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Using RFID-Technology For Improved Traceability And Information Sharing; Creating An Integrated Food Supply Chain From Farm To Fork

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ABSTRACT

Introduction: This paper investigates the driving and limiting factors influencing the implementation of RFID-technology as a traceability tool in the food supply chain. RFID-technology has not been widely implemented in the food supply chain, even though in other industries it has clear benefits for shrinkage and other traceability issues.

Methods: After an extended literature review, semi-structured interviewed were carried out in order to ensure an integrated view of existing literature and to find new and different insights into the main drivers and barriers of RFID-technology as a traceability tool in de food supply chain.

Results and Discussion: The most influential driver is the increase in Operational efficiency that RFID-technology would enable, increasing collaboration between supply chain actors and even within actors themselves, as the operational processes can be streamlined largely, diminishing manual actions and increasing accuracy. The largest added value on product level is the amount of information that can be stored on RFID-tags and the information exchange possibilities this offers, from farm to fork. The largest difficulties are with low-margin products, as the costs of a RFID-tag on products with low margins are initially harder on the profitability of these products, of which the food retail has so many. Also, the largest benefits come when all products are handled with RFID-tags, and the total investment in infrastructure and process changes this entails makes it a large operation. The big challenge there is who would take the responsibility to move first and how responsibilities will be shared.

Future research: For future research it would be the recommendation to broaden the research to different countries and organizations first, as well as reaching out to actors earlier in the food supply chain to find out how these supply chain actors' perspective on RFID-technology as a traceability tool changes through the food supply chain.

Keywords: RFID, Technology, Traceability, Food Supply Chain, Store of the Future

Table of Content

INDEX OF FIGURES

INDEX OF TABLES

LIST OF ABBREVIATIONS

Abbreviation	Meaning
RFID	Radio-frequency identification
EU	European Union
UN	United Nations
TTI	Time Temperature Indicator
ROI	Return on Investment

1. THE IMPLICATIONS OF SHRINKAGE AND THE IMPORTANCE OF TRACEABILITY OF DATA THROUGHOUT THE FOOD SUPPLY CHAIN

In the European Union alone around 20% of all produced food is being wasted each year. This amounts to around 173kg of food waste per capita (Chen, Brahma, Mackay, Cao, & Aliakbarian, 2020, p. 2; Toma, Font, & Thompson, 2020, p. 2). This equals around €143 billion worth of food being wasted in the EU alone. One of the goals of the UN's sustainable development goals, is to halve per capita the amount of food being wasted (UnitedNations, 2015). This makes it a major sustainability issue for retailers (Cicatiello, Franco, Pancino, & Blasi, 2016, p. 1), since these directly influence all of the participants of the food chain. Especially in the case of fresh products, which make up for around 40% of the total revenues of grocery chains, and are important drivers of customer loyalty (McKinsey&Company, 2014). Many consumers have a 'need for touch' when it comes to fresh produce (Kuhn, Lichters, & Krey, 2020, p. 2), which still drives them towards physical grocery stores and even choosing one supermarket over another (Wang & Li, 2012, p. 1). Because of this, the diverse availability and qualitative goods produce are essential for food retailers. It also means retailers have a potentially large influence on the reduction of food waste in the world, as mentioned by Parfitt, Barthel, and Macnaughton (2010, p. 5), since their choices influence the entire food supply chain, both downwards (to consumers) and upwards (to suppliers and manufacturers).

Inappropriate quality control and excessive inventories leads to high levels of unnecessary waste and an increase in visibility and traceability has great potential to improve operational efficiency in de food supply chain (Alfian et al., 2020, p. 2; Wang & Li, 2012, p. 11). Since organizational food waste has a greatly impacting and direct negative influence on profit numbers, the prevention of product losses is an important focal area. Increasing visibility and traceability through the emergence of more advanced identification and sensory technologies, such as Radio Frequency Identification (RFID) and Time Temperature Indicator (TTI), provides new and more effective tools for managing these perishable products (Aiello, Enea, & Muriana, 2015, p. 2; Alfian et al., 2020, p. 3; Kumar, Reinitz, Simunovic, Sandeep, & Franzon, 2009, pp. 5, 6; Wang & Li, 2012, p. 11), compared to manual controls and container

or other transportation unit checks. Technologies as such enable for much quicker and more detailed information captures of product and their individual properties along with other data, without even needing a direct line of sight (Kumar et al., 2009, p. 4).

Additionally, Aung and Chang (2014, pp. 2, 6) and Cuinas, Newman, Trebar, Catarinucci, and Melcon (2014, p. 2) discuss in their papers that traceability is seen as a tool to comply with the laws and regulations, since globalization has clouded the visibility of the entire food supply chain and effective traceability systems are necessary for organizations and supply chains to be able to fulfil the safety and quality requirements in these global markets. Though the paper is not recent, Attaran (2007, p. 2) mentioned that the costs for the implementation of RFID technology are relatively high, and the ROI when using traceability for just legislative compliance issues, as mentioned in Aung and Chang (2014, p. 6), is too low (Attaran, 2007, p. 2). The overall cost saving and operational efficiency capabilities of RFID technologies are the main drivers of the technology adoption, as it enables improved collaboration and more accurate planning up and down the food supply chain and reducing the inventory control costs by a large percentage. And as is mentioned by Alfian et al. (2020, p. 3), auto-identification systems using RFID technology, combined with other sensor technologies, provide effective and efficient solutions for food, improving the effectiveness and efficiency of the food supply chain. This is especially important when moving upstream in the supply chain, as Biswal, Jenamani, and Kumar (2018, p. 4) mention that the stability is strongly compromised by inventory inaccuracy when moving upstream in the supply chain and improving upon this is important. Traceability in the sense of how it is described in the abovementioned articles, can be defined as “the ability to trace the history, application or location of an entity by means of recorded identification” Bosona and Gebresenbet (2013, p. 3), which is the definition according to the International Organization for Standardization (ISO). Summarizing, Bibi, Guillaume, Gontard, and Sorli (2017, p. 5) argue that RFID-technology is worth investing in due to ‘the gain in competitiveness, effective tracking, reduction of food waste, the guarantee for safe and good quality food products, the improvement in the management of stock and the reduction of labour costs’.

Attaching RFID-tags can be done on different levels, such as on case/item-level, where the tag is attached to the product or integrated into the label, or for

example on pallet or larger transportation units, all offering different benefits on different scales. The food characteristics that make up the type of product also differentiate in the need for real-time and accurate tracking, since perishable products and products that are sensitive to quality deviations gain more benefits from the use of more accurate data. Similarly, certain packaging materials make reading RFID-tags more complicated – materials such as metals, glass and liquid decrease the reading quality (Balocco, Miragliotta, Perego, & Tumino, 2011, p. 8), although there are certain RFID-tags specifically equipped to deal with certain types of material, which are significantly more expensive (Balocco et al., 2011, p. 10).. Due to the costs of the tags, which are inevitably higher than regular barcodes traceability through paperwork (Camdereli & Swaminathan, 2010, p. 1), the solution is better suited for products with higher margins (Aung & Chang, 2014, pp. 10,11; Balocco et al., 2011, p. 11) or high shrinkage costs, even though the affordability of RFID tags is improving due to increased usage in the industry (Mejjaouli & Babiceanu, 2018, p. 11; Moretti et al., 2019, p. 11).

The goal of this thesis is to investigate the need for food supply chain actors to track, trace and RFID-tag their products through the food supply chain and what the capabilities towards this end are throughout the supply chain. Additionally, the effects of each of the drivers in relation to each other and to the different stages of the supply chain, is not yet researched enough. Chanchaichujit, Balasubramanian, and Charmaine (2020, p. 17) have performed an extensive literature review on articles of supply chain management with a focus on RFID's role therein. What they found was that none of these articles looked at all the benefits and their relative importance, which leaves a large gap in the literature. This led to the following research question:

''What are the driving and limiting factors influencing implementation and adaptation of RFID-traceability technology in the food supply chain?'

This thesis made several theoretical and practical contributions to existing literature by further investigating the growing importance of accurate and efficient access to data for traceability objectives throughout the entire food supply chain (Aung & Chang, 2014, p. 3), and the wide array of benefits that can be achieved throughout the entire chain when a broader approach is used, since this approach is lacking within

earlier research (Chanchaichujit et al., 2020, p. 17). Besides looking at the importance of traceability, this paper dived deeper into the extended applications RFID-technology and the increased usage of data has to offer. It aimed for a better understanding of the different drivers and influencing factors of RFID-technology and their relative importance.

By combining different articles on the factors influencing RFID-technology adoption, this study contributed by creating a theoretical model that provides a total overview of the different factors, since this broader and more integrated view was lacking in earlier research. Additionally, this model has been tested and adapted to add new factors that were not mentioned in the earlier research, but enable an even more integrated view on the different factors influencing RFID-technology adoption as a Traceability-tool, which can help organizations in offering direction when considering RFID-technology.

The research also resulted in practical implications by delving deeper into the limiting factors regarding the adoption and implementation of RFID-technology and uncovering the most important factors on which organizations should put their focus. Different perspectives have been taken into account in order to show what kind of products or supply chains can benefit most from this increased Traceability tools, where in the supply chain Traceability should start, as well as the recognition of responsibility and first-mover issues.

2. IDENTIFYING THE MOST IMPORTANT LINKS AND THE IMPORTANCE OF TRACEABILITY THROUGHOUT THE FOOD SUPPLY CHAIN

2.1 Literature review approach

To understand the food supply chain and its links, the drivers of food traceability systems and the properties of RFID-systems, it is important to review the existing literature to gain a better understanding of the current situation. To do so, the Web of Science database has been used to select published articles. Web of Science is a database easily accessible for students at the University of Twente and offers a lot of filter options. The chosen filters, key words and properties can be found in Appendix A. A similar approach is used in the different filters used. All of them were 'article' as document type and sorted on 'times cited', from highest to lowest. Most of them were filtered on publications from the last five years, although in some instances a ten-year span was chosen due to appropriateness. The filters were also similar in categories filtered on, with 'business', 'management' and 'food science technology' as the most prevalent categories. Based on the outcomes of these filters, relevant articles were selected based on their title, their abstract, the keywords used and the first impressions of the content. Through this process, the quality and the relevance of the articles that have been selected for the literature review has been assessed.

2.2 Different actors within the Food Supply Chain

This research started with investigating the different actors within the food supply chain, as well as looking into their influence and/or dependency on the chain. An actor in this case is "any group or individual who can affect or is affected by the achievement of an organization's objectives."(Aschemann-Witzel et al., 2017, p. 5). Most supply chains, and especially food supply chains, have a wide variety of actors and usually encompass more than just individual enterprises, but rather a diverse network structure of many enterprises (Aschemann-Witzel et al., 2017, p. 2). Additionally, in the food supply chain, there are also different non-commercial actors concerning the negative social and environmental aspects of food wastage, increasing the attention towards the importance of a sustainable supply chain (Aschemann-

Witzel et al., 2017), since food safety and quality issues, as well as environmental issues, are concerns for both many consumers and instances such as governments (Aiello et al., 2015, p. 1; Aschemann-Witzel et al., 2017, p. 4). To be able to pursue this goal, it is not enough to look at the boundaries of one company; goods are the product of multiple production steps and interactions between different participants throughout the entire supply chain and all contributing actors have to be considered and traced (Beske, Land, & Seuring, 2014, p. 6; Marconi, Marilungo, Papetti, & Germani, 2017, p. 3; Zhu et al., 2018, p. 3). Therefore, in order to make the food supply chain more sustainable, the different supply chain actors and their interests have to be aligned and coordinated (Govindan, 2018, p. 2). With the ever-changing demands of customers and consumers, leading to challenging issues in the food supply chain, a focus must be put on sustainable consumption and production (SCP). The goal of SCP is "creating a more efficient and more profitable production while using fewer raw materials as well as adding value to a product while creating less pollution and waste in the process" (Govindan, 2018, p. 2). Figure 1 offers a basic overview of the food supply chain actors.

Figure 1. *Basic overview of the actors in the food supply chain. Own adaption based on the models by (Aung & Chang, 2014, p. 6); Kamilaris, Fonts, and Prenafeta-Boldu (2019, p. 6); Zhu et al. (2018, p. 6).*

According to Aung and Chang (2014, p. 11), most of the earlier research on food traceability concerns traceability until the retail phase of the food supply chain, where most traceability stops. The step towards the consumer part of the food supply chain is therefore often missing. Since quality and food safety factors are increasingly important for customers as well (Chanchaichujit et al., 2020, p. 3; Wang & Li, 2012, p. 10), extending the traceability through retailers to customers is the next step to be taken, as well as the broader view on the supply chain as a whole. Retailers are the

link between these steps in the food supply chain. With the development, improvement and implementation of IT-supported systems, operational planning and operational food logistics processes could be increased; therefore IT-operations should be developed alongside the operational logistic processes of retailers in the food supply chain, since "traceability mechanisms and buyer-supplier coordination are mutually reinforcing" (Bosona & Gebresenbet, 2013, p. 5). The focus of this thesis touches upon both directions, and so influences the food supply chain both downwards and upwards. Bosona and Gebresenbet (2013, p. 4) recognize Figure 1 as a representation of the product flow, and differentiate between Tracing (backward traceability, downstream), Tracking (forward traceability, upstream) and the comprehensive definition 'Traceability information sharing' as the overarching movement in the process flow, going both ways.

Camdereli and Swaminathan (2010, p. 2), Balocco et al. (2011, p. 6) and Vlachos (2014, p. 9) already expected that the main beneficiaries of RFID would be among the downstream actors in de supply chain, as these are the actors that are expected to gain benefits from 'store and warehouse labour and inventory reductions'. Balocco et al. (2011, p. 7) even mention that in the case of RFID-tags on pallet-level offers similar benefits to both retailers and manufacturers, but when both pallet-level and case-level tags are in place, the benefits achieved by retailers are up to five times higher in a scenario where the manufacturer sustains most of the costs due to the tagging process being at this level. That downstream actors gain larger benefits has been noted again by Cannella, Framinana, Bruccoleri, Barbosa-Povoa, and Relvas (2015, p. 2) in 2015, mentioning that this is because the supplying actors in the supply chain base their levels of inventory on the forecast demands coming from downstream and this was again validated by Biswal et al. (2018, p. 4). Thus, a form of solution to this mismatch in cost/benefits could be to arrange some form of cost-sharing agreement, but the difficulty here lies within the necessity to share sensitive data as well as the fact that different actors within the supply chain may have different and conflicting objectives when it comes to transparency (Balocco et al., 2011, p. 7).

The benefits of the automatic data gathering provided by RFID-technology will reduce the manual counting operations in most of the stages of the supply chain (Aiello et al., 2015, p. 4), showing that every actor in the chain has some form of benefit to gain. But the authors from that article do mention that traceability in the

case of processed food will be more expensive, because such products usually are comprised of multiple raw materials, making the tracking more difficult. Other benefits would then be in the cold supply chains, as RFID-technology can support temperature monitoring data collection also endorsed in earlier research such as Abad et al. (2009, p. 2), but also in newer literature such as Bibi et al. (2017, p. 5) and Alfian et al. (2020, p. 4).

In terms of food safety crises and recalls, Piramuthu, Farahani, and Grunow (2013, p. 2) describe the lack of enough traceable and transparent information flow throughout the food supply chain, making it more difficult to pinpoint the actual source of the contamination. This means that the actual consequences, both financial and in for example reputation, do not necessarily go back towards the actual source. This is reinforced by different levels of traceability (e.g. class-level versus item-level) and traceability technology (e.g. barcode versus RFID) which in turn has a great influence on cost and liability implications (Piramuthu et al., 2013, p. 2). Therefore, price negotiations are influenced by some form of agreed liability, but certain levels of traceability and technology could enable a more transparent and fair shifting of liability levels. The authors show with their results that increased visibility is especially important in the lowest downstream levels of the food supply chain, and decreases in importance, regarding recall liability perspectives, when moving up towards the upstream actors (Piramuthu et al., 2013, p. 9). This would, again, argue that with regards to this factor, the downstream actors gain the most benefits, as mentioned by Camdereli and Swaminathan (2010, p. 2).

Another factor that is influential when it comes to RFID-adoption and implementation issues, not only in the food supply chain but in potentially every supply chain, is the starting point of operational efficiency levels of the industry and the maturity of the organization (Balocco et al., 2011, p. 7; Moretti et al., 2019, p. 6). The fashion industry is taken as an example, as at the time of the article by Balocco et al. (2011, p. 7), the starting efficiency levels of that industry were much lower than that of the food supply chain, making operational benefits easier to be gained. Additionally, at that time, the costs of RFID-tags and systems were considerably higher than they are now, as well as the fact that the perception of costs may differ between industries, also influencing the adoption and implementation of RFID-technology (Moretti et al., 2019, p. 11).

The large amount of data being generated by RFID-technology based systems and how this is managed, also influences the adoption rates, as is mentioned in recent studies by Moretti et al. (2019, p. 12) and Chanchaichujit et al. (2020, p. 17). The way the technology and the interpretation thereof are known to managers makes a strong difference between this technology as a traceability system and its effectiveness. This can also be explained regarding the organizational readiness towards this kind of technological change (Hastig & Sodhi, 2020, p. 12; Shin & Eksioglu, 2015, p. 6).

Lastly, economic and social issues factors influence the implementation of RFID technology, as increased awareness by consumers in a consumer-driven sector as the food supply chain (Govindan, 2018, p. 9) has led to consumers committing to a better lifestyle for themselves and the planet. Therefore, more transparent information on the origin, quality and usage of the product their buying, which Cuinas et al. (2014, p. 9) argues is achieved with RFID-technology, aids consumers in their contributions towards a more sustainable world. At the same time, organizations can distinguish themselves by proving their supply chain is more 'green' than others, improving their competitive advantage (Govindan, 2018, p. 9).

The main takeaways after looking at the different supply chain actors, is that in order to make the Food Supply Chain more sustainable, all contributing actors have to be aligned and coordinated in order to be able to adopt a broader view of the benefits increased traceability would deliver. The main expected benefits also increase when moving downstream in the case of the tagging process being at the start of the chain, as downstream actors have the most to gain from increased traceability and information sharing in this case.

2.3 Traceability ineffectiveness in the Food Supply Chain

Even though traceability, including product, process and measurement traceability amongst others, has been discussed in various papers on food supply chains, there are still missing elements. Badia-Melis, Mishra, and Ruiz-García (2015, p. 1) talk about the current inabilities in food supply chain traceability systems to link food chain records, along with the inaccuracy and abundancy of errors in databases and information systems. While quick and reliable access to this type of essential information is marked as key in for example cases of food disease outbreaks. Also,

most current traceability systems do not offer the complete potential of tracking and tracing products real-time, due to practical limitations, both technical and monetary. But optimizing the food supply chain for sustainability based on more accurate and actual data with such real-time information is a very valuable issue to be addressed (Zhu et al., 2018, p. 19). Especially for the food industry, it is essential to improve the standard of food safety, integrity and quality and the associated increased level of transparency throughout the entire food supply chain (Alfian et al., 2020, p. 1), as trust has been regarded as being one of the most significantly important factors in the food production industry (Astill et al., 2019, p. 1). In addition, the current food supply chain is inefficient and unreliable due to the issue of the exchange processes being complex and the process in its entirety not being transparent (Kamilaris et al., 2019, p. 5). Many food handling organisations have good internal traceability systems, but the exchange of information and data between different links and actors within the food supply chain is difficult, time-consuming and not transparent (Badia-Melis et al., 2015, p. 2). These factors lead to higher overall costs for products moving through the supply chain, with operational costs being estimated to account for around two thirds of the final cost of goods, leaving much room for improvement (Kamilaris et al., 2019). There are many papers on traceability, with differing definitions and operationalisations. For this review, this paper will focus on the works of Aung and Chang (2014); Bosona and Gebresenbet (2013); Behnke and Janssen (2020) and Hastig and Sodhi (2020), combining their models on traceability definitions, objectives, requirements, drivers and benefits.

2.3.1 Process optimization as the main driver for traceability

Organizations operating in the food supply chain have three primary objectives when it comes to using traceability systems, according to Aung and Chang (2014, p. 3). These objectives are to improve supply chain management, facilitate traceback for food safety & quality issues (Aiello et al., 2015, p. 9; Barge, Gay, Merlino, & Tortia, 2014, p. 1) and to differentiate foods with more subtle qualitative distinctions. These objectives are, as mentioned in their paper, associated with the following benefits: Lower distribution systems costs, reduced expenses related to recalls and the expansion of sales of the products that have attributes and qualities that are more difficult to discern. But these benefits are mostly operational, therefore Aung

and Chang (2014, p. 3) and Behnke and Janssen (2020, p. 2) also consider the following additional consequences of good traceability systems: to improve the food safety systems in place, to improve the quality of the raw materials, to improve inventory management, as a source of competitive advantages and as an increase in trust and confidence from the consumers perspective. The paper mentions a wider array of motivating factors or drivers for traceability in the food supply chain, enforced as a tool for answering the "who, what, when, where and why?" questions as the goal of traceability (Aung & Chang, 2014, p. 4). Bosona and Gebresenbet (2013, pp. 5, 6) combine and categorize these driving forces behind Food Traceability Systems as 'regulatory, food safety and quality, economic, social, and technological concerns', under which many specific driving forces have been grouped. Their paper also identifies the major benefits as an increase in customer satisfaction, improvement in food crises management, improvement in Food Supply Chain Management, enhanced company competence, enriched technological and scientific contribution and the contribution to agricultural sustainability.

Lastly, from the research of Hastig and Sodhi (2020, p. 7) the business requirements and critical success factors for the implementation of supply chain traceability systems are described. Their research uncovers certain themes and sub-themes on business requirements and critical success factors, which combined with the work of the earlier mentioned authors, make up the themes of drivers of Traceability as can be found in table 1. The works of these authors have led to the creation of four emerging themes of drivers of Traceability in de Food Supply Chain. None of the earlier research touches upon all the different drivers, but through combining the articles the larger scope can be covered. The articles from earlier years, such as Bosona and Gebresenbet (2013, pp. 5, 6) and Aung and Chang (2014, p. 4), have a larger focus on legislation and quality assurances, indicating that increased traceability was at first used more to increase compliance and was driven by macro influences of governments installing certain laws and regulations. Whereas the newer articles by Hastig and Sodhi (2020, p. 7) and Behnke and Janssen (2020, p. 2) have a larger focus on social and environmental issues, as well as organizational readiness and partner cooperation. This follows the growth of importance of these types of issues to consumers and organizations and is more in line with sustainable viewpoints. The articles had most overlap in increasing operational efficiencies, which shows that

this is a more important issues that keeps developing and is still a large driving force behind organizational change.

2.3.2 Driving forces behind Food Traceability Systems

By adapting and combining the models and different definitions and operationalisations, an overview is created of the driving forces behind Food Traceability Systems, as can be seen in Table 1. All identified themes are the consequence of the "who, what, when, where & why?" question as the bases for traceability in the food supply chain (Aung & Chang, 2014, p. 3).

After reviewing these factors these were divided between two dimensions, either Market-level or Organization-level factor, depending on the scope of the factors. In this section these factors have been explained in greater detail.

The first major driver of Traceability in the Food Supply Chain on Market-level is *Complying with regulatory legislation*. This regards all the factors regarding regulatory legislation and certifications that ensure food safety and uphold certain quality standardization. It is comprised of *Safety and Quality legislation, Quality assurance certifications* and *Product recalls.*

Safety and Quality legislation, concerns the compliance with the further development of legislation, industry guidelines and international standards regarding safety and quality issues (Aung & Chang, 2014, p. 5; Bosona & Gebresenbet, 2013, p. 5). Increasing globalization in the food trade leads to more movements of products and information between nations (Behnke & Janssen, 2020, p. 2), increasing the need and requirements for strict regulations to ensure food safety for consumers. Since effective traceability has to be built on global standards in order to enable interoperability between traceability systems (Aung & Chang, 2014, p. 5), development of those standards drives the need for improved traceability systems. *Quality assurance certifications* focusses on the quality of products and the assurance that certain standards have been met. Quality of products includes certain attributes of that product that are perceived with a certain value to the consumer, but do not refer to just the properties of that product. It can also say something about the way those attributes are achieved (Aung & Chang, 2014, p. 6), or, for example, how the live cattle has been treated (Bosona & Gebresenbet, 2013, p. 6). *Product recalls and food safety crises* is composed of the need for traceability, backwards as well as forward, in

the case of food safety hazards. Well-functioning traceability systems enable organizations to better isolate the source of the food safety hazard (Bosona & Gebresenbet, 2013, p. 6; Li, Liu, Liu, Lai, & Xu, 2017, p. 10), as well as tracing the product forwards through the chain, in order to specifically target the contaminated parts of the chain or specific batches (Piramuthu et al., 2013, p. 9). This can prevent larger amounts of products to be destroyed because of uncertainty whether that specific batch was contaminated. Accurate and easy to obtain information drives the need for traceability.

The second major driver of traceability on Market-level is *Addressing social and environmental issues*. These are the factors driving traceability through several social issues and public concern such as *Increased consumer awareness* and *Adoption of sustainable and environmentally friendly practices*.

Increased consumer awareness on quality and health covers more social issues such as the shift of quantity-oriented to quality-oriented lifestyles, driven by rising consumer income (Bosona & Gebresenbet, 2013, p. 6). Consumers are increasingly demanding (Chanchaichujit et al., 2020, p. 14) due to an increase in awareness about their health and weight control and therefore the nutritional values of food. It also looks to the restoration of public consumer confidence due to food safety crises from the past. Additionally, producers that are more environmentally friendly and provide better care for their product, will be perceived as delivering a qualitatively better product, which will improve their market positioning and ensure a better food price (Bosona & Gebresenbet, 2013, p. 6). The *Adoption of sustainable and environmentally friendly practices* on the other hand follows up on this, with a larger focus on creating sustainable and environmentally friendly production business practices where supply chains take on their responsibilities towards the environment (Hastig & Sodhi, 2020).

The third major driver, and the first on Organizational-level, *increasing operational efficiency*, consists of underlying themes and factors that affect or are affected by the operational processes of organizations such as *Process streamlining, Advancement in information technology* and *More control over food spoilage*.

Process streamlining is the result of less irrelevant time being used towards the collection of accurate data. More transparent operational processes throughout the chain and faster tracking/activity overviews enable the collection of data to be carried

out much faster and more accurate, decreasing the processing times, and increasing productivity and efficiency (Hastig & Sodhi, 2020, p. 10). *Advancement in information technology* is composed of the emergence of new information technology systems, as well as the decreased costs of existing systems such as RFID (Bosona & Gebresenbet, 2013, p. 14; Reyes, Li, & Visich, 2016, p. 11). The development of technology is rapid, and therefore the possibilities grow, both in application and in costs, driving the need and the potential of traceability systems towards each other. *More control over food spoilage* is driven by the high costs of food spoilage for organizations and, additionally, the wastage of food and resources used to produce unused products, which has a large negative effect on the environment (Aung & Chang, 2014, p. 4). Since most foods are perishable and sensitive to environmental conditions, logistical and qualitative traceability enables fast identification of problems throughout the food supply chain, which is able to reduce food waste and spoilage (Aiello et al., 2015, p. 5). It could potentially even offer possibilities for better tracking expiry dates throughout the supply chain, all the way to the consumer, to prevent food reaching its expiry date.

Finally, the last major driver of Traceability on Organizational-level in the Food Supply Chain is *Improving supply chain management*, which is mostly focused on the management part of the supply chain, addressing organizational change, inter-chain communication and cooperation. It has been divided in *Increased globalization and partner cooperation* and *Internal readiness for organizational change.*

Increased globalization and partner cooperation, which drives a more integrated traceability system because of the increased competition as a result of globalization (Hastig & Sodhi, 2020, p. 10), due to the accessibility of different markets, business models and nations. The added value of a qualitatively sound supply chain is one of the ways food supply chains are able to distinguish themselves, as increased partner cooperation, driven by the increased competition, leads to cost savings in the network and transaction costs and an improvement in supplier/customer relations (Hastig & Sodhi, 2020, p. 11). With more integrated information systems, the entire chain can become better connected and more responsive to market needs, making the supply chain more dynamic and flexible. *Internal readiness for organizational change* describes the degree to which an organization is willing and ready for organizational change. This comprises of different factors such as the

required know-how, capabilities to be able to assess the suitability of different applications to this specific organization and the ability to engage others towards this goal (Hastig & Sodhi, 2020, p. 12).

	Major drivers	Underlying themes	Sources
Market level	Complying with regulatory legislation	Safety and Quality legislation	Aung and Chang (2014, p. 4), Bosona and Gebresenbet (2013, p. 6), Behnke and Janssen (2020, p. 3)
		Quality assurance certifications	Aung and Chang (2014, p. 4), Bosona and Gebresenbet (2013, p. 6), Behnke and Janssen (2020, p. 2)
		Product recalls and food safety crises	Aung and Chang (2014, p. 4), Bosona and Gebresenbet (2013, p. 6), Behnke and Janssen (2020, p. 2)
	Addressing social and environmental issues	Increased consumer awareness on quality and health	Bosona and Gebresenbet (2013, p. 6), Hastig and Sodhi (2020, p. 7), Behnke and Janssen (2020, p. 2)
		Adoption of sustainable and environmentally friendly practices	Hastig and Sodhi (2020, p. 7)
Organization level	Increasing operational efficiency	Process streamlining due to increased transparency and information sharing	Aung and Chang (2014, p. 4), Hastig and Sodhi (2020, p. 7), Behnke and Janssen (2020, p. 2)
		Advancement in information technology	Bosona and Gebresenbet (2013, p. 6), Hastig and Sodhi (2020, p. 7)
		More control over food spoilage	Aung and Chang (2014, p. 4)
	Improving supply chain management	Increased globalization and partner cooperation	Aung and Chang (2014, p. 4); Hastig and Sodhi (2020, p. 7)
		Internal readiness for organizational change	Hastig and Sodhi (2020, p. 714)

Table 1. *Four emerging themes of drivers of Traceability in the Food Supply Chain. An adaptation on the works of Bosona and Gebresenbet (2013, p. 6), Aung and Chang (2014, pp. 3, 4), Behnke and Janssen (2020, pp. 2, 3) and Hastig and Sodhi (2020, p. 7).*

In summary, the factors that were found have been divided into market-level and organizational-level dimensions after reviewing all of the factors. These factors influence the need for increased transparency in the Food Supply Chain.

2.4 Enabling transparency in the Food Supply Chain

The technologies that can increase transparency in the food supply chain have to fulfil certain requirements to be able to fully enable the effectiveness of traceability systems (Astill et al., 2019, p. 3; Vlachos, 2014, p. 9). Data must be collected and processed accordingly throughout the supply chain and be able to make the high-quality data available to the appropriate stakeholders at the right time. With high information uncertainty and an often lacking form of standardized data, effective

implementations of Food Traceability Systems is rare (Accorsi, Cholette, Manzini, & Tufano, 2018, p. 2). Nonetheless, supply chains deal with high degrees of uncertainty, and the impact thereof can have large effects on supply chain volatility (Chen et al., 2020, p. 1), highlighting the need for more information and transparency. One way of facilitating this, is using Radio Frequency Identification (RFID) technology.

2.4.1 RFID-technology as a Traceability system

Another technology that is regarded as a high potential traceability technology, in combination with other technologies, is RFID-technology. The usage of RFID-technology isn't prevalent in the food retail industry, even though it is a hot technology in the field and is often considered as the successor of the barcode (Bibi et al., 2017, p. 5; Kayikci, Subramanian, Dora, & Bhatia, 2020, p. 3), giving room for exploring the potential benefits, limitations and different applications. Also, according to Manzini and Accorsi (2013, p. 11), the most important future challenge in food supply chains is "the integration of competences, problems, issues and decisions". Many food chains and enterprises are interested in this challenge, and complete traceability of products, processes and systems is essential for this purpose (Manzini & Accorsi, 2013, p. 11). RFID-based systems are very effective for product traceability and can therefore also aid in the control of Supply Chain systems, from manufacturer to customer (Bai et al., 2017, p. 7). Even though RFID-technology is already being considered as a food supply chain technology (Bibi et al., 2017, p. 5; Kayikci et al., 2020, p. 5), past literature often describes it as merely an inventory tracking tool rather than being used for the large potential applications it has (Marucheck, Greis, Mena, & Cai, 2011, p. 10). But according to Zhu et al. (2018, p. 19), RFID-technology can enable companies to make use of real-time and accurate information on products reaching further than just stock-flows, such as temperature fluctuation information. In the real world, perfect information is rarely available, more even so in the food supply chain, where many factors influence the quality of food products. RFID-technology has the capability to track and trace products in real-time and on item-level (Moretti et al., 2019, p. 2; Tsao, Zhang, & Zeng, 2017, p. 1; Zhu et al., 2018, p. 18) and has the potential to prevent possible theft and spoilage of inventory (Biswal et al., 2018, p. 14; Fescioglu-Unver, Choi, Sheen, & Kumara, 2015,

p. 3). It even has the capabilities to go as far as to evaluate the quality of the tagged products based on certain properties (Bibi et al., 2017, p. 6; Chen et al., 2020, p. 4).

RFID-technology is well-positioned to be the successor of the barcode when it comes to food labelling and traceability (Bibi et al., 2017, p. 5; Khan, Haq, Ghouri, Raziq, & Moiz, 2017, pp. 1, 2; Kumar et al., 2009, p. 4), as can be seen in figure 2. Even though barcodes are still the dominant food labelling technology (Bibi et al., 2017, p. 5), and can support in inventory control, stock (re)ordering and checkouts, the amount of information stored is limited. RFID-tags offer a much larger potential for storing information such as temperature, humidity, nutritional and supplier information, as well as offering a wide range of improvements on the barcode, such as real-time traceability through the entire food supply chain, easier and faster tag scanning of multiple products at the same time. (Alfian et al., 2020, p. 10; Bibi et al., 2017, pp. 5, 6; Fescioglu-Unver et al., 2015, p. 1; Khan et al., 2017, pp. 1, 2). Also, this would enable food companies to increase individual product visibility in-store in order to be able to gather real-time stock levels and contamination information throughout a products' production and distribution cycle (Zhu et al., 2018, p. 18). The potential application of RFID extends to all areas of the supply chain (Moretti et al., 2019, p. 3) and it is one of the most competitive technologies when it comes to technologies supporting operations related to logistics and supply chain management (Mabad, Ali, Ally, Wamba, & Chan, 2021, p. 3; Yan, Jin, Liu, & Liu, 2018, p. 2).

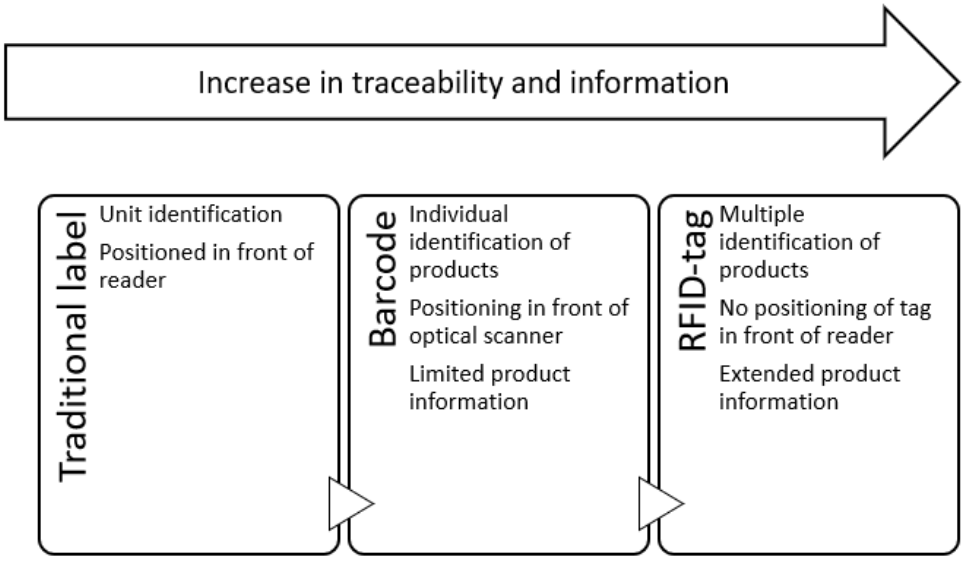

Figure 2. *Increase in traceability and information stored in food labels with newer technologies.An adaptation on the work of Bibi et al. (2017, p. 5)*

Fescioglu-Unver et al. (2015, pp. 3, 4) summarize the expected benefits of RFID technology to Supply Chain Management as can be seen in Table 2. The authors describe the different challenges and solutions RFID technology can offer, as are mentioned above. In a basic RFID embedded process individual items, cases, pallets and/or containers are tagged and at certain key locations or gateways, RFID-readers are installed (Fescioglu-Unver et al., 2015, p. 3). When a product passes that reader, information is read, updated, and stored in a database informing those parties involved with that process. This enables those parties to more effectively act on more accurate information.

Table 2. Expected benefits of RFID-technology on SCM (Fescioglu-Unver et al., 2015, p. 4).

Change in process	Ensuring the visibility and traceability to the products
	Recognizing the order pattern in real-time
	Improving the accuracy of forecasting demand
	Improving replenishment policy
	Reduction of the bullwhip effect
	Mixed shipping in a pallet possible
Direct benefits	Reduction of order cycle time, inventory, shortage, theft
	Improving the shelf efficiency
Automation	Automatic identification of delivery
	Automatic checking of inventory
	Point of Sale automation
	Reinforcing the security
	Improving the efficiency of expiration date management

2.4.2 RFID benefits and influencing factors

Although the potential benefits of RFID-technologies are abundant, they are also expensive, and they require businesses and supply chains to have an integrated

and extended information system and are also more difficult to implement by smaller scale businesses (Manzini & Accorsi, 2013, p. 4). The costs of RFID tags are less every year, but costs are nevertheless still one of the main issues of the applicability of RFID in SCM (Fescioglu-Unver et al., 2015, p. 7). The costs of RFID tags can be lessened by offering value in other parts of the business operations, such as by reducing labour costs, supply-chain costs and even an increase in sales across different parties due to better inventory management and product availability (Bibi et al., 2017, p. 6; Gaukler, 2011, p. 6). Therefore, the benefits of such a technology must be active for every or most of the involved parties throughout the supply chain, as it is unlikely that RFID-adoption will offer any form of profit to one actor alone if the costs aren't shared (Yan et al., 2018, p. 2; Yang & Chen, 2020, pp. 2, 21). Even though most literature agrees upon this, Piramuthu, Wochner, and Grunow (2014, p. 10) and Vlachos (2014, p. 9) recognize large benefits following the RFID-tagging of their entire stock on item-level, instead of just the expensive ones. The synergies created by the consistency in information flow following a complete RFID-tagged inventory are only at their maximum output in such a case, but this does mean that even items that cost less than the RFID-tag could be tagged and have a positive effect on the total profitability (Piramuthu et al., 2014, p. 11).

Table 3 lists six different product- and technology factors influencing the decision to adopt RFID-technology in the food supply chain. These factors are divided into product(ion)-specific and technology-specific groupings. One of the takeaways from the research will be to find out what kind of characteristics or products are better suited for certain types of traceability technologies, to fully adopt the potential increased traceability offers.

Table 3. *6 different influencing factors influencing the decision to adopt RFID-technology in the food supply chain. Own adaptation on the work of Aung and Chang (2014, pp. 10,11), Cuinas et al. (2014, p. 4) and Bibi et al. (2017, pp. 6, 11).*

Type	**Influencing factor**	**Description**
Product(ion) characteristics	Type of production process	Bulk products are often combined from multiple production plants, making traceability more complex, whereas fresh

		produce batches usually stem from the same production location.
	Type of product	The product characteristics influence the need for traceability, e.g., products that are perishable and sensitive to quality deviations have a need for different type of information and quality standards.
	Type of packaging	Certain packaging materials, such as metals, cardboard, glass, and liquids, may influence the reading quality of RFID-tags. Readability can also be influenced by the number of tags in a smaller area.
Technology characteristics	Implementation costs	Higher costs act as a barrier for small-scale producers & producers from developing countries since RFID-tags are price-sensitive to volumes.
	Information exchange factors	Continuous exchange of accurate information in a standardized format is one of the biggest challenges in Supply Chain Traceability, since different standards are being used in the Food Supply Chain.
	Price pressures	Due to the extra costs of tags and reading equipment, the margins on the products influence the applicability. Certain products (with higher margins) might be better suited than others.

2.5 Literature review synthesis: RFID-technology creating an Integrated Food Supply Chain

In the previous sections, the many potential benefits RFID-based Traceability technologies might offer and the factors influencing adaptation have been explained. But for the processes to be both cost effective and to unlock the full potential of the

capabilities such a system would be able to provide, the costs and information sharing must be divided between as many involved parties as possible. In this section, the influencing factors have been synthesized into a model providing an overview of all of them together.

All the links in the chain must work together to make the most out of such a Traceability system. This way, such a Traceability system could provide customers with full information of the food products, from farm to fork (Cuinas et al., 2014, p. 3), as well as improving data generation for analysis by supply chain actors (Chanchaichujit et al., 2020, p. 17). This type of data and collaboration could lead to a more integrated food supply chain where products could be traced throughout the entire chain (Li et al., 2017, p. 2).

There are multiple factors on different levels driving and influencing the need for Traceability, as can be seen in Figure 3, where these are grouped. The different drivers and other influencing factors have been researched, but not enough with a collective orientation (Chanchaichujit et al., 2020, p. 17).

When it comes to drivers on a Market level, *complying with regulatory requirements* and *addressing social and environmental issues* drive the increasing need for strong traceability throughout the supply chain. These are broad factors influencing every organization in the market since these are not limited to a certain organization or section. Both factors are also influenced by each other since the social pressures for change also influence the amount and strictness of regulatory requirements. Also, developments in technologies even enable regulations to be stricter since more data can be used and analysed to measure performance and quality.

Complying with regulatory requirements as a driver regards all the different factors regarding legislation and certifications that are needed to ensure food safety and upholding certain qualitative standardization. Due to strong competition following globalization, organizations benefit from guaranteeing their quality standards and origin of products, more so now that the food production market has transformed from multiple smaller markets to a global trade (Cuinas et al., 2014, p. 2). Further development of legislation, industry guidelines and international standards regarding safety and quality issues (Aung & Chang, 2014, p. 5; Bosona & Gebresenbet, 2013, p. 5) remain an important driver of the need for traceability due to the larger amount of products and information being transferred between markets and

nations (Behnke & Janssen, 2020, p. 2), which increases the need and requirements for strict regulations to ensure food safety for consumers and global standards enabling interoperability (Aung & Chang, 2014, p. 5).

Addressing social and environmental issues are factors driving traceability through several social issues such as increased consumer awareness and public concerns. Consumer confidence and therefore sales can increase when products are fully traceable (Cuinas et al., 2014, p. 3), due to the increase in awareness on social issues such as the shift of quantity-oriented to more demanding quality-oriented lifestyles, driven by rising consumer income (Bosona & Gebresenbet, 2013, p. 6). Environmental positioning become of a greater importance to organizations and their market share (Bosona & Gebresenbet, 2013, p. 6).

Also, one of the social and environmental issues is also the amount of food waste that is created by organizations in the Food Supply Chain. The social pressures that ask for more attention towards the environment coincide with the desire to reduce the wastage of food product.

Thus, on an organizational level, the pressures for organizations to perform better in their operational processes, reducing operational costs and creating economies of scale by collaborating on a more intense level, drive organizations to implement better Traceability systems (Hastig & Sodhi, 2020, p. 10). This enables organizations to reduce the time and costs on labour activities that can be allocated towards other ends (Aiello et al., 2015, p. 2). *Increasing operational efficiency* and *Improving Supply Chain Management* go hand in hand in this case, since both reinforce each other. Both are also driven by the development of new technologies, creating larger potential performance benefits. The increase in globalization and the merging of multiple markets on a global scale also suggest the increased need for more integrated traceability systems (Chanchaichujit et al., 2020, p. 3), since there are more parties involved (Hastig & Sodhi, 2020, p. 10). With more integrated information systems, the entire chain can become better connected and more responsive to market needs, making the supply chain more dynamic and flexible.

Lastly, the development of new *Production*- and *Technology characteristics* enable operational improvements since new technologies make different uses of data and communication possible. One of the goals of this research and this model will also be to figure out what kind of product(ion)- and technology characteristics best

suit certain traceability systems, and what challenges different types of products might face since not every system or technology is compatible with every product in a market.

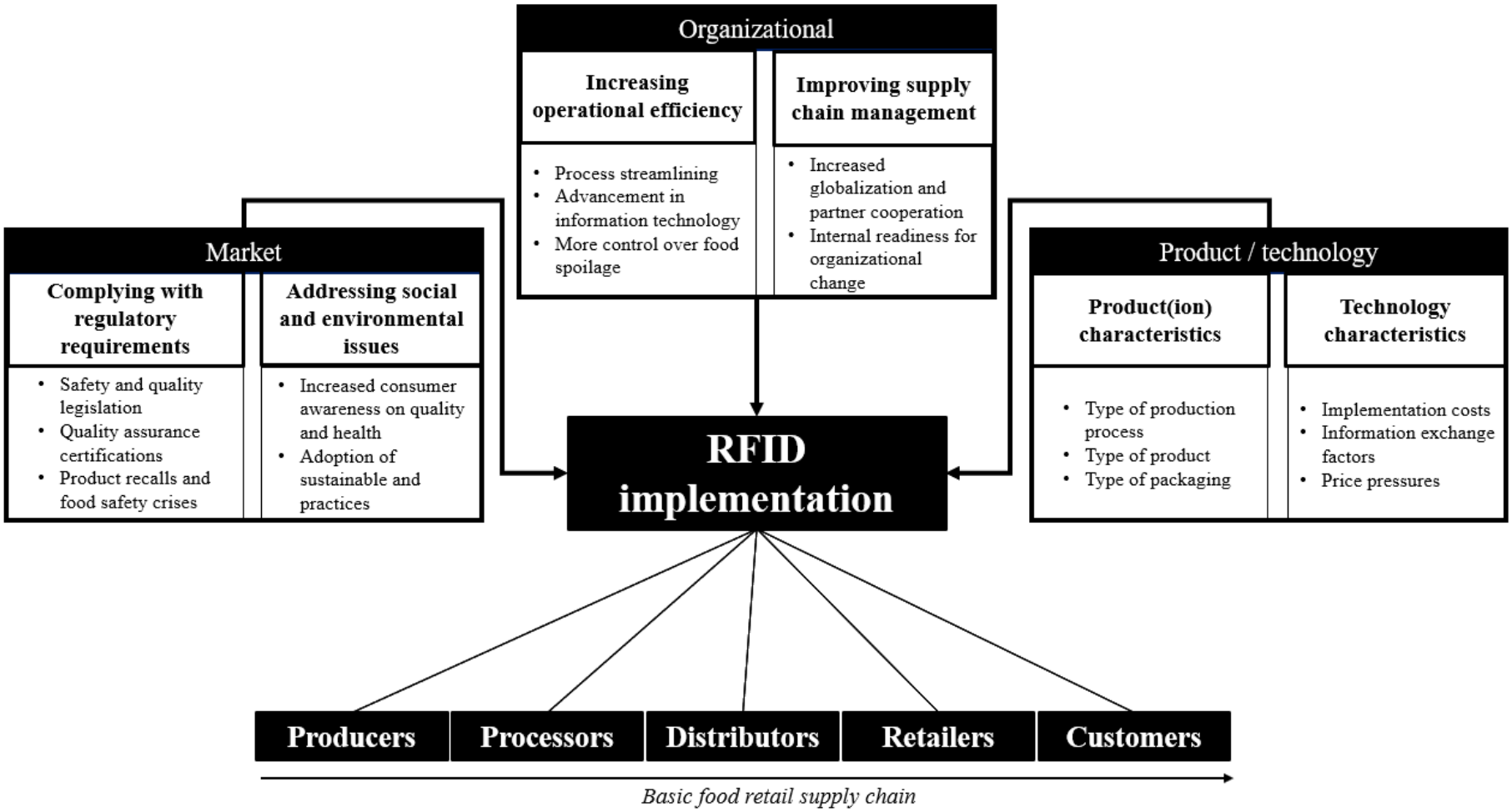

Figure 3. *Different factors influencing the different Supply Chain Actors.*

3. RESEARCH METHODOLOGY

This chapter will elaborate on the research methodology that was used to obtain the information and data needed to be able to reach the research objective and answer the research question. The goal was to better understand the collective challenges and drivers' food supply chains face, as well as finding out what factors influence the implementation and adaptation of RFID technology in the food supply chain.. The first part outlines the design of the research, after which the sampling, population and analysis is discussed.

3.1 Research design

The aim of this thesis was to dive deeper into the growing importance of traceability and the usage of data in a more integrated food supply chain. To do so, the actors in the food supply chain had to be identified, the main drivers and barriers of traceability had to be recognized along with the effect these have and the potential practical solutions that have been researched had to be further elaborated on.

The author of this thesis was interested to find out how big the existing challenges are for food retailers, and what initiatives there are looking to solve these. Especially the different factors influencing the implementation.

Since the goal of this thesis was to explore the need for food supply chain actors to track and identify their products throughout the food supply chain and explore the RFID-technology has for adding even more value in this process, a case study was carried out through semi-structured interviews. Subsequently, a case study design was selected. Case-studies are rich, empirical descriptions of certain phenomena, based on a wide variety of sources (Eisenhardt & Graebner, 2007, p. 2). For this case study, certain stakeholders and experts in the food supply chain and in the RFID industry have be selected, since these offer the most information and are able to shine a light on the deeper issues at hand and how these relate (Flyvbjerg, 2006, p. 12). Since case studies enable in-depth analysis of certain phenomena, potentially resulting in new insights (Eisenhardt & Graebner, 2007, p. 4), and the aim is to explore the potential of RFID-technology, this design is appropriate for this thesis. The downside of performing a case study is that the sample size is relatively small, and it would be difficult to be able to generalize this toward the entire food

supply chain. The interviews were conducted via the online meeting application Microsoft Teams.

3.2 Case selection

For this research, 9 individuals have been interviewed in a semi structured manner. Since the food supply chain touches upon many different industries and concerns both small and larger organizations, this scope of this research had to be focused. It was important to interview professionals that are involved or experienced in the management of certain parts of the food supply chain, since this ensured respondents would have viewpoints and influence on strategic decisions and directions. The researcher also looked for experience in the field of traceability, preferably in the field of the food supply chain, and certain traceability technologies. Aside from these prerequisites there are no other factors that were excluded since the goal was to remain open to different insights and find out as much as is possible.

In conclusion, the criteria in the following table have been used to ensure relevant respondents with relevant knowledge or experience are selected.

Table 4. *Inclusion/exclusion criteria for the case selection.*

Inclusion/exclusion criteria
Must have knowledge of RFID-technology.
Must have experience in or knowledge of Traceability systems.
Must have experience in the Food or near-Food Supply Chain.
Must be active in or have experience in a Supply Chain consisting of at least three organizations.

Following this framework, the overview of interviewees and interviews turned out as follows:

Table 5. *Interviewees and interview duration overview.*

Interviewee	Job title	Interview duration
I1	Product owner Transport and Logistics	00:29:31
I2	Business Development Consultant	00:22:23
I3	Developer Food Retail Solutions	00:50:15
I4	Supply Chain Innovation Consultant	00:50:04
I5	Supply Chain Product Manager	00:29:31
I6	Business Tech Consultant	00:36:39
I7	Project Manager Store Support	00:22:39
I8	Project Manager IT Support	00:29:19
I9	Business Controller Store Operations	00:18:59

3.3 Data collection

The interview protocol can be found in Appendix B and the interviews have been conducted on a face-to-face basis using digital meeting application Microsoft Teams.

The structure of each of the interviews was the same. Each one started with the introduction of the interviewer and interviewee and the objective and goals of the interview and the research. Interviewee's were also asked for permission to record the interviews, so that the data can be analysed in a later stage. After the interviewee has had the time to introduce themselves and their area of expertise or experience, the interviews started with the RFID-related questions, since the interview has a RFID-focused setup.

To establish the basic knowledge the interviewee has of RFID-technology, the first questions regarded their knowledge on the technology and the biggest advantages and current limitations of RFID-technology in general. Following this, the next questions followed the topics the interviewees had the most ideas on and knowledge of, in order to uncover as much information as possible. The goal here was to find the similarities and differences in relation to the conceptual model and in that way test the initially found themes of influencing factors, as can be found in figure 3.

Also, interviewee's were asked about their perception of most interesting supply chains or actors within supply chains to start with, as well as their top-3 factors influencing RFID-technology adoption.

3.4 Data analysis

All the interviews were transcribed using Amberscript transcription software. The collected data was then analysed using thematic content analysis to uncover the most important theme's, ideas, experiences, and patterns. This followed an inductive approach, based on the conceptual model found in figure 3. As the goal was to discover how the implementation and adaptation of RFID-traceability is influenced by the drivers of RFID-traceability technology, an inductive approach was be used to find both the similarities and the differences in the pre-setup conceptual model. The most important things to find in the data were different factors influencing RFID

implementation that might influence adaptation, as well as what factors might be the most important.

Starting analysis, the first step was get familiarized with the data by transcribing the audio files and taking initial notes. After the transcripts were finished, the coding started. The interview transcripts were coded using the ATLAS.ti programme, which is a qualitative research tool that allows for coding and analysing interview transcripts and supports the data visualization. The codes and themes can be seen in Table 6.

In comparison with the themes found in the literature, as synthesized in figure 3, there were new codes found in each of the themes. The *Privacy issues*, *Store of the Future* and *Alternative technologies* codes were found as influencing factors in the interviews but were not mentioned in the earlier synthesis.

Table 6. *Codes and themes that resulted from the interviews.*

Codes	Subcodes	Themes
○ Regulatory requirements		Market influences
	○ Governmental requirements	
	○ Organizational collective	
	○ Product recalls	
	○ Universal standards	
○ Social and environmental issues		Market influences
	○ Adoption of sustainable practices	
	○ Food waste	
	○ Increased consumer awareness	
	○ Increased theft	
	○ Unsustainability	
○ Privacy issues		Market influences
	○ Regulations	
	○ Sentiment	
○ Operational efficiency		Organizational influences
	○ Improving shrinkage prevention	
	○ Improving stock management	
	○ Improving traceability	
	○ Increasing productivity	
	○ Process streamlining	

○ Supply chain management		Organizational influences
	○ Number of involved actors	
	○ Increased cooperation	
	○ Moment of tagging	
	○ Total traceability & information exchange	
	○ Unit of tagging	
○ Store of the Future		Organizational influences
	○ In depth suggestions	
	○ No manual scanning	
	○ Seamless checkout	
	○ Total traceability	
○ Product(ion) characteristics		Product / technology influences
	○ Different label types	
	○ Higher margin/shrinkage products	
	○ Load carrier level	
	○ Order unit level	
	○ Product level	
	○ Tagging process	
○ Technology characteristics		Product / technology influences
	○ Cost savings	
	○ Implementation costs	
	○ Information standardization	
	○ Price / margin pressures	
	○ Total integration	
○ Alternative technologies		Product / technology influences
	○ 2D barcode / Data matrix	
	○ Camera technology	
	○ No specific alternative / application	
	○ Weight sensor	

4. RESULTS

In the following chapter, the results stemming from the interviews on the implementation on RFID technology in the food supply chain will be presented. The goal of these interviews was to gain a deeper and comprehensive understanding of the factors that come in to play when looking at the adaptation and implementation of RFID technology in the food supply chain, starting from the market level.

After analysing and categorizing the interview data, certain themes arose from the data, in line with the earlier shown scheme as can be seen in figure 3. These three core themes stand as ‘Market influences’, ‘Organizational influences’ and ‘Product/technology influences’. Each of these themes is supported by underlying categories which will provide the evidence in the form of quotations of the interviewees. These core themes are the same as the initial synthesized model as can be found in figure 3, but there are differences in the underlying categories.

The most important factors influencing the implementation of RFID technology in the food supply chain will also be presented at the end of this section, as well as the comparison between the earlier model and the new model, and will provide the base for the deeper analysis and interpretation in the next chapter.

The thematic model is simplified in comparison with the preliminary theoretical concept, since the major influences were found to all influence a larger scope than just the individual actors in the supply chain – major technological innovations influence the supply chain as a whole and are therefore looked at in that light in this model, as can be found in figure 4. The differences are the addition of one influencing factor in each of the dimensions, compared to the preliminary model.

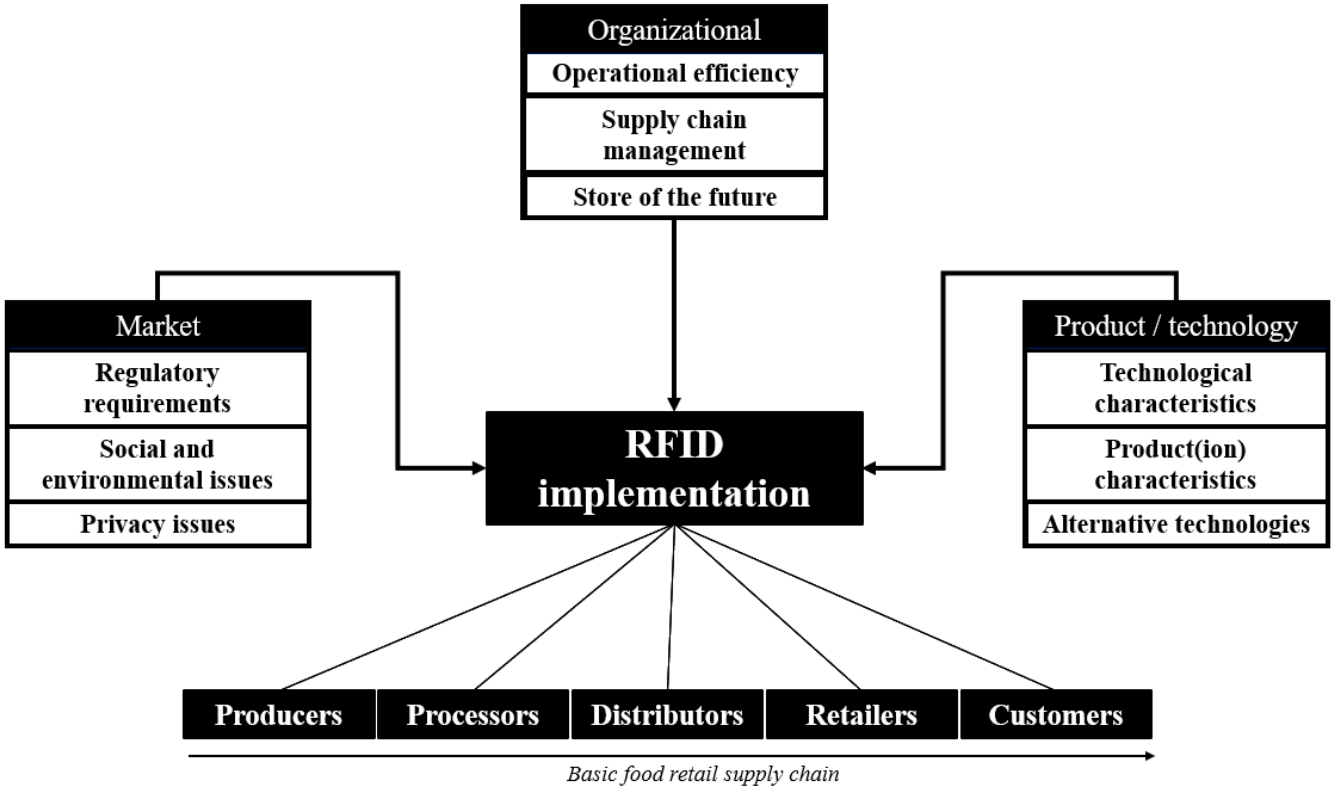

Figure 4. *Different factors influencing the implementation and adaptation of RFID technology in the food supply chain, with the addition of new factors found in the interviews.*

Also, a table has been created to show the mentions certain codes in different interviews, as can be seen in table 7.

Table 7. *The mentions of categories by interviewees, resulting from the analysis of the interviews, per category and for the top influencing factors.*

Category	I1	I2	I3	I4	I5	I6	I7	I8	I9	Total
Regulatory requirements		x		x	x	x			x	5
Social and environmental issues	x	x				x	x		x	5
Privacy issues				x					x	2
Operational efficiency	x	x	x	x	x	x	x	x	x	9
Supply chain management	x	x	x	x	x	x	x		x	8
Store of the future		x		x		x	x	x	x	6
Technology characteristics	x	x	x	x	x		x	x	x	8
Product(ion) characteristics	x	x	x	x		x	x		x	7
Alternative technologies	x	x		x	x	x	x	x	x	8
Top factors	**I1**	**I2**	**I3**	**I4**	**I5**	**I6**	**I7**	**I8**	**I9**	
Costs / profitability	x	x		x	x	x		x	x	7
Responsibility	x		x			x	x	x	x	6
Execution / scalability		x	x	x		x		x	x	6

4.1 Market dynamics as the instigators of technological change

Market-level dynamics are formidable forces with the ability to exert a large influence on innovation and technological change. In this section the main categories influencing the implementation and adaptation of RFID technology in the food supply chain that emerged from the interviews are presented.

Aside from the categories that were recognised beforehand, the regulatory requirements and the social and environmental considerations, a new sub-category emerged that did not arise earlier. Some interviewee's expressed their concerns on privacy issues and mostly the precepted privacy issues customers could have because of the usage of RFID technology in the food supply chain.

4.1.1 Regulatory requirements

One of the largest factors influencing the implementation of innovation, has been recognised as the interference of governmental or cross-organizational entities. When asked about why certain product groups are already tracked and traced on a much deeper level, such as for example tobacco or medicine, a Supply Chain Innovation Consultant said: *'Because that is what the government is asking for. Why do we only do it when there is legislation? Because these things often cost money. (I4)'*

This shows that in certain cases, the obligation by certain larger entities has a large impact on the operations organizations or even supply chains undertake. And that when faced with an option, many organizations will choose the cheaper option. When the requirements for food safety and quality assurances increases, organizations are forced to look towards different solutions to meet the standards, in an efficient and cost-effective way, where possible. When larger entities change their requirements, organizations will follow. One example of this is the fact that GS1 (Global Standards One), the organization that introduces the design and implementation of standards in the field of product identification, is introducing a new barcode (the 2D barcode) in the coming years. The reason this is being accepted by organizations: *'Because it is enforced, it is pushed from GS 1, so from the organization in which the standard is maintained' (I5).*

Following this view, an overarching entity would have to push regulations when this would benefit the larger societal or organizational goals in the longer term. This would ensure organizations and even supply chains work towards the longer-term goal, exploring possibilities that would enable them to do so in a cost-effective manner. Certain goals, such as sustainability, are a clear example of this. As a Business Development Consultant mentions: '*I still think that the sustainability perspective can be a decisive factor, where certain policies are going to be placed, so that you have to apply them and that everyone has to go along instead of being able to' (I2)*.

4.1.2 Social and environmental considerations

Often a predecessor of regulatory requirements, the social and environmental issues influence the shaping of the requirements that are needed from an industry and the responsibilities that have to be taken, according to a Business Tech Consultant: *'You could say that a government, or at least another body such as the EU, if that is really important, traceability from sustainability for example, from other forms of responsibility across the entire market, should do that' (I6)*.

Considerations on themes such as stock shrinkage and food waste are not only a liability and unnecessary costs for organizations, which in and of itself already pushes organizations to improve their traceability, these are also big items on sustainability agenda's. Different interviewees mentioned the importance of good traceability and the right data of for example expiration dates, also for food safety: *'Food waste really is, shall we say, the number one topic' (I7) & 'And a piece of (expiration) code management, you know, that is also something that is currently also receiving attention, also nationally' (I9).*

Aside from the regulatory requirements and the operational cost drivers associated with shrinkage, certain organizations might feel the pressure or the inclination to contribute to society and take on a more forerunner position when it comes to sustainability and different current issues.

In the context of sustainability, this is also where the first concerns with RFID-technology arose. With the addition of RFID-tags on products instead of just regular barcodes, questions were asked on the sustainability perspective on single-use tags. This could provide issues when certain packages are recyclable or bio-degradable: *'In terms of sustainability, is it sustainable to put a tag on everything? How much does it cost to put a tag on very cheap products? Suppose you have plastic, which is naturally degradable. Is that tag naturally biodegradable? (I4)'*

4.1.3 Privacy concerns

Not only the sustainability concerns were mentioned, but also a new category not found earlier in the research surfaced after delving deeper into potential RFID-issues. There was a distinction made between two streams of concerns, where the first one was focused on the sentiment of new technologies and the issues customers might

experience. The addition of tags emitting Radio Frequencies can lead to concerns. Another stream of thought was that of the regulations and specifically the violation of privacy issues: *'Okay, until when can you track those products? Or will the tag then be turned off the moment you, you know what I mean? Or suppose you steal a product, we can say: it is at your house, a salmon that you did not pay for, things like this. I can imagine that it is forbidden to follow people or trace products in such a way. (I9)'*

4.2 Organizational excellence shaping RFID implementation

The pursuit of organizational excellence is recognised as a driving factor behind the implementation and adaptation of innovation and is also mentioned as such when it comes to the implementation of RFID technology in the food supply chain. The two most mentioned factors of influence, the increase of operational efficiency and the integration of the supply chain, were recognized beforehand as well.

Beside those two factors, a third factor emerged as an important reason for the interviewees to delve deeper into new technologies, such as RFID. The focus on the longer-term future and the 'Store of the future', or even the 'Supply chain of the future', led to multiple interviewee's mentioning this as an important reason to explore the potential of RFID technology.

4.2.1 Operational process streamlining

The streamlining of operational processes and the pursuit of operational excellence was by far the most frequently mentioned factor influencing the implementation and showing the potential that RFID has to offer. There were 5 types of improvements recognised in the data. Improvements in stock management, productivity, traceability, shrinkage prevention and the integration of those improvements in the form of process streamlining.

In the first place the introduction of RFID technology would improve tracking and traceability capabilities throughout the entire food supply chain, when applied at the start of the chain. Aside from the products that can be tracked, it also offered benefits in the traceability of load carriers and other resources, which also lead to a significant amount of lost value: *'Particularly also that you can simply follow and*

track your articles throughout the entire chain. But not only your articles, but also your load carriers and your resources, because they often get lost too. (I5)'

Another factor of operational improvements and a factor that has a great influence on the cost-benefit analysis, is the impact on employee productivity and the corresponding lowering of labour costs. One of the benefits of RFID-technology is that there is no direct line of sight needed, which leads to the benefit that an infrastructure of RFID-gates can read RFID-tags from a distance, lowering the necessity for personnel to scan every load carrier or product. A Transport & Logistics Product owner explained the situation where he would be able to save a lot of manual work using RFID-technology: *'If you put the gate right in front of the dock and when you enter the truck that you have to go through that gate, that you know for sure, okay, he's in that truck, that saves a lot of manual scanning movements. (I1)'*

This was reinforced by a Supply Chain Innovation consultant, who had been responsible and involved with a lot of Distribution Centre innovations, by saying the cost savings of such a technology, if it would decrease the time needed for scanning movements by two seconds, would save around €1,2 million per week: *'Then you can count the other way, then we would save 1.2 million on a weekly basis. (I4)'.*

Improving shrinkage prevention is a multiple sided factor, with on the one side the knowledge of where the products are and prevent them from getting lost. On the other side, food waste has a large negative influence on the cost-benefits of the operations, as well as theft in stores. As a Business Controller Store Operations, who is responsible for the financial performance of a large area of food retail stores, managed to explain: *'Yes, exactly. So, in a perfect world we want to have, say, zero stock variance and zero variances on our expiration code management, and it all must be right. Well, I think this technology can make a huge contribution to that. (I9)'*

Also, theft prevention would be largely influenced, since tagging products with RFID-tags would enable the RFID-infrastructure to recognise unpaid products, and this would enable employees to perform targeted checks on unpaid products, instead of the random checks that are for example used at self-checkout places. A Food Retail Solutions developer, employed by an organisation that looks to offer technological solutions to retailers: *'You want to replace random checks with targeted checks, so really target only the people you think, there is something, because that makes us think that those whole random checks can become much less'(I3).*

All the earlier mentioned topics have a positive influence on stock management for organizations in a supply chain, from start to finish. But also, the stock management itself can be improved by the usage of RFID-technology. Eliminating human scanning movements and improving reliability would greatly benefit the stocks throughout the supply chain, as the Supply Chain Innovation consultant mentions: *'If you look back a bit, within our DCs we now also have a lot of trouble with stock, stock reliability, right? So, it would just help if I knew at any time what I have in my stock racks. That already opens doors to add a lot of value, if I could receive based on RFID. (I4)'.* For looking at the entire chain, this Project Manager Store Support states: *'I think RFID is also very suitable for that, if I say it right, so that we can forecast that even better, see what is in the chain. There is a huge opportunity there. (I7)'.* This would enable producers to lower their safety stocks and have a better starting position in their forecasting business, all of which would positively influence their operations.

Lastly, the interplay of all these operational benefits would streamline all the operational processes within organisation. A Supply Chain Product manager sums the benefits up as follows: *'Everyone sees, especially if you work in the supply chain and logistics, immediately sees the benefits, and especially because you naturally hope that it can remove errors from the process, can remove a number of scan actions at each step, which will save you a lot productivity and can ensure that you do not lose certain things or can find them back in a certain way. (I5)'*

The operational benefits would be visible in every area, and the combination of such would yield large cost savings. This combined approach would be able to save millions annually, in a large food retailer in the Netherlands, as explained by a Business Development consultant: *'The business case for supermarkets is basically on everything, say, what does it yield? So, I think you can achieve that in every area, so your stock differs, because in practice you can differ in your stock, you can hardly steal more than you can, or someone just must remove a tag manually. Well, that is really such a huge turnover per year, but also your stock. You really are going to save millions on an annual basis if that is applied. (I2)'*

4.2.2 Supply chain integration

Where the individual benefits per use case are quite clear when summing up the operational improvements, the real value cannot be found until this is integrated within the supply chain. Improvements in cooperation and information sharing is what would really deliver the real benefits, as the information saved on the tag would cover the entire chain, from start to finish: *'Then you are going to get the real value, I think. If you are really going to deploy integrally, if the supplier already starts with the correct tagging of the articles, up to and including you at the store, yes, that would be ideal of course. (I5)'.* Since the costs of RFID-technology and infrastructure are relatively high, the cooperation between organisations is necessary. This would help with the costs, but also offers the largest number of benefits: *'I think if everything had RFID in it, you could make all your retail processes so extremely efficient and valuable, from the beginning of the chain to selling, because an RFID tag naturally has a lot of valuable information that is passed on to everyone. in the chain, but also the consumer can read at home. (I2)'*

By adding the consumer to the equation, a new level of the supply chain is added since this does not end at the retailer or the final selling point – there are even benefits for consumers, as will be explained in the next section.

4.2.3 The store of the future

The third category that emerged is that of a store of the future – multiple interviewees talked about opening the possibilities of how stores would look like and function in the future, and that technologies that could play a part in the future should be explored already. From this viewpoint, certain applications have been laid out and the link with RFID is shown as well.

Increasing the depth of traceability and the attainability of this information, even for consumers, would open a lot of new doors and applications. Consumer would be able to scan a product with their phone, and see exactly where that product came from, what kind of farm or production plant. The interviewed Business Development consultant even sketched a more futuristic view, where RFID-technology would even be able to help consumers with their own 'stock at home': *'Then you start thinking about, for example, sustainability or making product*

information available to the consumer, because every iPhone nowadays has an RFID reader, so you can also imagine that you can create all sorts of apps for the customer, that you literally do your shopping. You have your entire cart, then put it in your phone and then you know exactly what your stock is in your fridge. (I2)'.

A different part of this store of the future, and one that is mentioned a lot, is that of a seamless checkout, where RFID could potentially play a large role. By removing the need for manual scanning movements by customers, it could be automatically registered when kind of products are carried by the customer. The Project Manager Store Support, who is also responsible for the development and the implementation of new self-checkout processes, portrayed a picture of the future: '*What's really the future, I think, is that you can just shop there without paying, in any way, that it scans all those tags on the products that you're carrying and you just walk out, and that it will be deducted from your account. (I7)'.*

4.3 The impact of product and technology characteristics on RFID adoption

Both product and technology characteristics influence the RFID adoption. Different underlying factors have an influence on the effectiveness and applicability of the technology. This section will dive deeper into the insights from the interview on different technological forces and product(ion) alignments and what these mean for the implementation of RFID technology in the supply chain.

Lastly, some alternative technologies that have been mentioned will be presented, to create a broader view on the different technologies available to solve certain problems.

4.3.1 Technological forces

The main reason given by interviewees for not being able to successfully implement RFID-technology is the food supply chain as of yet, remains the costs of implementing the infrastructure and the tags themselves. The main factor are the margins of food retail products with regards to the tags. Even though a Food Retail Solutions developer says the tags are: *'I think it's around three or four cents or so right now. In the early years it was around ten cents per label, that has already been*

drastically reduced and will be even lower. (I3)', most of the experts active in the food supply chain still believe the distance is too large for the individual use cases: *'I always have the idea why RFID doesn't work for us, because the individual RFID tag is too expensive compared to the retail price of our items. (I4)'*.

Nevertheless, it is recognised that certain types of products are at a better price point to not only benefit the most from the potential cost savings, but also where the 3-4 cents price increase would not harm the price point position due to the already higher price of the product. As an example the Business Controller Store Operations said: *'The customer who is willing to pay nine euros for a piece of salmon anyway, I think he will feel less pain if it goes from nine euros to nine euros ten, while these are the products of the people who do not want to pay for them, who therefore come steal. (I9)'.*

This shows that the use case for certain products is easier made than other ones – but the main point of the technology is that a total integration yields the most benefits. The increase in information sharing, along with quick and reliable accessibility to this data is what offers the largest benefits and is necessary if the goal is to automate the story or offer a comprehensive solution to theft or other shrinkage issues: *'So you would like to take a step within your store for a solution for theft or for an automated store. Then a certain percentage of your products can't have it, and a certain can't, it's actually all or not, because otherwise you can't use the final solution. Because if half of our products do have RFID, and the other half don't, yes, then we can't automate the store (I2)'*. This Business Development Consultant is very clear about the necessity of total integration in order to achieve the automated store.

4.3.2 Production alignment

In terms of the alignment of the processes, the interviewees mostly mentioned that the most benefits would be gained when tags would be placed on every individual product: *'I strongly believe that you should actually do it for everything, so then you immediately get the most out of it (I6)'*, since that would enable the supply chain to know exactly what the individual product characteristics are: *'the big advantage lies in knowing exactly what those article properties are. (I4)'*, and track the product back through the chain, all the way to the starting point.

This does inherently mean that the tagging process starts at the first step in the supply chain, since that would mean information can be processed from the start. This would mean every step of the supply chain, all of the involved actors, would be able to reap the benefits, enabling the costs to be shared among multiple actors.

4.3.3 Alternative technologies

In terms of alternative technologies, a few were mentioned during the interviews. Technologies that could be able to solve for certain 'problems' as well, but none offered the same total package of benefits RFID-technologies seems to offer. One change in identification technology that is taking place within a few years, is de addition of the 2D barcode (or QR-code) alongside the traditional barcode. A Supply Chain Product Manager explains: '*Where we are going in 2027 is that there will be a 2D barcode on it, so that is such a QR code. Such a grid will be placed next to the regular barcode, so there will be two. (I5)'*. This more extensive barcode will be able to store more information than the traditional barcode and will therefore already solve for some of the issues that there are currently in the technological identification field of the food retail.

The alternative technology that is mentioned the most and that is also being tested already, is that of camera's. Cameras are able to solve for certain issues, mostly on the automated checkout and inventory control front – which does mean that this technology is mostly useful in the final stages of the supply chain, with the most benefits coming in the store part of the chain. Also, the technology on camera's is not yet developed entirely, and the infrastructure behind it is also very expensive: *'For the Automated Store, camera technology is now very much used. But cameras are extremely expensive, complicated and that technology is not fully developed yet. (I2)'*

4.4 Key factors in the implementation and adaptation of RFID technology in the food supply chain

In this section the largest and most important or influential factors influencing the implementation and adaptation of RFID technology in the food supply chain are mentioned. These factors are the result of looking for recurring mentions throughout the interviews, as well as the direct question towards interviewees on what they believed the most important factors were. The top factors mentioned can be seen in the following figure:

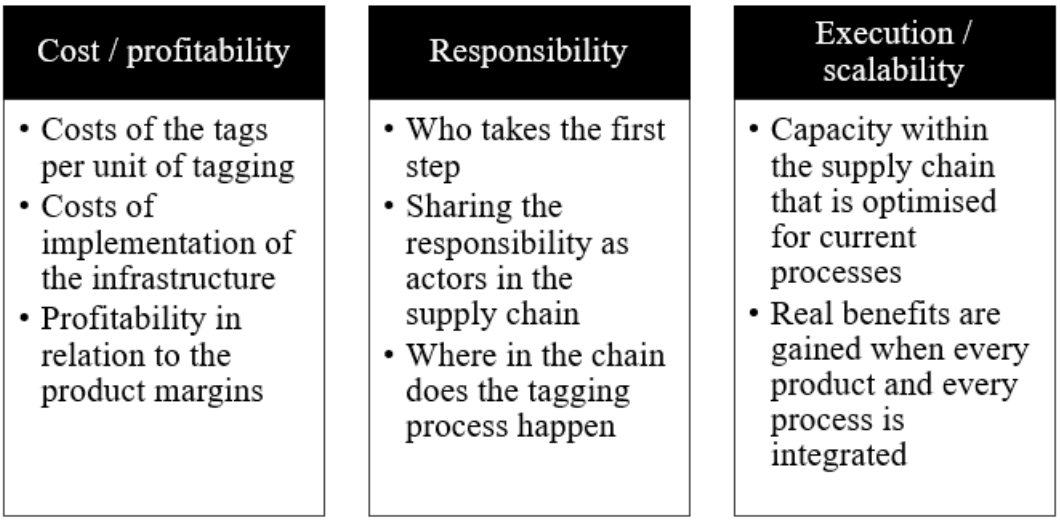

Figure 5. *The top factors influencing implementation and adaptation of RFID technology in de food supply chain.*

One of the recurring factors influencing RFID implementation, was that of execution and scalability of the technology. The main driver behind this factor is the argument that in order to reap the most benefits of RFID technology, every product should be tagged with an RFID tag, as is mentioned in the interviews: *"I still think that, but here we come back to the scalability, the scale. This kind of thing also only works if it is on all products. (I4)'* . This is a large investment, and leads to many questions as to where does the tagging process start (where does the execution start) and how can such a process be expanded. Also, food supply chain capacity is optimised for the current processes, which means that altering the entire chain is a large task and currently leads to too many difficulties.

The next large influencing factor is captured by a Project Manager Store Support: *'So who will intervene where in the process to make this possible. That is of course simply the biggest question there is and that you actually need the entire chain for that. For that, yes, to be able to do that really well together (I7)'*. The question what responsibility lies where is an important what. The questions who, what & where are important questions to answer and differ largely on what the goal is. Different use cases lead to different goals, and the beneficiaries differ per use case.

But the biggest and most often mentioned factor are the costs/profitability. On the one hand, the investments on infrastructure are large. And on the other hand, the application of a tag, even if it's a few cents, has a large impact on 'cheap' product. Even though it is recognised that the costs will not be the largest influential factor in the future (*'Yes, I think costs and stuff, but that's really the most surmountable thing, so I'd really put that at the bottom. That's just something to think about. But I think if you go into something like that, start scaling and the technology is moving forward every year as well. We'll get over that within now and x years. (I2)'*), balancing the potential profits and the positive effects of RFID technology against the costs remains the most important factor as of now, as mentioned by a Supply Chain Innovation Consultant: *'I think that's the trade-off. How do I calculate the business case? That's what it's all about. How do you do that? (I4).'*

5. DISCUSSION & CONCLUSION

In this chapter, the insights resulting from the interview are compared with the theoretical framework that was found beforehand. By synthesizing and comparing the new data with the preliminary theoretical constructs, it was found that the preliminary model had a strong base on which the larger themes did align. In the deeper subcategories there were a few differences found, as well as the introduction of some new categories that were not apparent beforehand.

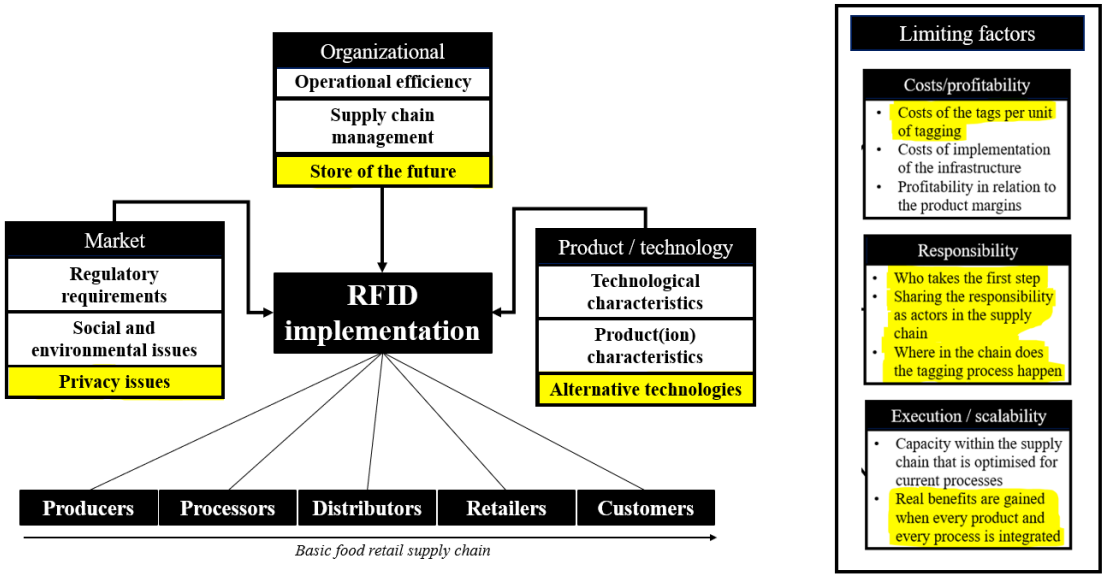

Figure 6. *The total overview of driving and limiting factors in the implementation of RFID technology in the food supply The factors marked in yellow are new factors resulting from the interviews.*

5.1 Key findings

This study demonstrates a lot of potential benefits and many limiting factors related to the implementation of RFID-technology in the food supply chain. It is clear from the results that the implementation and adaptation of RFID-technology as a traceability tool in the food supply chain is a difficult process dependent on a lot of different factors that should be aligned in order to attain the maximum benefits.

Specifically, this paper focussed on the extended benefits and drivers of RFID technology throughout the food supply chain and from the different perspectives, enabling a broader approach to assess the effects of a more integrated food supply chain. The research question was as follows:

'What are the driving and limiting factors influencing implementation and adaptation of RFID-traceability technology in the food supply chain?'

For the driving factors of implementation of RFID-technology, a distinction was made between *Market-level influences*, *organizational-level influences* and *product/technology-level influences*.

The Market-level influences show that regulatory requirements and associated social and environmental issues function as a large driving factor when it comes to technological innovations in large and matured industries. Supply chains such as the Food supply chain are not keen on changing effective strategies when these can encompass a larger risk or a high investment. When larger entities enforce regulations for the good of the bigger picture, organizations have no choice but the adapt and innovate in order to find a new most cost-effective way. The obligation of increased traceability would enable more testing to be done with RFID-technology if organizations and supply chains as a whole would be supported in doing so.

On Organizational-level influences this study indicates that the most influential driver, by far, is the increase in Operational efficiency that RFID-technology would enable. By using RFID-tags on product, traceability throughout the entire food supply chain would increase, generating benefits for each of the different actors. The main benefits would ensure increased collaboration between supply chain actors and even within actors themselves, as the operational processes can be streamlined largely, diminishing manual actions and increasing accuracy by decreasing the amount of human errors.

On Product/technology-level it is clear that the driving benefits are large for certain products with higher price margin points – but by diminishing shrinkage, large benefits can be obtained on every price category. But the largest added value of RFID-technology on product level is the amount of information that can be stored on RFID-tags and the information exchange possibilities this offers. From producer to customer, throughout the entire chain the possibilities of information that can be given is almost endless. The total amount of benefits as a whole are able to revolutionize the food supply chain and the way organizations and consumers interact with products and information associated with those products.

On the limiting side, the main limiting factors can be categorised in *Costs/profitability*, *Responsibility* and *Execution/scalability.* These are the factors recognised by the interviewees as the hurdles to overcome in order to be able to successfully implement RFID-technology as a traceability tool in the food supply chain.

The Costs/profitability issue consists of the issue that the implementation of a different technology as traceability tool will inevitably ensue certain investments and the implementation of a new infrastructure itself would already be a significant investment. Besides infrastructure, the costs of tagging each product with RFID tags, which are as of now of a higher cost than regular barcodes, influences the profit margins on products. The complications here lie mostly on products with small profit margins and often low prices.

The Responsibility limiter is shown mostly in the discussion of who should take the first step and how organizations would share the responsibilities, and benefits, amongst each other. One actor will have to take the first step in order for this process to be able to start, but this would also mean one actor would have to take the risk.

The Execution/scalability limitations lie in the fact that changing the entire supply chain is a costly and complicated endeavour, and with the efficient and optimised state of the food supply chain this would mean the investment would be large. Furthermore, the technology can only by used optimally when every product is tagged and every process is integrated – which leads to scalability issues on itself.

All in all, in order to answer the research question, a synthesised theoretical model (figure 6) has been created as the result of the interviews in combination with the preliminary theoretical model. This model provides an overview of the different influencing factors and subfactors on RFID implementation, as well as the limiting factors. The new factors revealed from the interviews have been marked in yellow:

5.2 Theoretical implications

The results build on and support the existing research of different drivers of RFID-technology as a Traceability tool in the food supply chain. The Market-, Organizational- (Aung & Chang, 2014, pp. 3, 4; Behnke & Janssen, 2020, pp. 2, 3; Bosona & Gebresenbet, 2013, p. 6; Hastig & Sodhi, 2020, p. 7) and Product/technology-levels (Aung & Chang, 2014, p. 11; Bibi et al., 2017, pp. 6, 11; Cuinas et al., 2014, p. 4) remain the same, but the underlying categories have been extended with new perspectives that add to the integrated view of factors influencing RFID-implementation. This leads to the following three contributions to theory.

The first contribution is that these results indicate that consumers and larger entities overarching industries, such as governments, play a large role in influencing the implementation of improved Traceability in the food supply chain, as sustainability goals might have to be enforced by external priorities. Aligning with Aung and Chang (2014, p. 11), both consumer demand and government regulations have to converge in order to create Traceability 'From Farm to Fork', increasing the visibility throughout the Food Supply Chain.

The second contribution to be drawn from the results, and one in which previous research was lacking (Chanchaichujit et al., 2020, p. 17), is the notion that the drivers and enablers of RFID-technology have to be looked at as a collective approach. The implementation responsibility, and mainly the costs associated with implementation, should not lie with one actor in the chain, as the benefits would not be sufficient. The next step in RFID-based Traceability can be achieved when all of the actors collaborate on better information sharing, since that would help in achieving complete traceability, as mentioned by Manzini and Accorsi (2013, p. 11), and dividing the costs of a new innovation that has the potential to revolutionize the food supply chain.

Lastly, the third contribution is the recognition of three new factors influencing RFID-implementation that were not mentioned in the earlier research of Bosona and Gebresenbet (2013, p. 6), Aung and Chang (2014, pp. 3, 4), Behnke and Janssen (2020, pp. 2, 3) and Hastig and Sodhi (2020, p. 7) on which the theoretical model was built. Privacy issues, the Store of the Future and Alternative Technologies

are all factors that resulted from the interviews and that play a role in the adoption of RFID-technology as a Traceability-tool.

5.3 Practical implications

The results showed three main categories of limiting factors influencing the implementation of RFID-technology in the food supply chain. Even though benefits are clear, these limiting factors have slowed the implementation and even testing of the technology as a Traceability tool. The three main limiting factors, being *Costs/profitability*¸ *Responsibility* and *Execution/scalability* should all three be solved for in order for organizations to be able to implement RFID. Since the real benefits are not gained until the entire process, products and actors are integrated, the technology has to be tested on smaller samples that will be able to uncover most of the benefits already. This could then scaled. The data shows that this is the most difficult part, since someone has to take the first step and take on the responsibility to start this process.

First, when testing RFID-technology, it is clear from the data that the tagging process should start as early in the supply chain as possible, as the importance of 'source-tagging' products, where traceability and information exchange starts at the beginning of the chain, is mentioned as an important step ensuring every actor along the chain is able to reap the benefits. This would add to the sharing of the benefits, costs and responsibility between more actors within the supply chain as this would ensure most of the benefits to be apparent for most of the actors. Therefore, supply chains or part of supply chains that are mostly in control of one organization should be chosen to implement RFID-technology in first, as this would enable a more integrated testing environment that could best resemble the entire food supply chain.

Secondly, RFID-technology should also be looked at as more than just a Traceability tool, since the applications are larger and more extended and the potential benefits can be found in many more areas than just the tracking and tracing of products. The total amount of benefits as a whole are able to revolutionize the food supply chain and the way organizations and consumers interact with products and information associated with those products. By working out an overview of all of the potential applications, the benefits of increased information exchange possibilities can show the cost-effectiveness of such a Traceability tool, even with the high investment costs.

Lastly, when selecting where to start, organizations should look towards products with higher price margins and higher shrinkage costs, as products with higher margins can more safely increase the initial production costs due to their relative price in comparison to the price of a RFID-tag. Also, products with high shrinkage cost, such as many perishable foods such as fresh meats, fish, dairy and fruits/vegetables, or relatively expensive products such as alcohol, medicine or other Non-Food items, can gain the most cost-benefits from a better and more visibly Traceability tool since the costs associated with shrinkage can be diminished.

5.4 Limitations and future research

The biggest limitation of this research is the relatively small sample of interviewee's, with a total of 9 persons who were interviewed. Also, most interviewee's were employed by the same, and the largest, food retail organization in The Netherlands. As the market leader, it could be expected that openness to innovations and operational improvements would be viewed as more positive.

Also, there were no interviewees employed by the first steps of the food supply chain, i.e. producers, processors or transporters. These links in the chain could have a different viewpoint on certain items in the research.

Lastly, with all of the interviewees residing in The Netherlands, different countries, cultures or industries might react differently than has been done here.

Therefore, for future research it would be my recommendation to broaden the research to different countries and organizations first, as well as reaching out to actors earlier in the food supply chain to find out how these supply chain actors' perspective on RFID-technology as a traceability tool changes through the food supply chain.

Also, a more in-depth research of industries such as the fashion retail, where RFID-technology is already widely used as a traceability and shrinkage-controlling tool, could provide better insights in what is necessary before such a technology can be implemented, and how this would relate to different kinds of products. Also, best practices in testing the technology could be researched.

6. APPENDIX

Appendix A: Literature review Approach

Keywords	Initial hits	Automatically filtered on:				Used articles	Search key
		Years (hits)	Categories (hits)	Document types (hits)	Sorted on:		
"Food Supply Chain Stakeholders" (topic)	629	2017 – 2021 (373)	Business, Management, Operations Research Management Science, Food Science Technology, Environmental Sciences (205)	Article (161)	Times Cited (by highest)	4	TOPIC: (food supply chain stakeholders) Refined by: PUBLICATION YEARS: (2021 OR 2020 OR 2019 OR 2018 OR 2017) AND WEB OF SCIENCE CATEGORIES: (ENVIRONMENTAL SCIENCES

							OR FOOD SCIENCE TECHNOLOGY OR MANAGEMENT OR BUSINESS OR OPERATIONS RESEARCH MANAGEMENT SCIENCE) AND DOCUMENT TYPES: (ARTICLE)
“Food Supply Chain Sustainability” (topic)	1524	2017 – 2021 (1029)	Business, Management, Operations Research Management Science,	Article (567)	Times Cited (by highest)	3	TOPIC: (food supply chain sustainability) Refined by: PUBLICATION YEARS: (2021 OR 2020 OR

			Food Science Technology, Environmental Sciences (680)				2019 OR 2018 OR 2017) AND WEB OF SCIENCE CATEGORIES: (ENVIRONMENTAL SCIENCES OR MANAGEMENT OR FOOD SCIENCE TECHNOLOGY OR OPERATIONS RESEARCH MANAGEMENT SCIENCE OR BUSINESS) AND DOCUMEN

							T TYPES: (ARTICLE)
“Food Supply Chain Traceability” (topic)	809	2011 – 2021 (677)	Business, Management, Operations Research Management Science, Food Science Technology, Environmental Sciences (381)	Article (277)	Times Cited (by highest)	7	TOPIC: (food supply chain traceability) Refined by: PUBLICATION YEARS: (2021 OR 2015 OR 2020 OR 2014 OR 2019 OR 2013 OR 2018 OR 2012 OR 2017 OR 2011 OR 2016) AND WEB OF SCIENCE CATEGORIES: (FOOD SCIENCE TECHNOLOGY OR

							MANAGEMENT OR OPERATIONS RESEARCH MANAGEMENT SCIENCE OR ENVIRONMENTAL SCIENCES OR BUSINESS) AND DOCUMENT TYPES: (ARTICLE)

Appendix B: Interview protocol

1) Opening
- Introduction of researcher.
- Thank interviewee's time for the interview.
- Ask for permission to record the interview (explain confidentiality).
- Explain the purpose and objective of the research and interview.

2) Interviewee
- Job description/responsibilities.
- Field of work.
- (Potentially: Country of operation.)

First part: In depth questions, related to model/RQ's

1) What is your knowledge on RFID-technology?
    a. What are the biggest advantages of RFID-technology?
    b. What are the biggest (current) limitations of RFID-technology?

2) When would RFID-technology be an appropriate fit for traceability in the Food Supply Chain?
    a. Possibly: Differences between products/production processes?
    b. Possibly: Differences between industries?
    c. Possibly: How do market-level developments influence the adoption of (RFID-technology for) traceability purposes?
    d. Possibly: What are organizational drivers of improving traceability in the Food Supply Chain?
    e. Possibly: What other factors/dimensions not mentioned could influence?

3) What type of products or supply chains would be the most interesting to start with?
    a. Possibly: Where in the Supply Chain would be the best place to attach the RFID-labels?

4) Could you rank a top 3 of factors influencing RFID-technology adoption?
    a. Possibly: in terms of the impact they have on implementation?
    b. Possibly: in terms of the ease of changing/influencing them?
5) Closing
6) Is there anything we discussed that you would like to clarify or discuss some more?
7) Would you wish to be informed on the results afterwards?
8) Thank interviewee's for their time.

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