support the operating model of the Austrian social supermarket. Blockchain analytics provides the capability to retrieve and visualise the datasets contained in the blockchain framework. These data sets can be cross-referenced with external data to support operational and strategic decisions in the food supply chain.

Blockchain analytics can support the traceback investigations required by authorities when foodborne disease outbreaks and incidents occur. Additionally, blockchain analytics can track food provenance of the foodstuffs in the supply chain and the final destination of the food donated. Notably, it can support the activities of identification and tracking for product recovery and food reallocation.

Proactively blockchain analytics can monitor the close 'best before date' of food and if the environmental conditions of the food are below of the retailers' standards to be sellable but still fit for human consumption, then it can notify sending alerts to the participants in the network. This functionality can support the reverse logistic decision-making process of retailers to redistribute the food to Charity Organisations either centralised in their distribution warehouses or decentralised in each of the outlets.

These findings also suggest that blockchain analytics can underpin the lifecycle costing of the food from harvest to surplus food redistribution; therefore, retailers can determine the economic benefit of the surplus redistribution. What is more, blockchain analytics can provide valuable information for the supply chain and social supermarkets regarding what distribution channels are most cost-effective than others, as well as monitor the logistic capacity of each social supermarket.

A critical aspect to consider is that there are no technological standards to achieve the interoperability between blockchain and external systems, including other blockchain networks. This study identified two main mechanisms, one of them is by developing APIs that interact with the blockchain framework selected, and the second option is to implement additional blockchain frameworks that have been designed to achieve the interoperability among networks such as Chain Link, Tendermint, and others. Both methods are not data invasive but operate at the business logic level of the systems.

From the front-end application perspective, the findings showed that it also involves the software development of applications to enable the interaction among the participants. Given the push and pull logistic strategies for food donations, the variability of the surplus food supply and the clear identification of the need of United Nations to implement a marketplace for food donations, it is suggested the development of a decentralised digital marketplace where donors can publish their offers and social supermarkets can also publish their demands and distribution capacities.

In the study conducted by (Subramanian 2018), it was identified that a decentralised e-marketplaces can support traders to transact with each other directly and the records of each transaction and manage the offers and demands of the market, achieving with this the matching between offers and demands. Therefore, a digital marketplace for surplus food redistribution is proposed.

A digital marketplace on top of a blockchain-based solution can provide three main functionalities to end-users. First, the list of items and products intended to be donated can be publicly available with the current conditions and specifications for transportation, storage and delivery, considering the food donations at zero cost. Second, the agreements for trading and transfer of goods will be entirely digital, reducing the operational, monitoring and compliance costs. Third, the auditability of the transactions can be made by Authorities and validators of the network.

Figure 6.1 illustrates the conceptual design of the decentralised blockchain-based marketplace with Internet of Things for surplus food redistribution.

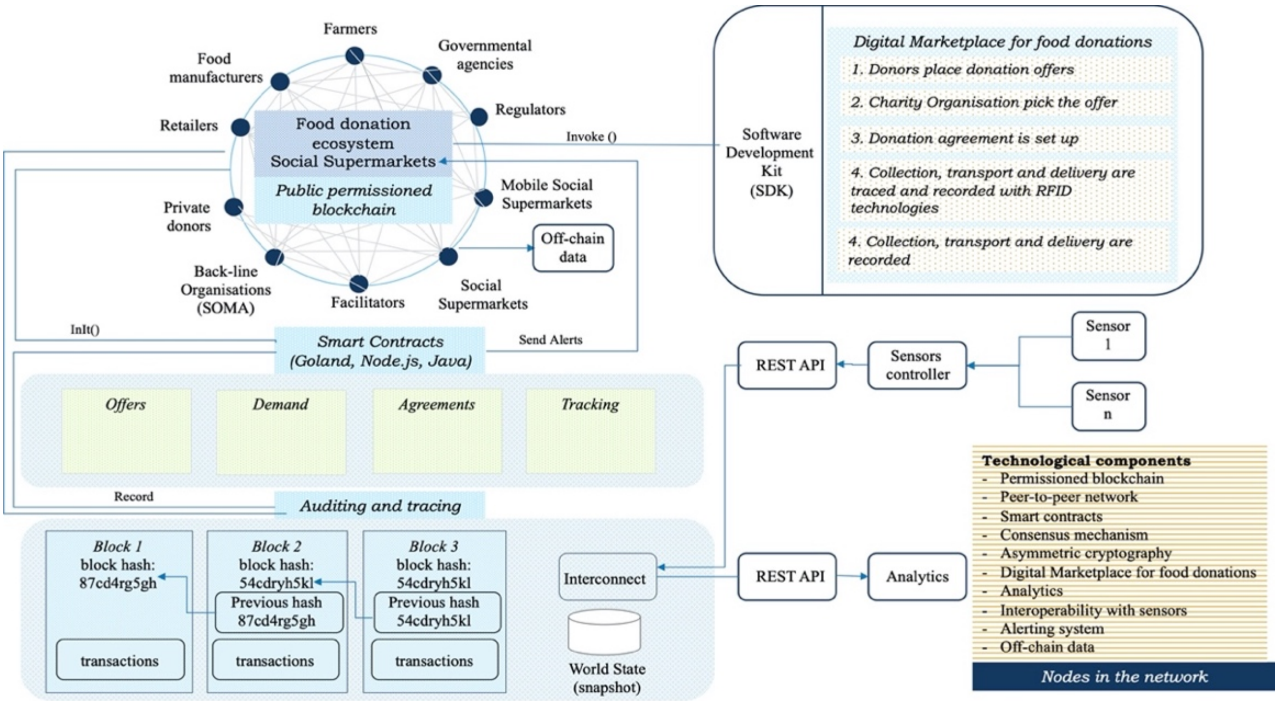


**Figure 6.1** Conceptual design of a decentralized digital marketplace for surplus food redistribution via Social supermarkets. Source: (The Author).

Four blockchain frameworks were identified in this study to meet the social supermarket requirements, which are Hyperledger Fabric, Hyperledger Sawtooth, R3 Corda blockprovenance, as well as IBM Food Trust and Fresh Insights. However, one relevant aspect to consider before the implementation is to identify the existing systems of their donors and their willingness to share their data in an existing platform such as IBM Food Trust. In addition to assessing new emerging blockchain frameworks focusing on enabling the interoperability among networks such as Tendermint, ChainlInk, Holochain and others.

In light of the above, the research propositions were validated using the existing literature and experts' consultations, which are answered below:

**Proposition 1:** IF blockchain can support the functions of the operating model of social supermarkets THEN a decentralised ecosystem can be implemented to address the inter-organisational collaboration for the surplus food redistribution via social supermarkets.

***True.*** *Blockchain as a core system with five additional technological components can meet the requirements of the Austria social supermarkets creating a decentralised ecosystem to streamline business processes and achieve inter-organisational collaboration to support the surplus food redistribution via social supermarkets.*

**Proposition 2:** IF blockchain and Internet of Things are a suitable solution for the food donation chain THEN the requirements of transparency, traceability, auditability and data security can be achieved.

***True.*** *A public permissioned blockchain framework with sensors for Internet of Things can achieve the requirements of transparency, traceability and auditability of the food donation chain, storing the data securely in the network.*

**Proposition 3:** IF the data of the conditions of the foodstuff can be digitally available using blockchain and Internet of Things THEN they can support the decision-making process for re-use, reallocate and redistribute foodstuffs.

***True.*** *Blockchain technology running jointly with Internet of Things and Analytics can increase the visibility capabilities to know the actual conditions of the food so as retailers can make informed decisions to reuse, reallocate and redistribute the foodstuffs to Charity Organisations,*

**Proposition 4:** IF blockchain technology and Internet of Things can facilitate the pull and push strategies to match the offer and demand for food donations, THEN the operational efficiency of the food donation chain can increase.

***True.*** *A decentralised digital marketplace based on blockchain technology jointly with analytics and Internet of Things can increase the matching of offers and demands for the surplus food redistribution to Charity Organisations.*

In addition to the technological aspects, there are three critical aspects to consider for project planning and implementation. First, it is crucial to define a clear roadmap of the implementation under an agile approach to produce small and incremental pieces of the system. The second aspect is piloting the concept first; this is, it is essential to roll out the system at small scale before implementing it at large scale so variables such as resistance to change can be managed effectively. Finally, a key aspect is to select the right people with the competencies needed to manage changes in different dimensions: organisational, cultural and behavioural aspects.

# 7 Conclusions and future work

This study set out with the aim of developing a guide that identifies practices and tools to support the surplus food redistribution between retailers and social supermarkets by implementing blockchain and Internet of Things, which leads to enable the UN Zero Hunger goal.

Three sub research questions supported this study. The first sub research question sought to determine how the social supermarkets concept can contribute to the achievement of the UN Zero Goal. It was selected the Austrian social supermarket model, which is the most similar case in Europe, notably this model has ranked first for its social integration in previous studies. The analysis was performed following a holistic single case study approach by using both document content analysis technique and collection of qualitative empirical data from experts' consultations.

The results of the case analysis cast a new light on the understanding of processes, stakeholders' relationships, information flow, logistics and the legal context of the Austrian social supermarket concept. Six key aspects of the social supermarket model were identified, which can support the achievement of the UN Zero Hunger goal:

1. **Community focus**. Social supermarkets are enterprises driven by social innovation that seek to improve the social and economic situation of local communities. Their profits are usually reinvested in the same location or community. Social supermarkets can gain a deep understanding of the community issues; therefore, it allows for implementing actions with significant local impact.

2. **Promote social inclusion** by implementing spaces and activities to enable the interaction of customers, such as coffee shops, cooking programs, and others.

3. **Support the implementation of sustainable practices** by limiting food waste, alleviating hunger and poverty by redistributing food surpluses to people in need and bringing environmental benefits by reducing greenhouse gas emissions and carbon footprints.

4. **Multi-stakeholders value capturing** via regular food donations made by retailers, food producers, and others, as well as the occasional donations obtained from charity events.

5. **Diversified delivery methods** to reach people who cannot afford to buy food for the whole month but are reluctant to benefit from the charity. The Austrian social supermarket model is combining choice, freshness, quality and respect for habits in a retail-like environment; as well as to reach people in remote places via mobile supermarkets.

6. **Implementation of social programs**. The socio-economic model implemented in Austria allows for the creation of private initiatives within the social welfare system to reduce the unemployment of people who are hard to place.

The second sub research question targeted to determine how blockchain and Internet of Things can increase the operational efficiency of the Austrian social market operating model between retailers and social supermarkets. Five functions were identified that can enhance the processes and data availability significantly in the food donation chain, which is described below:

1. **Streamline the business process to enable inter-organisational collaboration.** Blockchain provides a decentralised data and network structure, which, jointly with smart contracts can support the inter-organisational collaboration among the different stakeholders 'groups in the food donation chain.

2. **Management of the food donation agreements.** The properties of digital trading assets provided by smart contracts and cryptographic digital signatures can shift the manual process of the food donation agreements into digital agreements keeping the same aspects for legal liability transfer.

3. **Increase visibility capabilities in the food donation chain**. Blockchain and Internet of Things can collect, register and track the data of the conditions and locations of the foodstuffs securely to ensure food quality and food safety. Additionally, other activities with the use of analytics can be performed, such as traceback investigations, identification and location of foodstuffs that are close to their 'best before date' and proceed with the reallocation of foodstuffs.

4. **Transparency, accountability and auditability**. The immutability and comprehensibility of the data recorded in the blockchain can increase the transparency, accountability and auditability in the food donation chain. It also can contribute to the implementation of metrics to measure the social, economic and environmental benefits obtained from social supermarkets.

5. **Support push and pull logistic strategies in the food donation chain**. A decentralised digital marketplace can support the interaction of traders including donors, receivers, back-line organisations to enable a coordinated effort to couple the offer and demands, mainly to handle food donations of large volume,

6. **Autonomous decentralised ecosystem via process automation**. The implementation of all the technological components of this study can reduce the administrative burden and operational costs via process automation.

The third research question aimed to identify how to implement a blockchain-based solution using Internet of Things to increase the operational efficiency of the Austrian social supermarket. This study identified six technological components to achieve this goal that are following described: (1) a public permissioned blockchain framework, (2) sensors for Internet of Things, (3) Inter-Planetary File

Systems to pair the on-chain and off-chain data to provide large scalability and performance of the implementation, (4) software development to achieve the interoperability with external systems and (5) analytics to support the operational and strategic decision making for product recovery and food reallocation and (6) a decentralised digital marketplace to enable donors, receivers, back-line organisations transact with each other directly or through the SOMA network.

This thesis contributes to our understanding of how blockchain technology can be useful to increase the operational efficiency of the social supermarkets concept. It provides generalisation for its applicability to other social supermarkets models of other European countries, as well as to other Charity Organisations with similar information flow and source flow materials.

The conceptual design of the decentralised digital marketplace can be useful to achieve the sustainability targets of the United Nations and the European Commission of food waste reduction, alleviate hunger, poverty and environmental factors. This conceptual design also can be useful for all the stakeholders in the food donation process to reduce costs and especially for social entrepreneurs interested in creating a local, national or regional platform to handle the increasing offers of surplus food.

The study was limited by the information available of social supermarkets. Owing to the ongoing situation of COVID-19 and the change of the warehouse of SOMA and Wiener Tafel to another location, it was not possible to collect data directly from the field and from the management of the Austrian social supermarkets, who were not available to be interviewed.  Notwithstanding, experts in social supermarkets who previously collected data in the field validated the operating model and provided an in-depth explanation of their observations in the field.

Another limitation of this research is that the assessment of the blockchain frameworks was considering the leading architectures in the food supply chain. Therefore, some emerging blockchain frameworks were not included in this analysis, such as Tendermint and Holochain. Nevertheless, the blockchain frameworks evaluated have a certain level of maturity since they have already been implemented in the food supply chain. Nowadays, there are more than 100 blockchain initiatives in the market, and it is expected as well that they increase their level of specialisation gradually.

A natural progression of this work is to analyse the design of a reference architecture for a digital marketplace for surplus food redistribution. Furthermore, to analyse the power play of the stakeholders' group involved in the surplus food redistribution to design an economic model based on incentives for participation, as well as to study what competencies are needed for the implementation of the solution proposed in this study. On the other hand, further research should be carried out to establish a methodological framework to measure the economic, social and environmental impact of social supermarkets at large scale.

## References

Abe, H., Ashiki, T., Suzuki, A., Jinno, F., and Sakuma, H. 2009. "Integrating Business Modeling and Roadmapping Methods - The Innovation Support Technology (IST) Approach," *Technological Forecasting and Social Change* (76:1), Elsevier Inc., pp. 80–90. (https://doi.org/10.1016/j.techfore.2008.03.027).

Accorsi, R., Ferrari, E., Gamberi, M., Manzini, R., and Regattieri, A. 2016. "A Closed-Loop Traceability System to Improve Logistics Decisions in Food Supply Chains: A Case Study on Dairy Products," *Advances in Food Traceability Techniques and Technologies: Improving Quality Throughout the Food Chain*, Elsevier Ltd, pp. 337–351. (https://doi.org/10.1016/B978-0-08-100310-7.00018-1).

Agung, A. A. G., Dillak, R. G., Suchendra, D. R., and Robbi, H. 2019. "Proof of Work: Energy Inefficiency and Profitability," *Journal of Theoretical and Applied Information Technology* (97:5), pp. 1623–1633.

Albizzati, P. F., Tonini, D., Chammard, C. B., and Astrup, T. F. 2019. "Valorisation of Surplus Food in the French Retail Sector: Environmental and Economic Impacts," *Waste Management* (90), Elsevier Ltd, pp. 141–151. (https://doi.org/10.1016/j.wasman.2019.04.034).

AMS Österreich. 2017. *Living and Working in Austria*, pp. 1–63.

Attaran, M. 2007. "RFID: An Enabler of Supply Chain Operations," *Supply Chain Management* (12:4), pp. 249–257. (https://doi.org/10.1108/13598540710759763).

Aung, M. M., and Chang, Y. S. 2014. "Traceability in a Food Supply Chain: Safety and Quality Perspectives," *Food Control* (39:1), Elsevier Ltd, pp. 172–184. (https://doi.org/10.1016/j.foodcont.2013.11.007).

Bano, S., Sonnino, A., Al-Bassam, M., Azouvi, S., McCorry, P., Meiklejohn, S., and Danezis, G. 2017. *Consensus in the Age of Blockchains*. (http://arxiv.org/abs/1711.03936).

Behnke, K., and Janssen, M. F. W. H. A. 2020. "Boundary Conditions for Traceability in Food Supply Chains Using Blockchain Technology," *International Journal of Information Management* (52:March), Elsevier, pp. 1–10. (https://doi.org/10.1016/j.ijinfomgt.2019.05.025).

BitcoinCore. (n.d.). "Bitcoin Core Integration." (https://github.com/bitcoin/bitcoin, accessed April 7, 2020).

De Boeck, E., Jacxsens, L., Goubert, H., and Uyttendaele, M. 2017. "Ensuring Food Safety in Food Donations: Case Study of the Belgian Donation/Acceptation Chain," *Food Research International* (100:August), pp. 137–149. (https://doi.org/10.1016/j.foodres.2017.08.046).

Bowen, G. A. 2009. "Document Analysis as a Qualitative Research Method," *Qualitative Research Journal* (9:2), pp. 27–40. (https://doi.org/10.3316/QRJ0902027).

Bundesministerium für Land- und Forstwirtschaft, U. und W. 2011. *Federal Waste Management Plan 2011*, (2), pp. 1–180.

Caraher, M., and Cavicchi, A. 2014. "Old Crises on New Plates or Old Plates for a New Crises? Food Banks and Food Insecurity," *British Food Journal* (116:9), pp. 1–12.

(https://doi.org/10.1108/bfj-08-2014-0285).

Carson, B., Romanelli, G., Walsh, P., and Zhumaev, A. 2018. "Blockchain beyond the Hype: What Is the Strategic Business Value?," *McKinsey Quarterly* (2018:4), pp. 118–127.

Christidis, K., and Devetsikiotis, M. 2016. "Blockchains and Smart Contracts for the Internet of Things," *IEEE Access* (4), IEEE, pp. 2292–2303. (https://doi.org/10.1109/ACCESS.2016.2566339).

Corda. (n.d.). "Corda." (https://github.com/corda/corda, accessed April 7, 2020).

Defourny, J., and Borzaga, C. 2018. "The Emergence of Social Supermarkets in Britain: Food Poverty, Food Waste and Austerity Retail."

Enterprise Ethereum Alliance. (n.d.). "Enterprise Ethereum Alliance." (https://github.com/EntEthAlliance, accessed April 7, 2020).

Ethereum. (n.d.). "Ethereum." (https://github.com/ethereum, accessed April 7, 2020).

EU Fusions Project. 2014. "Stimulating Social Innovation through Policy Measures."

European Commission. 2017. "EU Guidelines on Food Donation," *Official Journal of the European Union* (73:1907), pp. 260–263.

European Commission. 2019. *Redistribution of Surplus Food: Examples of Practices in the Member States*, (May). (https://ec.europa.eu/food/safety/food_waste/eu_actions/eu-platform_en).

European Fundraising Association. 2018. *Tax Incentives for Charitable Giving in Europe*, (December), pp. 1–10. (www.efa-net.eu).

European Parliament. 2002. "General Food Law Regulation (EC) Nº 178/2002," *Official Journal of the European Communities* (L31), pp. 1–24. (https://doi.org/2004R0726 - v.7 of 05.06.2013).

European Union. 2013. "Council Directive 2013/59/Euratom," *Official Journal of the European Union* (56), p. 216. (https://doi.org/10.3000/19770677.L_2013.124.eng).

Eyob, E. 2007. "Evaluating Methodologies of Financial Cost and Benefit Aspects of E-Government," in *Encyclopedia of Digital Government* (Vol. 1), A.-V. Anttiroiko and M. Mälkiä (eds.), Hershey, PA: Idea Group Reference, pp. 784–789. (http://www.loc.gov/catdir/toc/ecip0611/2006010087.html).

FAO. 2006. *Food Security, Policy Brief*, (2), pp. 1–4. (http://www.fao.org/fileadmin/templates/faoitaly/documents/pdf/pdf_Food_Security_Cocept_Note.pdf).

FAO. 2015. "Food Loss and Waste Facts. Food and Agriculture Organization of the United Nations." (http://www.fao.org/3/a-i4807e.pdf).

French, M. L., and Laforge, R. L. 2006. "Closed-Loop Supply Chains in Process Industries: An Empirical Study of Producer Re-Use Issues," *Journal of Operations Management* (24:3), pp. 271–286. (https://doi.org/10.1016/j.jom.2004.07.012).

Galli, F., Hebinck, A., and Carroll, B. 2018. “Addressing Food Poverty in Systems: Governance of Food Assistance in Three European Countries,” *Food Security* (10:6), Food Security, pp. 1353–1370. (https://doi.org/10.1007/s12571-018-0850-z).

Galvez, J. F., Mejuto, J. C., and Simal-Gandara, J. 2018. “Future Challenges on the Use of Blockchain for Food Traceability Analysis,” *TrAC - Trends in Analytical Chemistry* (107), Elsevier Ltd, pp. 222–232. (https://doi.org/10.1016/j.trac.2018.08.011).

Georgiadis, P., Vlachos, D., and Iakovou, E. 2005. “A System Dynamics Modeling Framework for the Strategic Supply Chain Management of Food Chains,” *Journal of Food Engineering* (70:3), pp. 351–364. (https://doi.org/10.1016/j.jfoodeng.2004.06.030).

Gol, D. A. 2019. “An Analysis of Consensus Algorithms for the Blockchain Technology,” *International Journal for Research in Applied Science and Engineering Technology* (7:2), pp. 675–680. (https://doi.org/10.22214/ijraset.2019.2096).

Govindan, K., Soleimani, H., and Kannan, D. 2015. “Reverse Logistics and Closed-Loop Supply Chain: A Comprehensive Review to Explore the Future,” *European Journal of Operational Research* (240:3), Elsevier B.V., pp. 603–626. (https://doi.org/10.1016/j.ejor.2014.07.012).

Gustavsson, J., Cederberg, C., Sonesson, U., van Otterdijk, R., and Meybeck, A. 2011. “Global Food Losses and Food Waste: Extent, Causes and Prevention,” *International Congress: Save Food!*, Rome, Italy: Food and Agriculture Organization of the United Nations. (https://doi.org/10.1098/rstb.2010.0126).

Hermsdorf, D., Rombach, M., and Bitsch, V. 2017. “Food Waste Reduction Practices in German Food Retail,” *British Food Journal* (119:12), pp. 2532–2546. (https://doi.org/10.1108/BFJ-06-2017-0338).

Holweg, C., and Lienbacher, E. 2011. “Social Marketing Innovation: New Thinking in Retailing,” *Journal of Nonprofit and Public Sector Marketing* (23:4), pp. 307–326. (https://doi.org/10.1080/10495142.2011.623548).

Holweg, C., Lienbacher, E., and Peter Schnedlitz. 2010. “Social Supermarkets: Typology within the Spectrum of Social Enterprises,” in *ANZMAC 2010*, New Zealand: WU Vienna University of Economics and Business.

Holweg, C., Lienbacher, E., and Zinn, W. 2010. “Social Supermarkets-a New Challenge in Supply Chain Management and Sustainability,” *Supply Chain Forum: An International Journal* (11:4), pp. 50–58. (https://doi.org/10.1080/16258312.2010.11517246).

van der Horst, H., Pascucci, S., and Bol, W. 2014. “The ‘Dark Side’ of Food Banks? Exploring Emotional Responses of Food Bank Receivers in the Netherlands,” *British Food Journal* (116:9), pp. 1506–1520. (https://doi.org/10.1108/BFJ-02-2014-0081).

Hyperledger Fabric. (n.d.). “Hyperledger Fabric EVM Chaincode.” (https://github.com/hyperledger/fabric-chaincode-evm, accessed April 7, 2020).

Hyperledger Iroha. (n.d.). “Hyperledger Iroha.” (https://github.com/hyperledger/iroha, accessed April 7, 2020).

Hyperledger Sawtooth. (n.d.). “Core Repository for Hyperledger Sawtooth.”

(https://github.com/hyperledger/sawtooth-core, accessed April 7, 2020).

Imbault, F., Swiatek, M., De Beaufort, R., and Plana, R. 2017. "The Green Blockchain: Managing Decentralized Energy Production and Consumption," *Conference Proceedings - 2017 17th IEEE International Conference on Environment and Electrical Engineering and 2017 1st IEEE Industrial and Commercial Power Systems Europe, EEEIC / I and CPS Europe 2017*. (https://doi.org/10.1109/EEEIC.2017.7977613).

Kadena. (n.d.). "Kadena Public Blockchain." (https://github.com/kadena-io/chainweb-node, accessed April 7, 2020).

Kamath, R. 2018. "Food Traceability on Blockchain: Walmart's Pork and Mango Pilots with IBM," *The Journal of the British Blockchain Association* (1:1), pp. 1–12. (https://doi.org/10.31585/jbba-1-1-(10)2018).

Kewell, B., Adams, R., and Parry, G. 2017. "Blockchain for Good?," *Strategic Change* (26:5), pp. 429–437. (https://doi.org/10.1002/jsc.2143).

Klindžić, M., Knežević, B., and Marić, I. 2016. *Stakeholder Analysis of Social Supermarkets*, pp. 151–166. (https://pdfs.semanticscholar.org/b0f0/451c02e524ae99e84b80880b96d81b774872.pdf).

Knezevic, B., Davidaviciene, V., and Skrobot, P. 2017. "Social Networks as a Communication Tool in Social Supermarkets," *SOTICS 2017,The Seventh International Conference on Social Media Technologies, Communication, and Informatics* (June), pp. 5–10. (https://www.thinkmind.org/index.php?view=article&articleid=sotics_2017_1_40_68008).

Kouhizadeh, M., Zhu, Q., and Sarkis, J. 2019. "Blockchain and the Circular Economy: Potential Tensions and Critical Reflections from Practice," *Production Planning and Control* (7287), Taylor & Francis. (https://doi.org/10.1080/09537287.2019.1695925).

Krikke, H., le Blanc, I., and van de Velde, S. 2004. *Product Modularity and the Design of Closed-Loop Supply Chains*.

Krikke, H., Pappis, C. P. ., Tsolfas, G. T. ., and Bloemhof-Ruwaard, J. 2001. *Design Principles for Closed Loop Supply Chains*, (May 2014).

Krikke, H. R., Pappis, C. P., Tsoulfas, G., and Bloemhof-Ruwaard, J. 2001. *Design Principles for Closed Loop Supply Chains*, (January), pp. 1–14.

Kumar, N. M., and Mallick, P. K. 2018. "Blockchain Technology for Security Issues and Challenges in IoT," *Procedia Computer Science* (132), Elsevier B.V., pp. 1815–1823. (https://doi.org/10.1016/j.procs.2018.05.140).

Lambie-Mumford, H. 2016. "The Rise of Food Charity: Issues and Challenges," *Geography* (101:1), pp. 11–17.

Lamport, L., Shostak, R., and Pease, M. 1982. "The Byzantine Generals Problem," *ACM Transactions on Programming Languages and Systems (TOPLAS)* (4:3), pp. 382–401. (https://doi.org/10.1145/357172.357176).

Landesgesetzblättern der Länder. 2002. *Abfallwirtschaftsgesetz 2002*, Austria, pp. 1–125.

(https://www.ris.bka.gv.at/GeltendeFassung.wxe?Abfrage=Bundesnormen&Gesetzesnummer=20002086).

Lee, H., and Kim, J. 2006. “Privacy Threats and Issues in Mobile RFID,” *Proceedings - First International Conference on Availability, Reliability and Security, ARES 2006* (2006), pp. 510–514. (https://doi.org/10.1109/ARES.2006.96).

MA, R., YAO, L., JIN, M., REN, P., and LV, Z. 2016. “Robust Environmental Closed-Loop Supply Chain Design under Uncertainty,” *Chaos, Solitons and Fractals* (89), Elsevier Ltd, pp. 195–202. (https://doi.org/10.1016/j.chaos.2015.10.028).

Margulis, M. E. 2013. “The Regime Complex for Food Security: Implications for the Global Hunger Challenge,” *Global Governance* (19:1), pp. 53–67. (https://doi.org/10.1163/19426720-01901005).

Maric, I., Knezevic, B., and Kovac, J. 2015. *Attitudes of Young Population Towards Managing Social Supermarkets in Croatia*, pp. 059–066. (https://doi.org/10.2507/daaam.scibook.2015.06).

Meissner, M., and Schneider, F. 2011. “Results of the ECR Austria Working Group " Social Sustainability ".”

Mingxiao, D., Xiaofeng, M., Zhe, Z., Xiangwei, W., and Qijun, C. 2017. “A Review on Consensus Algorithm of Blockchain,” *2017 IEEE International Conference on Systems, Man, and Cybernetics, SMC 2017* (2017-Janua), pp. 2567–2572. (https://doi.org/10.1109/SMC.2017.8123011).

Mourad, M. 2016. “Recycling, Recovering and Preventing ‘Food Waste’: Competing Solutions for Food Systems Sustainability in the United States and France,” *Journal of Cleaner Production* (126), Elsevier Ltd, pp. 461–477. (https://doi.org/10.1016/j.jclepro.2016.03.084).

Multichain. (n.d.). “MultiChain Linux Build Notes.” (https://github.com/MultiChain/multichain, accessed April 7, 2020).

Nikolakis, W., John, L., and Krishnan, H. 2018. “How Blockchain Can Shape Sustainable Global Value Chains: An Evidence, Verifiability, and Enforceability (EVE) Framework,” *Sustainability* (10:11), pp. 1–16. (https://doi.org/10.3390/su10113926).

OECD. 2020a. “OECD Regions at a Glance,” *Choice Reviews Online*. (https://doi.org/10.5860/choice.45-2390).

OECD. 2020b. “Poverty Rate (Indicator).” (https://data.oecd.org/inequality/poverty-rate.htm, accessed March 23, 2020).

Official Journal of the European Union. 2008. *Directive 2008/98/EC of the European Parliament and of the Council on Waste and Repealing Certain Directives*, pp. 3–30.

Ølnes, S., Ubacht, J., and Janssen, M. 2017. “Blockchain in Government: Benefits and Implications of Distributed Ledger Technology for Information Sharing,” *Government Information Quarterly* (34:3), pp. 355–364. (https://doi.org/10.1016/j.giq.2017.09.007).

Open Chain. (n.d.). “Open Chain.” (https://github.com/OpenFuturePlatform/open-chain, accessed April 7, 2020).

Osterland, T., and Thomas, R. 2018. "Engineering Sustainable Blockchain Applications," *Proceedings of the 1st ERCIM Blockchain Workshop 2018, Reports of the European Society for Socially Embedded Technologies* (10), pp. 1–8. (https://doi.org/10.18420/blockchain2018).

Osterwalder, A., and Pigneur, Y. 2010. *Business Model Generation*, United States of America: John Wiley & Sons, Inc., Hoboken, New Jersey.

Papargyropoulou, E., Lozano, R., K. Steinberger, J., Wright, N., and Ujang, Z. Bin. 2014. "The Food Waste Hierarchy as a Framework for the Management of Food Surplus and Food Waste," *Journal of Cleaner Production* (76), pp. 106–115. (https://doi.org/10.1016/j.jclepro.2014.04.020).

Pearson, S., May, D., Leontidis, G., Swainson, M., Brewer, S., Bidaut, L., Frey, J. G., Parr, G., Maull, R., and Zisman, A. 2019. "Are Distributed Ledger Technologies the Panacea for Food Traceability?," *Global Food Security* (20:November 2018), Elsevier B.V., pp. 145–149. (https://doi.org/10.1016/j.gfs.2019.02.002).

Quorum. (n.d.). "Quorum." (https://github.com/jpmorganchase/quorum, accessed April 7, 2020).

Rauchs, M., and Hileman, G. 2017. "Global Blockchain Benchmarking Study," *Cambridge Centre for Alternative Finance Reports*.

Regattieri, A., Gamberi, M., and Manzini, R. 2007. "Traceability of Food Products: General Framework and Experimental Evidence," *Journal of Food Engineering* (81:2), pp. 347–356. (https://doi.org/10.1016/j.jfoodeng.2006.10.032).

Rezaee, M. 2019. "Opportunities of Blockchain Technologies in Closed-Loop Supply Chain Management," Politecnico di Milano.

Ripple Inc. (n.d.). "Ripple." (https://github.com/ripple, accessed April 7, 2020).

Rogers, D. S., and Tibben-lembke, R. 2001. *An Examination of Reserver Logistics Practices*, (22:2), pp. 129–148.

Rowley, J. 2002. "Using Case Studies in Research," *Management Research News* (25:1), pp. 16–27. (https://doi.org/10.1108/01409170210782990).

Runeson, P., Höst, M., Rainer, A., and Regnell, B. 2012. *Case Study Research in Software Engineering: Guidelines and Examples*, Wiley. (http://www.worldcat.org/title/case-study-research-in-software-engineering-guidelines-and-examples/oclc/828789615&referer=brief_results).

Saberi, S., Kouhizadeh, M., Sarkis, J., and Shen, L. 2019. "Blockchain Technology and Its Relationships to Sustainable Supply Chain Management," *International Journal of Production Research* (57:7), pp. 2117–2135. (https://doi.org/10.1080/00207543.2018.1533261).

Samaras, G. M., and Horst, R. L. 2005. "A Systems Engineering Perspective on the Human-Centered Design of Health Information Systems," *Journal of Biomedical Informatics* (38:1), pp. 61–74. (https://doi.org/10.1016/j.jbi.2004.11.013).

Saveen A. Abeyratne, and Radmehr P. Monfared. 2016. "Blockchain Ready Manufacturing Supply Chain Using Distributed Ledger," *International Journal of Research in Engineering and*

*Technology* (05:09), pp. 1–10. (https://doi.org/10.15623/ijret.2016.0509001).

Schneider, F. 2013. "The Evolution of Food Donation with Respect to Waste Prevention," *Waste Management* (33:3), pp. 755–763. (https://doi.org/10.1016/j.wasman.2012.10.025).

Schneider, F., Scherhaufer, S., BOKU University Austria, Montoux, H., Gheoldus, M., O'Connor, C., and Derain, A. 2015. *Advancing Social Supermarkets across Europe*, (July), p. 67.

Seawnght, J., and Gerring, J. 2008. "Case Selection Techniques in Case Study Research: A Menu of Qualitative and Quantitative Options," *Political Research Quarterly* (61:2), pp. 294–308. (https://doi.org/10.1177/1065912907313077).

Sgarbossa, F., and Russo, I. 2017. "A Proactive Model in Sustainable Food Supply Chain: Insight from a Case Study," *International Journal of Production Economics* (183:2017), Elsevier, pp. 596–606. (https://doi.org/10.1016/j.ijpe.2016.07.022).

SOMA. (n.d.). "Eine Idee, Die Hilft. Auf Schiene Gebracht." (http://www.sozialmarkt.at/index.php?id=5, accessed March 23, 2020).

Subramanian, H. 2018. *Decentralized Blockchain-Based Electronic Marketplaces*, p. 7.

Szmelter-Jarosz, A. 2016. "Specifics of Closed Loop Supply Chain Management in the Food Sector," *Journal of Reverse Logistics* (2:1), pp. 14–19. (https://www.researchgate.net/publication/313895849_Specifics_of_Closed_Loop_Supply_Chain_Management_in_the_food_sector).

Tendermint. (n.d.). "Tendermint." (https://github.com/tendermint/tendermint, accessed April 7, 2020).

Tian, F. 2016. "An Agri-Food Supply Chain Traceability System for China Based on RFID & Blockchain Technology," *2016 13th International Conference on Service Systems and Service Management, ICSSSM 2016*, IEEE, pp. 1–6. (https://doi.org/10.1109/ICSSSM.2016.7538424).

Toro-Jarrín, M. A., Ponce-Jaramillo, I. E., and Güemes-Castorena, D. 2016. "Methodology for the of Building Process Integration of Business Model Canvas and Technological Roadmap," *Technological Forecasting and Social Change* (110), Elsevier Inc., pp. 213–225. (https://doi.org/10.1016/j.techfore.2016.01.009).

United Nations. 2018. "Transforming Our World: The 2030 Agenda for Sustainable Development," *A New Era in Global Health*. (https://doi.org/10.1891/9780826190123.ap02).

USAID. 2015. "Infographic: How to Fight Hunger," pp. 48–51. (https://www.usaid.gov/infographics/50th/how-to-fight-hunger, accessed January 29, 2020).

Vos, D., Overweel, L., Raateland, W., Vos, J., Bijman, M., Pigmans, M., and Erkin, Z. 2018. "DEFenD: A Secure and Privacy-Preserving Decentralized System for Freight Declaration," *Proceedings of the 1st ERCIM Blockchain Workshop 2018, Reports of the European Society for Socially Embedded Technologies* (10), pp. 1–8. (https://doi.org/10.18420/blockchain2018).

Wang, S., Ouyang, L., Yuan, Y., Ni, X., Han, X., and Wang, F. Y. 2019. "Blockchain-Enabled Smart Contracts: Architecture, Applications, and Future Trends," *IEEE Transactions on Systems, Man, and Cybernetics: Systems* (49:11), IEEE, pp. 2266–2277.

(https://doi.org/10.1109/TSMC.2019.2895123).

Webster, J., and Watson, R. 2002. “Analyzing the Past to Prepare for the Future: Writing a Literature Review,” *MIS Quarterly* (26:2).

Weichselbaum, E. 2009. “SOMA - an Initiative to Help the Poor in Austria,” *British Nutrition Foundation Bulletin*, pp. 64–65.

Weis, S. A. 2003. “Security and Privacy in Radio-Frequency Identification Devices,” *Security*, Massachusetts Institute of Technology.

Wiener Tafel. (n.d.). “Armut in Österreich,” pp. 2–3. (https://www.wienertafel.at/index.php?id=418, accessed March 23, 2020).

Wolfson, R. 2018. “Understanding How IBM And Others Use Blockchain Technology To Track Global Food Supply Chain,” pp. 5–11. (https://www.forbes.com/sites/rachelwolfson/2018/07/11/understanding-how-ibm-and-others-use-blockchain-technology-to-track-global-food-supply-chain/#71dc9a012d1e, accessed May 7, 2020).

Wolfson, R. 2019. “Albertsons Joins IBM Food Trust Blockchain Network To Track Romaine Lettuce From Farm To Store,” pp. 2–7. (https://www.forbes.com/sites/rachelwolfson/2019/04/11/albertsons-joins-ibm-food-trust-blockchain-network-to-track-romaine-lettuce-from-farm-to-store/#2abe61f66219, accessed May 7, 2020).

Wust, K., and Gervais, A. 2018. “Do You Need a Blockchain?,” *Proceedings - 2018 Crypto Valley Conference on Blockchain Technology, CVCBT 2018* (i), pp. 45–54. (https://doi.org/10.1109/CVCBT.2018.00011).

Xu, X., Weber, I., Staples, M., Zhu, L., Bosch, J., Bass, L., Pautasso, C., and Rimba, P. 2017. “A Taxonomy of Blockchain-Based Systems for Architecture Design,” *Proceedings - 2017 IEEE International Conference on Software Architecture, ICSA 2017*, pp. 243–252. (https://doi.org/10.1109/ICSA.2017.33).

Yin, R. K. 2018. “Case Study Research and Applications. Sixth Edition,” *Case Study Research and Applications. Sixth Edition* (Vol. 53), SAGE Publications Inc.

Yuan, Y., and Wang, F. Y. 2018. “Blockchain and Cryptocurrencies: Model, Techniques, and Applications,” *IEEE Transactions on Systems, Man, and Cybernetics: Systems* (48:9), IEEE, pp. 1421–1428. (https://doi.org/10.1109/TSMC.2018.2854904).

Zafar, M. A., Sher, F., Janjua, M. U., and Baset, S. 2018. “Translating Solidity Contracts into Javascript for Hyperledger Fabric,” *SERIAL 2018 - Proceedings of the 2018 Workshop on Scalable and Resilient Infrastructures for Distributed Ledgers*, pp. 19–24. (https://doi.org/10.1145/3284764.3284768).

Zhao, X., Fan, H., Zhu, H., Fu, Z., and Fu, H. 2015. *The Design of the Internet of Things Solution for Food Supply Chain*, (Emim), pp. 314–318. (https://doi.org/10.2991/emim-15.2015.61).

Zheng, Z., Xie, S., Dai, H.-N., Chen, X., and Wang, H. 2017. “Blockchain Challenges and Opportunities : A Survey Shaoan Xie Hong-Ning Dai Huaimin Wang,” *International Journal of*

*Web and Grid Services* (14:4), pp. 1–24. (https://doi.org/10125/41338).

University of California Berkley. 2019. ‘Blockchain Technology’. *edX Platform.* Accessed online: https://www.edx.org. (October 18, 2019).

Food waste and SSMs expert. 2020. ¨Food waste prevention and social supermarkets¨. (April 24, 2020).

Retailing and SSMs expert. 2020. ¨Food waste prevention and social supermarkets¨. (May 6, 2020).

CTO Blockchain expert. 2020. ¨Food waste prevention and social supermarkets¨. (April 28, 2020).

Blockchain consultant. 2020. ¨Blockchain and Internet of things potential for the food donation chain¨. (May 13, 2020).

Process mining on blockchain expert. 2020. ¨Blockchain and Internet of things potential for the food donation chain¨. (June 4, 2020).

IBM Senior Architect. 2020. ¨Blockchain and Internet of things potential for the food donation chain¨. (May 8, 2020).

Holweg, C., Lienbacher, E. 2016. ¨Social Supermarkets in Europe: Investigations from a retailing perspective in selected countries¨ (2016).

# Appendices

## Appendix A – Extract of Concepts Matrix

| | | | Concepts | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Year** | **Title** | **Author** | Surplus food management | Sustainable supply chain | Blockchain | Blockchain and IoT | Social Supermarkets | Methodology |
| 2016 | Recycling, recovering and preventing "food waste | M. Mourad | X | | | | | |
| 2014 | The food waste hierarchy as a framework for the management of food surplus and food waste | E. Papargyropoulou | X | | | | | |
| 2018 | Transforming Our World: The 2030 Agenda for Sustainable Development | United Nations | X | | | | | |
| 2005 | A system dynamics modeling framework for the strategic supply chain management of food chains | P. Georgiadis | | X | | | | |
| 2015 | Reverse logistics and closed-loop supply chain: A comprehensive review to explore the future | K. Govindan | | X | | | | |
| 2006 | Closed-loop supply chains in process industries: An empirical study of producer re-use issues | M. L. French | | X | | | | |
| 2017 | Global Blockchain Benchmarking Study | M. Rauchs and G. Hileman | | | X | | | |
| 2017 | A Taxonomy of Blockchain-Based Systems for Architecture Design | X. Xu et al. | | | X | | | |
| 2018 | Blockchain beyond the hype: What is the strategic business value? | B. Carson | | | X | | | |
| 2016 | Blockchains and Smart Contracts for the Internet of Things | K. Christidis and M. Devetsikiotis | | | X | | | |
| 2016 | An agri-food supply chain traceability system for China based on RFID & blockchain technology | F. Tian | | | | X | | |
| 2015 | Advancing social supermarkets across Europe | F. Schneider *et al* | | | | | X | |
| 2011 | Social Marketing Innovation: New Thinking in Retailing | C. Holweg and E. Lienbacher | | | | | X | |
| 2013 | The evolution of food donation with respect to waste prevention | F. Schneider | | | | | X | |
| 2017 | Social Networks as a Communication Tool in Social Supermarkets | B. Knezevic | | | | | X | |
| 2018 | Engineering Sustainable Blockchain Applications | T. Osterland and R. Thomas | | | | | | X |
| 2018 | Do you need a blockchain? | K. Wust and A. Gervais | | | | | | X |
| 2010 | Business Model Generation | A. Osterwalder and Y. Pigneur | | | | | | X |

## Appendix B – Interview Guide

| | Question area | # | Interviewee profile |
|---|---|---|---|
| **1.** | **Frameworks and challenges for surplus food redistribution**<br>• Frameworks and Indexes<br>• Benefits (retailers)<br>• Challenges (retailers and charity organisations) | 6 | Sustainability specialists |
| **2.** | **Sustainable supply chain practices**<br>• Challenges and limitations for implementation<br>• Applicability in the food donation process | 2 | Sustainability specialists<br>Supply Chain Expert |
| **3.** | **Social supermarkets in Austria**<br>• Operating model / Actors<br>• Business Processes Identification<br>• Resource Flow in the food donation chain<br>• Information Management Requirements | 4 | Sustainability specialists |
| **4.** | **Criteria for selecting Enterprise blockchain frameworks**<br>• General aspects<br>• Technical Properties | 2 | Blockchain and IoT experts |
| **5.** | **Blockchain enterprise frameworks for food supply** | 1 | Blockchain and IoT experts |
| **6.** | **Blockchain properties for food supply chain**<br>• Tools for traceability<br>• Tools for auditability (process mining and analytics)<br>• Alerting System<br>• Data security<br>• Data on-chain versus data off-chain | 5 | Blockchain and IoT experts |
| **7.** | **Business Process Modelling on blockchain**<br>• Tools for modelling and manage the business process design and implementation<br>• Tools for developing the front-end | 2 | Blockchain and IoT experts |
| **8.** | **Interoperability frameworks for blockchain and IoT**<br>• Approaches | 1 | Blockchain and IoT experts |

## Appendix C – List of Interviewees

| Identification | Position / Organization | Area of expertise | Date |
|---|---|---|---|
| Food waste and SSMs expert | Thünen Institute, Germany - Institute of Market Analysis) – G20 Food Loss and Waste Initiative | Sustainability Expert | April 24, 2020 |
| Retailing and SSMs expert | Institute for Retailing and Marketing Vienna University of Economics and Business | Retailing and Social Supermarkets expert | May 06, 2020 |
| CTO Blockchain expert | Aequalis, India | Blockchain expert | April 28, 2020 |
| IBM Senior Architect | IBM | Blockchain expert | May 08, 2020 |
| Blockchain Consultant | Aqar Chain, Saudi Arabia | Blockchain expert | May 13, 2020 |
| Process mining and blockchain expert | Sapienza University, Italy | Blockchain expert with specialization in Process Mining | June 4, 2020 |

## Appendix D – Questionnaire for Sustainability and Social supermarkets experts

### Section 1: Segmentation Questions

- Could you please briefly introduce yourself?
- What is your role in your Organisation?
- Could you please mention your experience with topics related to food waste management and social supermarkets?
- Are you currently involved in any initiative connected with food waste prevention or efforts to alleviate hunger to enable United Nations Sustainable Development Goals (SDGs)?
    - If yes, what is your role in these initiatives?

### Section 2: Frameworks and challenges for the management of food surplus

1. What are the most common frameworks used that serve as guidance for the management of food surplus (3R, Waste hierarchy, etc.)? Why?
2. Why do many organisations only have set indexes to measure waste streams but not for surplus food redistribution?
3. Is there any guide or best practices available for sorting surplus food for human consumption used by food producers and retailers?
4. In your opinion, what are the main challenges for retailers to donate surplus food?
5. What are the incentives or benefits for retailers to donate surplus food?
6. In your opinion, what are the challenges for Charitable Organisations to administer the collection and delivery of the food donated?

### Section 3: Social supermarkets

7. The following figure was created to show a simplified representation of the typical social supermarket model in Austria, would you add or remove any of its elements? (Figure 4.1)
8. The following diagram illustrates the activities and sequence of the surplus food distribution process for regular donors. Do the activities, and their sequence show correctly the food donation process between retailers and social supermarkets?

If not, what should it be modified? (Figure 4.3)

9. From the supply chain perspective the following figure illustrates the flow of the foodstuffs during the food donation chain taking into account three scenarios: 1) surplus food redistribution performed directly by independent social supermarkets, as well as their possible interaction with joint logistics performed by the SOMA network 2) a joint logistics process carried by SOMA network, and 3) when food banks may distribute surplus food from retailers and manufacturers to social supermarkets. (Figure 4.2)

10. Would you modify or add any flow of the surplus food redistribution to the diagram?
11. What are the challenges for implementing sustainable supply chain practices such as reverse logistics or closed-loop design for food donation?
12. Following are described the requirements for information management to support the food donation process. Would you add any other requirement?
    If yes, please specify
    - Customers profile
    - Management of food donation agreements
    - Traceability
    - Alert system
    - Auditability and accountability
    - Transparency
    - Inter-organisational collaboration
    - Flexibility design and interoperability with existing systems of retailers
    - Data security
13. Is there any existing system that captures, stores and manages the data generated across the surplus food redistribution between retailers and social supermarkets or between food banks and social supermarkets?

## Appendix E – Questionnaire blockchain experts

### Methods and Tools for implementing blockchain and IoT technologies for the food donation chain

**Section 1: Segmentation Questions**

- Could you please briefly introduce yourself?
- What is your role in your Organisation?
- What is your experience with DLT/blockchain technologies?

**Section 2: Criteria for selecting blockchain enterprise frameworks**

1. What factors do you usually look out for choosing an Enterprise DLT/blockchain framework? In other words, factors such as support, development roadmap, ease of use, etc.
2. Which technical properties do you take into account for choosing and DLT/blockchain Enterprise Framework? (permission, writers, etc.)?

**Section 3: Blockchain enterprises frameworks for food supply chain**

3. In your opinion, what DLT/blockchain frameworks can or potentially meet the functional and technical requirements for implementing a food supply chain solution? Why?

**Section 4: Blockchain properties for food supply chain**

4. What properties and tools of DLT/blockchain would you recommend to achieve the traceability of foodstuffs across a supply chain solution?
5. What properties or tools would you recommend to achieve the auditability of the transactions recorded across a food supply chain solution on DLT/blockchain? (including process mining, analytics)

**Section 5: Business process modelling and process mining on the blockchain**

6. What tools would you use to design and create smart contracts to enable an inter-organisational business process for a food supply chain solution on DLT/blockchain?
7. What tools do you usually use for developing front-end applications running on DLT/blockchain frameworks?

**Section 6: Interoperability frameworks for blockchain and IoT**

8. What methods would you use to achieve the interoperability amongst compatible DLT/blockchain networks?

9. What methods would you use to achieve the interoperability between blockchain platforms and external systems (including non-compatible DLT/blockchain networks)?
10. If you would have to implement the interoperability of DLT/blockchain framework with RFID technologies, what methods would you use to achieve it (oracles, smart contracts, APIs, etc.)?

## Appendix F – Initial diagrams of the Social Supermarket model for validation

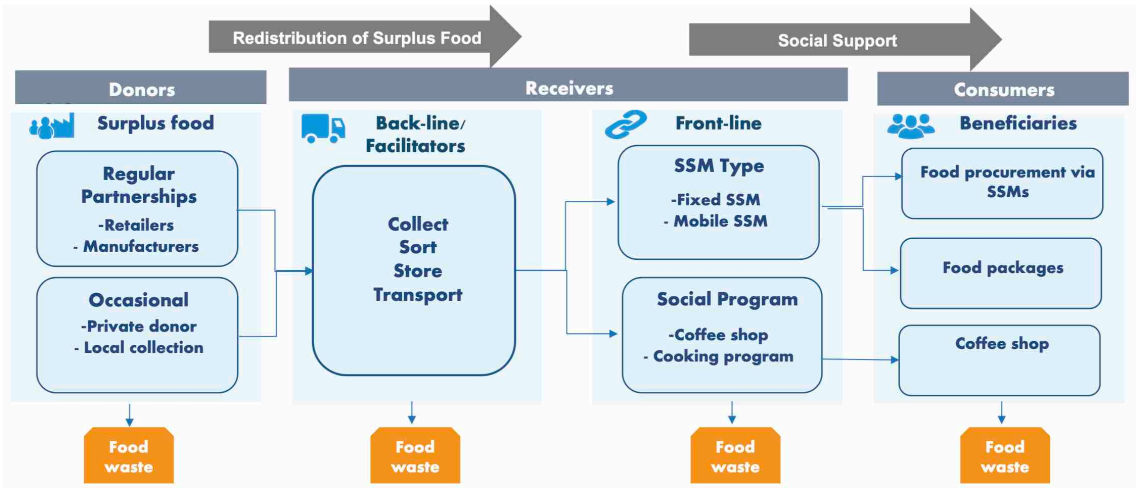


**Figure 0.1** Simplified representation of the Austrian social supermarket model. Source (The Author).

Figure adapted from (Defourny and Borzaga 2018) pp.12, and enriched form previous studies (Holweg, Lienbacher, and Peter Schnedlitz 2010; Schneider 2013; Schneider et al. 2015)

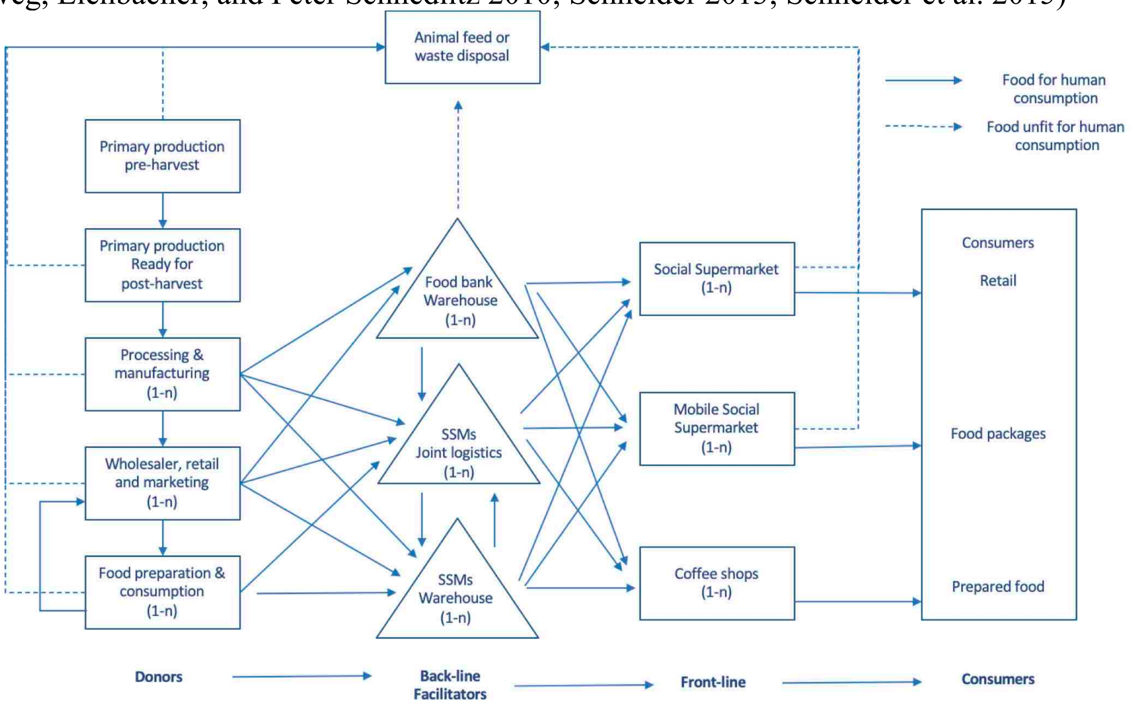


**Figure 0.2** Simplified resource flow in the food donation chain of Social Supermarkets in Austria. Source: (The Author).

Figure adapted from (De Boeck et al. 2017; H. R. Krikke et al. 2001) and created based on previous studies of social supermarkets (Holweg, Lienbacher, and Zinn 2010; Schneider et al. 2015)

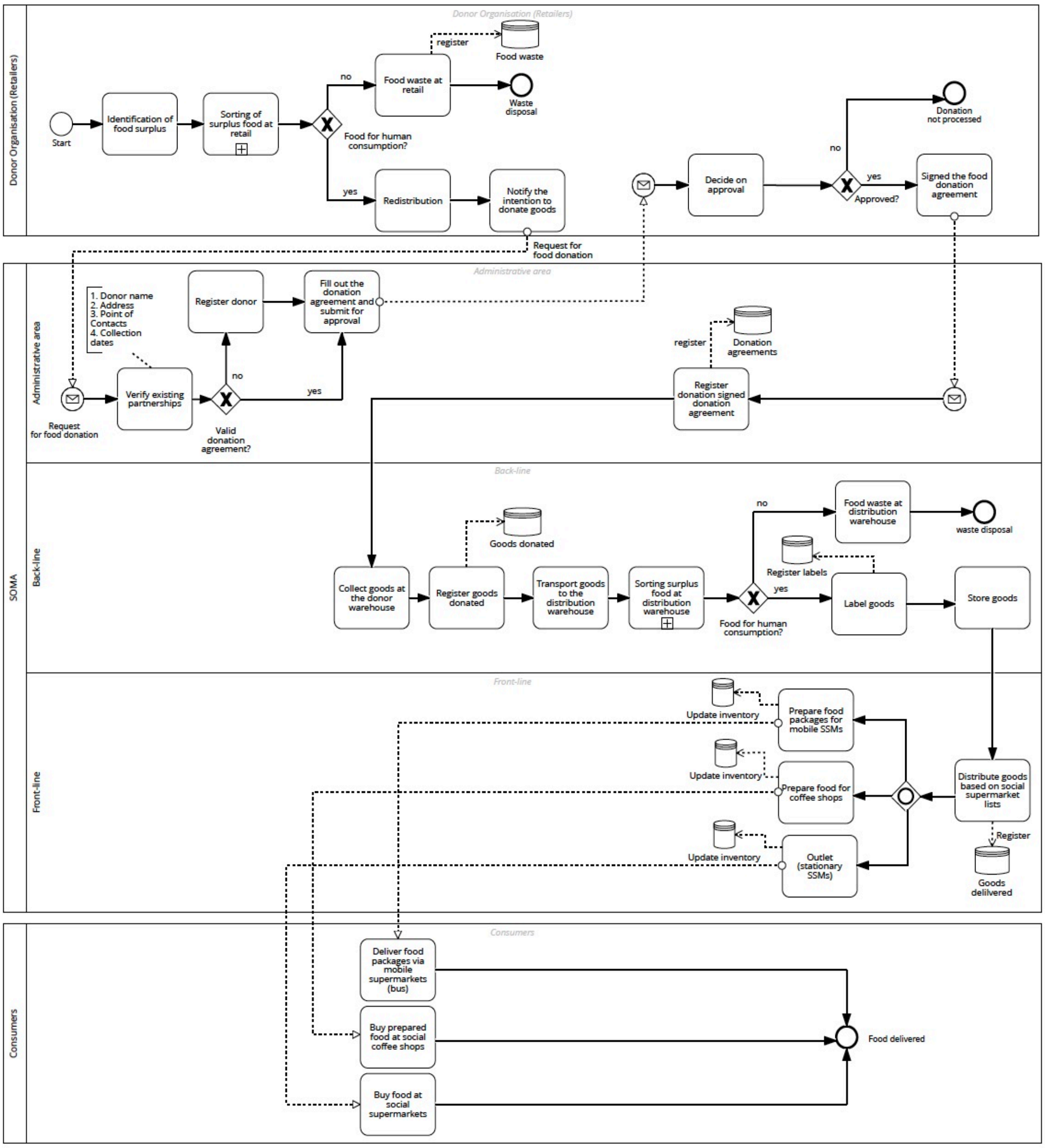


**Figure 0.3** Business Process Identification of surplus food redistribution from manufacturers and retailers to Social Supermarkets in Austria. Source: (The Author).

## Appendix G – List of blockchain frameworks

| # | Name | Maintainer | Permission | Consensus | Smart Contracts | IoT | Supply Chain |
|---|---|---|---|---|---|---|---|
| 1 | Bitcoin | Bitcoin | Permissionless | Proof-of-Work | Smart contract code (scripting) | No | No |
| 2 | Ethereum | Ethereum Foundation | Permissionless | Proof-of-Work | Smart contract (solidity) | No | No |
| 3 | Enterprise Ethereum | Ethereum Foundation | Permissioned | Proof-of-Work and Pluggable consensus mechanisms | Smart contract (solidity) | Yes | Yes |
| 4 | Hyperledger Sawtooth lake | The Linux Foundation Intel Corporation | Both | Proof of Elapsed Time (PoET) and Practical Byzantine Fault Tolerance | Smart Contracts (Java and Java Scripts) | Yes | Yes |
| 5 | Hyperledger Fabric | The Linux Foundation IBM | Permissioned | Practical Byzantine Fault Tolerance (PBFT) and Pluggable consensus mechanisms | Chaincode (Golang, Java and JavaScript) | Yes | Yes |
| 6 | Hyperledger Iroha | The Linux Foundation | Permissioned | Byzantine Fault Tolerance (BFT) - YAC | No | No | No |
| 7 | Ripple | Ripple Labs | Permissioned | Ripple | Custom | No | Yes |
| 8 | Corda | R3 | Permissioned | Custom (Validity and Unique consensus) and pluggable consensus mechanism | Smart contract code (e.g. Kotlin) and Smart legal contracts (legal prose) | No | No |
| 9 | Quorum (based on Go Ethereum) | JP Morgan Chase & Co. | Permissioned | Raft | Smart Contracts | No | Yes |
| 10 | Tendermint / Cosmos | All in Bits Inc | Permissioned (middleware) | Byzantine Fault Tolerance | No | No | No |
| 11 | Kadena | Kadena LLC | Permissionless | Chainweb (Parallelized proof of work) | Smart Contracts | No | No |
| 12 | MultiChain | Coin Sciences Ltd | Permissioned | Practical BFT | Smart filters (Java script) | No | No |
| 13 | OpenChain | Coinprism | Permissioned | Portioned Consensus | Smart contracts | No | No |

**Appendix H – Blockchain Sustainability Canvas for the food donation process.**

<table>
<tr>
<td rowspan="2">Network participants<br>Who are the participants of the network?<br><br>- Donors<br>- Facilitators<br>- Back-line operators<br>- Social Supermarkets (stationary and mobile)<br>- Government agencies<br>1. Tax Office<br>2. Employment Office<br>3. Local Social Welfare Office</td>
<td>Participation incentives<br>What are the advantages of participating to the blockchain network for every party?<br>- Cost reductions<br>- Traceability & Transparency<br>- Food donation agreements management<br>- Alerting system<br>- Performance indicators<br>- Push-pull strategies<br>- Supply chain planning</td>
<td>Trust Enabler<br>Where provides the blockchain trust?<br>- All actors are known<br>- There should validators of the transactions in the blockchain network<br>- There should be validators of the data sensors capturing</td>
<td rowspan="2">Business Processes<br>What business processes are involved in the use of blockchain?<br><br>1) Customers registration,<br>2) Regular food donations<br>3) Occasional food donations<br>4) Administering of social programs for unemployed people in coordination with Governmental agencies, and<br>5) Declaration of donors for tax deduction (only for counties where is applicable)</td>
<td>Elimination of intermediaries<br>What are the intermediaries will be removed or replaced from the business process?<br>-Less dependency on the administrative area of SOMA for logistics coordination</td>
<td rowspan="2">Process Re-engineering<br>What processes need to be re-engineered?<br><br>- On-line transparency<br>- Closed-loop planning<br>- The physical flow of goods.<br>- Implementation of methodological frameworks for the sustainability impact of social supermarkets<br>- Local segmentation<br>- Inventory management<br>- Matching demand and supply</td>
</tr>
<tr>
<td>Participation Disadvantages<br>What disadvantages can be identified for participants by applying the blockchain to the network?<br>- Increase operational costs</td>
<td>Change of Governance<br>Who governs the access to the blockchain?<br>- SOMA network</td>
<td>Side Channel<br>Are there additional means of communication apart from blockchain?<br>-E-mail<br>-Administrative systems<br>- Local Inventory systems</td>
</tr>
<tr>
<td colspan="2">Incentive for (fair) change</td>
<td colspan="3">Innovation for networking</td>
<td>Process Optimization</td>
</tr>
</table>

## Appendix I – Interview Transcripts

Interview transcripts are available in a separate file