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M.Sc. Management of Technology Thesis
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Imagineering use of augmented reality in food supply chains: A study of Cargill's food safety and quality processes

Imagineering use of augmented reality in food supply chains
A study of Cargill's food safety and quality processes

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Table of Contents

List of Figures

List of Tables

Summary

> *"Imagineering is letting your imagination soar, and then engineering it down to earth." (Alcoa Aluminum, 1942)*

The fourth industrial revolution is focused on integrating technologies into the production environment that can increase revenue and optimize production. As the lines between the physical and digital worlds are blurring with the introduction of new technologies, companies have to be open to digital transformations and employ new management approaches. Industry 4.0 has also shown to be a great opportunity for the progress of the food sector. With growing concerns of food safety and food security internationally, organizations need to invest in technological developments that can enable higher efficiency rates, lowered production costs, and seek competitive advantage by generating products of greater added value. Augmented reality smart glasses, a technology that is worn like normal glasses but overlays the user's view with virtual information is one such technology within Industry 4.0 that can transform the internal processes of a business.

Cargill is a multinational corporation operating in the areas of food, agriculture, financial, and industrial products, that started exploring the usage of augmented reality smart glasses in the early stages of the COVID-19 pandemic. Since non-essential employees were confined to work from home and were not able to travel freely, certain business processes in the manufacturing environment that required on-site visits such as food auditing almost came to a halt. During these dire times, Cargill explored the solution of AR smart glasses for conducting remote food audits. The expert from a remote location would join a video call and the Manager on site would wear the smart glasses and tour the plant. However, this device was limited to this use case only and the innovation team within Cargill Global IT was keen on expanding the applications of the novel technology. Additionally, they were looking for an implementation plan to adopt smart glasses in different use cases. Also, from literature, though the importance of digitalization was apparent for competitive advantage in the long run, the opportunities for digitalization in the food sector remained under-researched. Though smart glasses are considered to be a breakthrough solution for businesses and theoretically there are many applications for manufacturing industries, it is unclear where they can add value to the food supply chains. Besides, studies had not covered the possibilities

of digitalizing food safety and quality business processes using smart glasses. This leads to the main research question of this thesis for which use cases were imagineered: *How can augmented reality smart glasses be used to digitalize business processes in food supply chains and how can organizations be adequately resourced?*. Resources, according to Daft (1983), include all the assets, capabilities, organizational processes, firm attributes, information, or knowledge that are managed by a firm that enable them to draft and implement strategies that improve their efficiency and effectiveness.

An exploratory, qualitative research design was chosen because not much is known about how smart glasses could be used in food companies and this needs to be documented before quantitative data could be gathered. A technology roadmap was also chosen as the research framework, along with a case study at Cargill to make it easier for companies in the food sector to navigate through planning, strategizing, and adoption of Industry 4.0 technologies.

For answering the upcoming sub-research questions, a combination of literature review and case study interviews (including external parties) was conducted to collect information. While seeking answers to the *first research question*, it was identified that the functioning of smart glasses is rooted in three working principles: tracking, registration, and visualization. Several hardware and software components that are incorporated in the device decide what applications it can be used for. This has been well illustrated in figure A-5. The pattern of development and diffusion used to analyze the level of adoption and maturity of smart glasses indicated that the technology is still in the adaptation phase. This is because of the technological, organizational, and ergonomic challenges it faces. But even though such challenges exist, there are also value drivers of smart glasses that make these devices desirable for the business-to-business (B2B) markets. These include the ability of smart glasses to make information accessible by overlaying it on the real world of the user, provide hands-free assistance and flexibility, and foster collaboration between employees that are pushing it to the market. In industries, it is mainly used for business activities such as prototyping, training of employees, production operations, and inspection and maintenance. Nevertheless, in B2B markets, some of the challenges faced by the device like issues with regulatory compliance and safety of the end-user seem to be more influential when purchase decisions are made. Analyzing the technology using Gartner's hype cycle revealed that augmented reality as a discipline might be in the trough of disillusionment phase. This means that the technology would pick up pace in the upcoming years and the future is promising. Complementary technologies and disciplines like 5G, AR Cloud, and interoperability could solve a few of the challenges faced by smart glasses.

Before imagineering use cases for smart glasses in the food industry, it was imperative to gain an understanding of food safety and quality processes. While food safety processes are mandatory and are in place to produce food free of harmful contaminants, food quality processes are requested specifically by the customers of food companies for certain factor enhancements, like color or textures. Food safety processes might follow the HACCP framework that assists manufacturers to control the safety of their products by constituting pre-requisite programs and operational pre-requisite programs. These programs are aimed at monitoring and controlling safety parameters along the production lines. Similar programs can also be put in place to monitor and control quality. To uphold food safety and quality, auditing is performed regularly by manufacturers, their suppliers, and customers (second-party audits), or hired third-party companies. These pre-requisite programs and operational pre-requisite programs, along with auditing processes that are in place at Cargill within the edible oils supply chain was closely studied to identify possibilities for digitalization.

Seven business processes that can be digitalized using smart glasses, referred to as use cases were imagineered, comprising of workflow sign-off, quality and safety checks in labs, remote assistance, instructional training, on-site inspection, and on-site and remote auditing. A list of associated process-related benefits and risks was discussed. Based on the business value that each use case might add and implementation complexity supplemented by a few assumptions, a value complexity matrix was created to categorize the use cases.

Organizations might have to arrange for or manage their resources to implement the use cases. Moreover, companies would seek to gain a sustainable competitive advantage, which can be achieved with the combination of tangible and intangible resources. Resources, competencies, and capabilities such as talent and training, standard operating procedures, technology infrastructure, communities of practice/centers of excellence, and technology governance teams would be required.

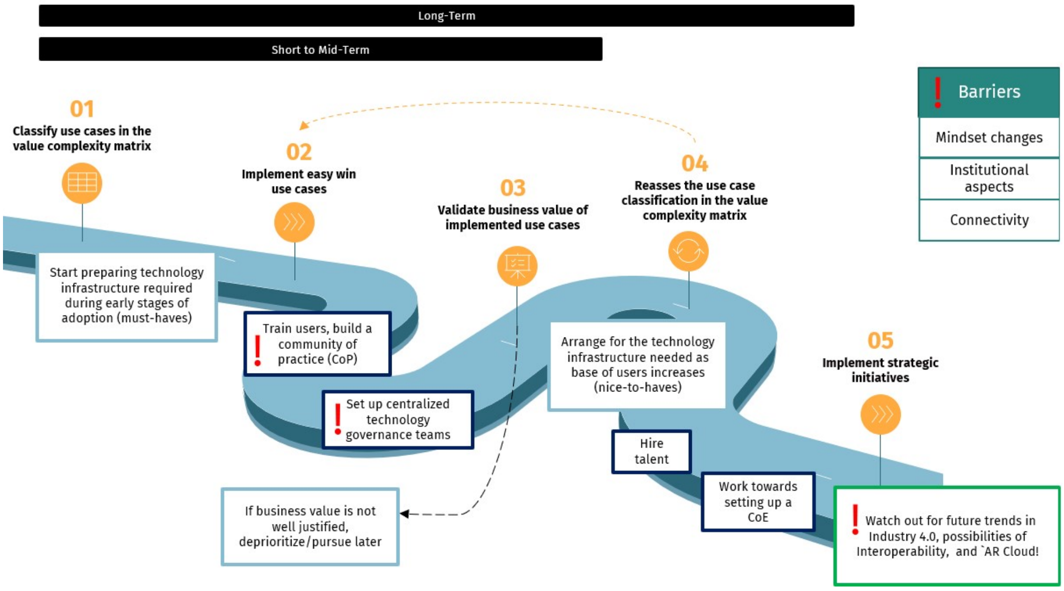

Figure 1: Implementation plan for food organizations to adopt smart glasses

Finally, the value complexity matrix was used to draft an implementation plan for organizations in the food sector that are seeking to adopt smart glasses. Additionally, resources, competencies, and capabilities identified during the literature review and case study to adopt the device were incorporated in the implementation plan. At different stages along the implementation plan, the main barriers to B2B adoption of smart glasses which include mindset changes, institutional aspects, and connectivity could be addressed. This is illustrated in 1.

As with any research, this thesis has certain boundary conditions within which the findings may hold valid, and what could not be taken into consideration during the study was addressed in limitations. Four limitations for this thesis were listed. Subsequently, future recommendations include suggestions for future research that stems from the limitations of the thesis and learning during the study.

Acknowledgements

Writing this thesis has been an extremely fulfilling process, like giving birth to my brainchild. This experience has been like no other, with its own set of ups and downs. On a few occasions, I felt on top of the world, and on other days, I would have dramatically reached a superficial rock bottom. I would like to thank a few individuals who have consistently been a part of my emotional roller-coaster journey, on both good days and bad.

I would like to thank my first supervisor and professor, Ir. Marcel Ludema for introducing me to the opportunity at Cargill and motivating me to achieve more. Your support during the times of the pandemic has helped me finish my research work. I would also like to extend my gratitude to my professor and Dr. Ir. Marijn Janssen for being very responsive and providing valuable feedback at crucial stages of the graduation process. I would like to thank the folks at VR Zone, TU Delft who readily agreed to be interviewed and shared their knowledge on augmented reality devices.

Moving on, a huge thank you to Anthi and David at Cargill for selecting me to perform my graduation project at Cargill. It was a pleasure to work with someone like Anthi who has been through a similar experience and was aware of the expectations. I would like to offer the biggest chunk of acknowledgment to Juul. Thank you so much for being there every step along the way. Honestly, it was amazing to have you as my mentor. Thank you for guiding me based on your experience and simultaneously giving me the freedom to write my own story. You have been extremely inspiring, available to discuss at all times, and honest with feedback. If I would ever get an opportunity to be a mentor, I would aspire to embody the qualities you have! Not to forget, thank you Claudiu for ensuring that I was on track, helping me set deadlines, plan, and overall be prepared!

My professional experience at the organization of Cargill was comforting and rewarding, thank you to everyone at the innovation team for making me feel like I belonged and other employees who participated in the interviews that successfully bought this thesis to fruition.

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Chapter 1

Introduction

1-1 Digitalization of industries

The transformation of operations, functions, models, processes or activities by leveraging the merits of digital technologies is referred to as digitalization. Digitalization is an enabler of new business models and one of the strong drivers of innovation. Industry 4.0 has been kick-started by the potential of digitalization and the Internet, with their abilities to transform production methods in manufacturing industries (Gürdür, El-khoury, & Törngren, 2019). The nine technological drivers or pillars of Industry 4.0 that led to the emergence of Industry 4.0 include big data and analytics, autonomous robots, simulation, horizontal and vertical integration, cybersecurity, industrial internet of things (IIOT), augmented reality, the cloud, and additive manufacturing (Noor Hasnan & Yusoff, 2018).

The term Industry 4.0 was first discussed at the 2011 Hannover Trade Fair in Germany as the revolution headed towards automation and data exchanges in technologies (Kagermann, Wahlster, & Helbig, 2013; Lasi, Fettke, Kemper, Feld, & Hoffmann, 2014). Some of the main principles of Industry 4.0 include interoperability, virtualization, decentralization, real-time capability, service orientation, and modularity. Sensors, machines, workpieces, and IT systems are linked together along the value chain beyond a single organization. The connected systems are referred to as cyber-physical systems that are capable of conducting data analysis to forecast failure, configure themselves, and align to changes by communicating with each other using standard Internet-based protocols (Rüßmann et al., 2015). The food and beverage sector is known to have high levels of product variants and strict requirements for food safety and face constant shift of regulations. The embracement of Industry 4.0 technologies in this industry is therefore, expected to be as progressive as in the automobile, aerospace, and semiconductor industries (Noor Hasnan & Yusoff, 2018).

The coronavirus pandemic is also changing the way manufacturing operations are conducted. The health and safety of employees is at the forefront, while food manufacturing environments need to strictly follow social distancing guidelines. The food organizations are facing difficulties due to changing consumer demands and habits, supply chain and logistics costs, and lapses in existing food systems to name a few (Jawed, Tareen, Cauhan, & Nayeem, 2020). Despite this, it is imperative that manufacturers orchestrate and sustain digital transformations to be able to face the long-lasting changes that would be introduced in the operating environment post the pandemic (de Boer, Fritzen, Khanam, & Lefort, 2020). Augmented reality technology has shown the value of remote participation and could serve as a tool in bridging gaps in space and expertise by providing and collecting visual information from a user's point of view (Parker & Hitchcock, 2020).

An influential thinker on management strategies and competitiveness, Michael E. Porter along with his colleague, discuss the potential of smart connected products (SCPs) to transform how we learn, make decisions, and interact with the physical world. Since there is a fundamental disconnect between the wealth of digital data available to us and the physical world in which we apply it, technologies like augmented reality that bridge the gulf between real and physical worlds and provide us with the ability to take advantage of the torrent of information and insights produced will change the way enterprises manage their value chains and how they compete. The pioneering organizations implementing it despite facing a few challenges have observed a major impact on quality and productivity as it improves the ability to rapidly and accurately absorb information, make decisions, and complete required tasks efficiently. This era of digital revolution is increasing productivity and value across the economy with access to explosion of data from SCPs. However, the challenge to tackle is not that of lack of data and information, but how can organizations assimilate and act on them and build an interface with humans for which AR seems to be a solution (Porter & Heppelmann, 2017).

All in all, digital transformations are said to add resilience and flexibility to operations and once the crisis comes to an end, it would be easier for organizations that underwent such transformations to ramp up production and gain a significant advantage over their competitors. They need to realize where technologies add value in their operations and supply chains, what they need to be equipped with, and how they visualize this journey. For the food industry, innovations are key for an organization to retain its competitiveness in a challenging and evolving landscape where overall demand is high and consumer behaviours are changing but the safety and security of food supply cannot be compromised upon (Parker & Hitchcock, 2020).

1-2 Company context

Cargill is a multinational organization that provides food, agriculture, financial, and industrial products and services to the world. Started in 1865 by William Wallace Cargill in Conover, Iowa as a small grain storage business, Cargill now maintains a global presence as over the years, the company has provided faster market access to farmers' grains, served customers globally with the help of TRADAX, increased consumer satisfaction by delivering products using innovative transport, helped farmers market and sell specialty wheat and increase their profits, and completed an acquisition of with Provimi to enhance their presence in the animal nutrition industry. Operating on core values of doing the right thing, putting people first, and reaching higher, the global international team employs over 160000 people across 70 countries who work in the functions of agriculture, animal nutrition, beauty, bioindustrial, food and beverage, food service, industrial, carbon solutions, meat and poultry, pharmaceutical, risk management, trade and capital markets, and transportation and logistics. The key activities include:

Elaborating on the key activities of the company, Cargill helps farmers optimize yields, store crops and access the best market and efficiently manage risk and stabilize pricing for farmers and corporate customers. They actively develop food ingredients that promote health and formulate better tasting recipes for restaurants and packaged foods. Their international presence allows them to create supply chains and ship products to more than 6000 ports worldwide. With over 150 years of experience, together with farmers, customers, governments, and communities, Cargill helps people thrive by applying their insights and are committed to feeding the world in a responsible way, reducing environmental impact, and improving communities where people live and work.

This thesis will be facilitated with guidance majorly from the Global IT function of Cargill. Within Global IT, this work was carried out with the help of the innovation team. The innovation team consists of a group of enthusiastic Cargill employees and graduate trainees who devote a bunch of their time ideating, prototyping, and testing radical technologies in different business processes. One such initiative involves identifying and testing augmented reality for applications within the business.

1-3 Relevance

1-3-1 Academic

Though there are promising applications for augmented reality, conventionally, digitalization in the food industries seems to be under-researched. The lack of studies addressing this topic prompts this research. The food sector is said to have lower research intensities and consequently, food companies also adopt technologies much slower (Demartini et al., 2018; Penco, Serravalle, Profumo, & Viassone, 2020). Research question one is directed at assisting food organizations get an idea of the technology, drivers, barriers, and future potential of the technology and drive adoption.

Rejeb, Keogh, Leong, and Treiblmaier (2021) state that the role of AR in enhancing food safety and quality could be a potential research application. Also, literature claims that the benefits of AR in the food industry have not been captured or comprehensively investigated and even in general, the impacts, opportunities, and risks of integration of smart glasses in industrial work processes needs to be explored (Hein & Rauschnabel, 2016; Feng & Mueller, 2019). Moreover, the embryonic nature of the technology in supply chains has called for increased academic attention and recognition (Rejeb, Rejeb, & Keogh, 2021). Based on the suggestions and claims, research questions two and three were framed to seek use cases for smart glasses to digitalize food safety and quality processes and information on the qualitative benefits and risks of digitalizing those processes.

Lastly, according to Akyazi, Goti, Oyarbide, Alberdi, and Bayon (2020), the food industry does not have a roadmap that can guide the sector through Industry 4.0. It also requires strategies for establishing the needs and meeting the current and future skill requirements. The chosen research framework of this thesis may act as a guide that can assist organizations in adopting augmented reality smart glasses, which is a key technology in the Industry 4.0

domain. Though it is a technology roadmap, several academic theories have been used. The resources, capabilities, and competencies that have been identified through research question four may establish not only the skill requirements but also other tangible and intangible resources needed.

1-3-2 Practical

Though in theory the use of augmented reality is shown to be promising, there are comparatively lesser use cases in practicality in the manufacturing industry, which implies that there is a gap between popularity in theory and practical use cases that are documented (Kohn & Harborth, 2018). The need for significant investigations in the area of digitalization of the food industry has been recognized in literature (Demartini et al., 2018). Research shows that the increased smartness of smart glasses would drive adoption in business to business (B2B) markets (Liao, Deschamps, Loures, & Ramos, 2017). At such a juncture, instead of losing hope over the challenges that may arise when AR is integrated in food supply chains, practitioners need to work hard to solve obstacles to maintain competitiveness and react to customers' safety and quality needs (Rejeb, Rejeb, & Keogh, 2021).

Undoubtedly, the ongoing pandemic of COVID-19 has affected food supply chains and in some cases, has sparked organizations' interest in digital tools could be used for complementing the verification of activities such as physical inspections. The hampering of abilities of food certification bodies to carry out onsite regulatory audits and issue certifications to supply chain actors due to the ongoing pandemic has exposed the industry to new challenges for monitoring food safety and delivery of safe food products to consumers (Shahbaz et al., 2020).

Traditionally, during the process of food auditing, food safety experts and auditors (both internally and external customers') were flying across the globe to different plants for conducting internal and external audits, if and when necessary. But due to strict travel restrictions during the pandemic, Cargill identified the possibility to conduct remote food audits using AR smart glasses. This also resulted in an observed reduction of travelling expenses of experts and auditors to plant sites for food audit visits. So far, they have trained users and conducted tests in plants (trial audits), raised awareness in Leadership teams (live demoed to IT Leadership), and participated actively in knowledge sharing with vendors.

However, it is not evident how such devices can be used beyond just the purpose of remote food audits. Cargill is vested in finding other applications for smart glasses in their supply chains. This leads to our thesis objective and questions.

1-4 Thesis objective

Cargill is seeking to unlock business value through the power of innovation and digitalization. Apart from focusing on adapting to fast-changing environments and growth, they are also in search of fresh, new innovations. With the advent of COVID-19, the need for such a technology has become more apparent. However, since the technology is still in its infancy, the organization is interested in weighing the potential impact of AR to their business processes which would also serve as the main research objective of this thesis. The sub thesis objectives are as follows:

- *To understand the technology of AR smart glasses:* Exploring the fundamentals of the technology, applying the pattern of development and diffusion to identify which phase the device is currently and what barriers and drivers exist to adoption, and how the future of the technology is going to look like with the help of the hype cycle needs to be covered. This information along with complementary factors that would influence the future of smart glasses is studied to prepare Cargill for adopting the technology and make choices between device alternatives.
- *To study the food safety and quality processes at Cargill:* A case study on Cargill's edible oils supply chain, food safety and quality processes within the edible oils production and packaging environment.
- *To imagineer use cases for augmented reality smart glasses:* Through workshops, interviews, and brainstorming sessions, possibilities for digitalizing the food safety and quality processes are to be found.
- *To investigate the repercussions of digitalizing select food safety and quality processes:* Examining the qualitative benefits and risks of digitalization of identified applications using AR smart glasses through interviews.
- *To find out what resources are required for digitalization:* Discovering the resources (both tangible and intangible) needed to ensure successful digitalization. Theory on resource based view provides a foundation for identifying the right resources that can help firms achieve sustained competitive advantage.
- *To devise an implementation roadmap:* After assessing the technology, developing use cases and studying the associated benefits and risks, and identifying the resources required to embrace the technology, an implementation roadmap for manufacturing organizations (especially food) can be created.

1-5 Research questions

This research is exploratory and qualitative in nature. In order to achieve the research objectives stated in the previous section, the following research questions are framed. The main research question guiding the thesis is **How can augmented reality smart glasses be used to digitalize business processes in food supply chains and how can organizations be adequately resourced [1]?** The sub-research questions are as follows:

- RQ1: How has the technology of augmented reality smart glasses evolved?
- RQ2: How can augmented reality smart glasses be used to digitalize food safety and quality processes along the supply chain?

[1] A firms resources can be defined as all assets, capabilities, organizational processes, firm attributes, information, knowledge, etc. controlled by a firm that enable the firm to conceive of and implement strategies that improve its efficiency and effectiveness (Daft, 1983)

- RQ3: What are the qualitative benefits and risks of using smart glasses to digitalize food safety and quality processes?
- RQ4: What resources[1] do companies need to digitalize food safety and quality processes when using augmented reality smart glasses?

The structure of this research is shown in Figure 1-1

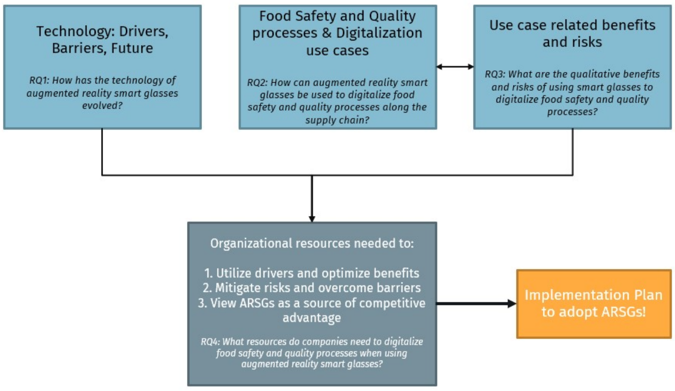


Figure 1-1: Research structure and associated research questions

1-6 Thesis outline

The outline of this thesis is illustrated in Figure 1-2. The teal colored boxes represent the research methodologies used whereas the orange colored boxes represent the chapters and expected outcomes.

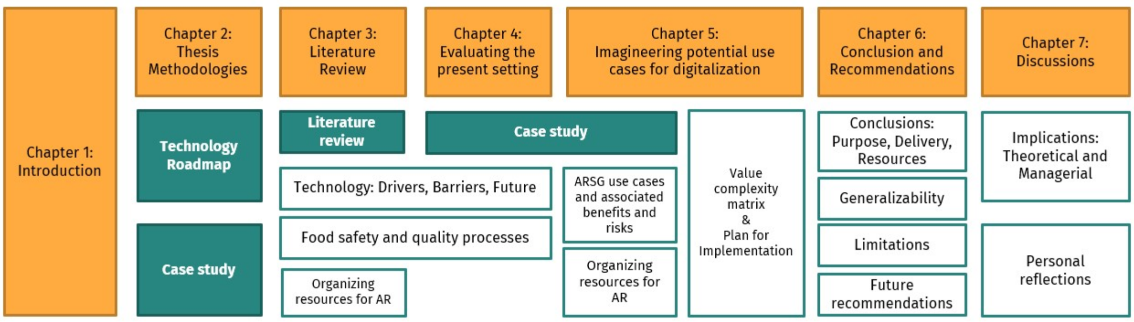


Figure 1-2: Outline of this thesis

Chapter 1 provides an introduction to the thesis, and the following **Chapter 2** introduces the research frameworks and methodologies used.

Chapter 3 is a literature review on the technology of augmented reality, the market adoption trends, food safety and quality processes that could be digitalized, and resources required for embracing augmented reality technologies. The first section will explore the working principles of augmented reality technologies, related hardware and software components, and the definition of augmented reality smart glasses chosen for this thesis. Market studies and literature that reported the barriers, drivers, and the future of the technology will also be discussed in the subsequent section. Following this, food safety and quality processes such as HACCP and quality management systems will be described in detail. These are the processes that could be potentially digitalized using smart glasses. Finally, the resources, competencies, and capabilities needed to adopt augmented reality smart glasses identified from the literature will be mentioned.

In **Chapter 4**, to validate and add on to the information collected through the literature review, a case study at Cargill will be conducted. It will consist of several interviews with internal employees and external stakeholders. The data for the case study was also collected from archival documents and records and direct observations. The present setting will include the views of interviewees on augmented reality smart glasses, associated value drivers and barriers to adoption, and what they perceive the future of the technology will look like. The responses received on this topic will be coded using *Atlas.ti* to highlight the significant drivers and barriers to B2B adoption. Next, information on the food safety and quality processes at Cargill that have opportunities for digitalization will be presented.

Chapter 5 discusses the imagineered use cases derived from the existing food safety and quality processes at Cargill. As a part of the case study, a set of employees at Cargill will be interviewed to elaborate upon the benefits and risks associated with the use cases and resources required to implement them and adopt augmented reality smart glasses. Finally, a value complexity matrix will be used to classify the use cases based on their business value and implementation complexity, and an implementation plan with the actions that need to be carried out to adopt smart glasses will be drafted.

The penultimate **Chapter 6** concludes the findings from the literature review and the case study at Cargill. The purpose, delivery of augmented reality smart glasses, and resources required will be established in the conclusion. The generalizability of the findings and limitations of this study is also reflected upon. Further, the recommendations section provides a list of future topics that can be researched.

The theoretical and managerial implications associated with this thesis are presented in **Chapter 7**. Lastly, The personal reflections section includes a brief description of my thesis journey and experience.

Chapter 2

Project Methodologies

2-1 Research design: Exploratory

Sekaran and Bougie (2016) argue that exploratory research designs could be chosen when not much is known about a particular phenomenon and relies on qualitative approaches to data gathering. The collection of data for such approaches include interviews and case studies which have been performed along with the use of academic literature, consulting reports, and Cargill documentation and records for this thesis.

As established by the content in subsection 1-3-1, an exploratory research is suitable for this thesis. There is not enough published and articulated information on how smart glasses could be used for digitalizing food safety and quality processes, what are the associated benefits and risks, and how can organizations plan to adopt this technology.

2-2 Project frameworks

2-2-1 Overall: Technology roadmap

The development of technology roadmaps dates back to the 1970s when American telecommunication organization Motorola and Corning used it to link strategic product and technology plans. Fast forward years later, this roadmap has been adopted and adapted by several organizations across sectors to support a range of strategic goals. A roadmap is essentially created to find answers to three questions considering a range of perspectives, markets, products, and technology which are as follows (Phaal, Farrukh, Mills, & Probert, 2003; Phaal, Farrukh, & Probert, 2005): (1) Where are we going? (2) Where are we now? (3) How can we get there?

The generalized structure of a roadmap is segregated into three layers (where sub-layers could be identified) which offers a generalized approach and makes this tool applicable to different situations (Phaal et al., 2003, 2005):

- The top layer of the roadmap is related to the organizational aspirations ('know-why'). In this layer, factors such as trends and drivers that would influence the purpose of the technology are taken into consideration. At firm level, this would include both the internal and external perspectives (market and business).

- The middle layer is focused on different ways through which the purpose could be achieved. Products, services, and operations that reflect the tangible 'know-how' are usually included in this layer at firm level. This layer of delivery is directly related to revenue generation.

- The bottom layer includes the resources and technologies that need to be arranged and integrated to develop the delivery mechanisms ('know-how').

This generalized framework was created by Phaal, Farrukh, and Probert (2004) after performing an applied research program for three years where more than 20 roadmaps were developed in cooperation with different company types in different industries. The paper by (Phaal et al., 2004) was chosen as the technology roadmap framework for this thesis and it currently has over 1500 citations. But it is known that a highly cited article does not mean it is of great value (seminal) because of the challenges that exist in citation analysis (University of Maryland Global Campus, 2021; Muppidi & Reddy, 2018). However, the contributions by Phaal et al. (2004) in laying the theoretical foundation for technology roadmapping is acknowledged to be important and valuable by researchers who conducted a literature overview on technology roadmapping between 1997 and 2011 and hence, was referred to when customizing a roadmap for augmented reality smart glasses (Carvalho, Fleury, & Lopes, 2013).

The **motivation** to choose this as the overall framework of the thesis was because it can help organizations structure their planning process, indicate gaps in strategic planning, and align future goals and the activities currently present in the organization. This way, they could determine and prioritize sustainable competitive advantage and rightly allocate the resources (technological and human) of the organization. Such a roadmap would be useful for organizations looking to adopt smart glasses in their business processes. Phaal (2011) compiled a list of technology roadmaps publicly accessible until 2011. Though there was a specific classification for industrial, business, and other organizational roadmaps, there was no mention of augmented reality or smart glasses roadmaps. Currently, a keyword search for 'smart glasses technology roadmap' yields no substantial results.

The technology roadmap was customized for this thesis, using tools and theories of academic and practical relevance to study the purpose, delivery, and resources. To determine the purpose or 'know-why', tools such as the pattern of development and diffusion by Ortt and Schoormans (2004) and Gartner's hype cycle were used. While the pattern of development diffusion helped us understand the competitors, drivers and barriers, the Gartner's hype cycle was imperative to learn about the environment, market, and trends. For delivery, a case study was performed at Cargill, within the Edible Oils Supply Chain and food safety and quality domain. Opportunities for augmented reality to digitalize food safety and quality processes ('know-what'), and the associated benefits and risks were identified. Finally, the 'know-how' resources such as competencies, knowledge, skills, organization and other specific resources required for smart glasses to develop delivery mechanisms was found. The resource based theory developed by Barney (1991) was used a theoretical foundation to describe what

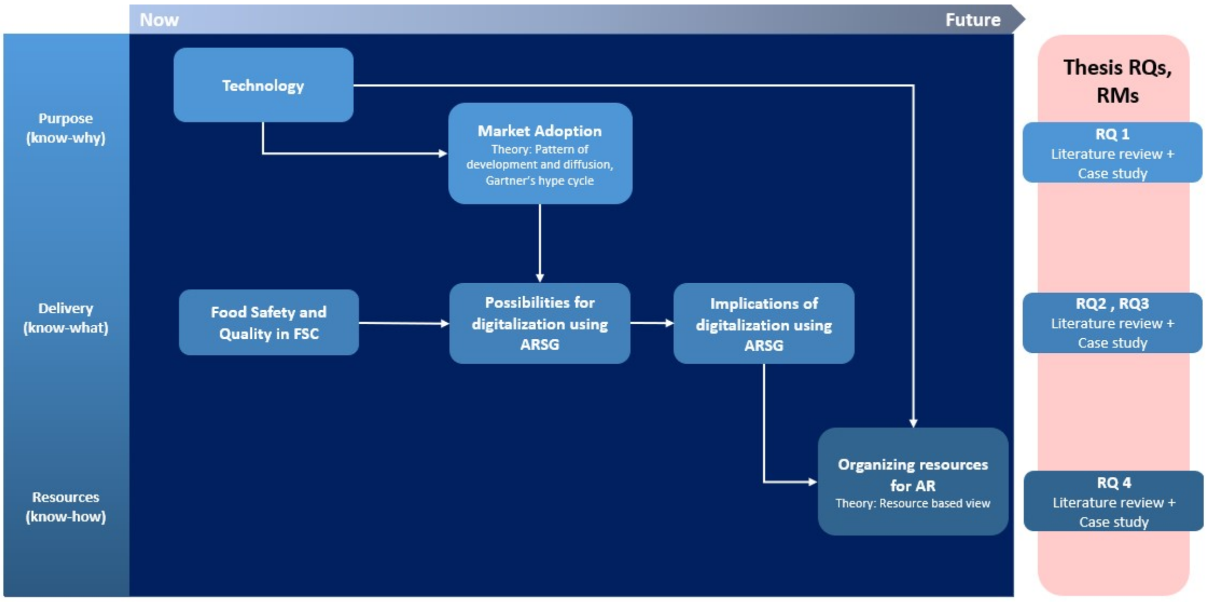


Figure 2-1: Customized research framework with academic theories for this thesis

constitutes as resources, how can firms leverage such resources, and what combination of resources could bring about sustained competitive advantage for the firm.

2-2-2 Case study

According to Yin (2018), a case study should be chosen as a research method if the form of the research question is how or why, if there is no required control over behavioral events, and the focus is on contemporary events.

This research method is considered apt for this study because: *(1) it focuses on how questions (2) relevant behaviors cannot be manipulated as food safety and quality control processes still have to be conducted stringently (3) but there is also a desire to study contemporary events and is not focused on historical events as augmented reality smart glasses could possibly benefit their current ways of working.* To assist in designing the case study and generalizing the information obtained through case study interviews in conclusions, a literature review was done to understand existing theory. A single, embedded case study with multiple units of analysis was chosen as the design for the case study. The greater setting is the edible oil supply chain of Cargill, within which a particular area of Food, Safety, Quality, and Regulatory (FSQR) was chosen. The units of analyses (sub-units) were FSQR employees who worked in the refineries and packaging units of the organization. Embedded case studies are those that have more than one level of units of analysis where attention is given to more than one sub-unit (Yin, 2018). This was chosen because of the nested nature of this study within different levels of the organization, namely Global IT, Edible Oils, and Food Safety and Quality.

2-3 Research methods

2-3-1 Data collection methods

The data collection methods used in this study include: scientific articles and papers, consulting reports, interviews, and Cargill documentation and archival records.

Literature review

A broad literature review was conducted to determine and support the academic relevance established previously and develop an answer for the research questions. The papers were collected from several sources such as Google Scholar and Scopus, and books from the TU Delft Library.

For the *first research question*, literature on augmented reality technologies were studied to get a grasp on the concepts, fundamentals, principles that govern the functioning augmented reality technologies. A definition for what devices would constitute as augmented reality smart glasses, and how is augmented reality different from other mixed realities was made. Keywords such as 'augmented reality', 'augmented reality smart glasses', 'augmented reality technology', 'smart glasses' were used. Further, to understand the market characteristics, reports and articles that reported the challenges, advantages, B2B markets and future of augmented reality smart glasses were read, along with papers on the theory of S-curve and diffusion, pattern of development and diffusion, and hype cycle technology. Many articles that stated such information were also application oriented in the industries of manufacturing and food, and fields such as supply chains. Keywords used in this phase include 'Diffusion of technologies', 'S-curve diffusion', 'pattern of development and diffusion', 'augmented reality smart glasses applications', 'AR (smart glasses) in industries', 'AR (smart glasses) in manufacturing industries', 'AR (smart glasses) applications in food industries', 'consumer behavior in B2B markets', 'drivers/advantages of AR (smart glasses)', 'challenges/disadvantages of AR (smart glasses)', 'trends in AR (smart glasses) market', 'future of AR (smart glasses)', and 'gartners hype cycle'.

Partially seeking answers to *research question two*, information on food safety and quality standards, with a focus on HACCP, and food safety auditing were reviewed to gain theoretical understanding of concepts. Keywords that were used include 'food safety programs', 'food safety and quality', 'food auditing', 'food safety auditing', 'food quality programs', 'food safety processes', and 'food quality processes'.Answers to how the current food safety and quality processes can be improved which is a part of *research question two research question three* was not available in literature and was answered in the case study.

For *research question four*, an insight on the resources required to make the delivery of the device in the chosen use cases a success was required. To guide this, the resource based view theory was studied to identify how resources are defined, categorized, and how firms can utilize them to sustain their competitive advantage. Keywords used in this stage are as follows: 'resource based view' and 'resource based view of firm'. Lastly, articles and reports were studied to suggest organizations to adopt augmented reality technologies and discover relevant resources required.

Case study

To answer the research questions, a case study was conducted at Cargill. Since case study research is not limited to a single source of data, there is a combination of multiple sources of evidence. Data sources for this research include archival documents and records, direct observations, and a mix of semi-structured and unstructured interviews.

Interviews

Sekaran and Bougie (2016) define interviews as guided, purposeful conversations among people which is also widely used as a method for collecting data in business research to obtain information on issues of interest. For *research questions one, two, and four*, the interviews were semi-structured. Since an outline of what sort of responses were expected was known in advance through the literature review for these questions, this method of interviewing was chosen (Sekaran & Bougie, 2016). Based on the literature review, a set of default questions were asked. Participants that were selected for interviews were either a part of the organization Cargill, TU Delft, or external universities. Participants within the organization of Cargill were chosen through the method of snowballing, where the existing participants recommended and recruited their acquaintances who could assist in providing answers to the research questions (Ghaljaie, Naderifar, & Goli, 2017). Participants were also chosen through purposive judgement sampling to enhance the findings. Sekaran and Bougie (2016) define purposive judgement sampling as a non-probability sampling method where participants chosen are in the best position to provide relevant information and are advantageously placed in such a position.

Unstructured interviews were also conducted to find answers for *research question three* because it was exploratory in nature. According to Sekaran and Bougie (2016), in unstructured interviews, interviewers do not have a planned sequence of questions to ask of the respondents during the setting. They further state that a primary objective of such an interview is to bring to light preliminary issues to the surface so that researchers have an opportunity to perform a in-depth investigation later on factors of interest. This method was chosen because there was no prior available data on the use cases derived in this thesis and these use case related benefits and risks when smart glasses are incorporated.

The use cases were clearly explained to the participants and the floor was open to brainstorming the possible benefits and risks. Relevant follow-up questions were also posed if clarity was needed. These meetings were also recorded for which permissions were asked prior to the session and were transcribed to be analyzed and discussed. Also, the information that was obtained through this interview was later investigated in depth to see how benefits can be extracted and risks could be overcome. A purposive judgement sampling was done to choose employees within the organization as participants for these interviews (Sekaran & Bougie, 2016).

An interview guide (refer to A-2 under Appendix) was prepared in advance with a list of questions that were asked in logical order based on the role of the interviewee. In the beginning of every interview, a personal introduction was given along with the purpose of the interview. An introduction to the thesis was presented via a presentation. Questions were then posed to the participants and sometimes, questions that were not on record were also asked to gain a deeper understanding. These spontaneous questions were framed based on the responses of the participants. As the interviews proceeded, key points were jotted. Since most of the interviews happened online on Microsoft Teams due to COVID-19 restrictions, permissions were asked prior recording. There were also few probing tactics due to lag in responses and occasional connectivity issues (Sekaran & Bougie, 2016). These recordings were later reviewed and transcribed for analyzing and finding answers to the research questions. The empirical findings were also useful in validating what was found in literature.

2-3-2 Data evaluation

Qualitative data analysis

The interviews from all interviews were transcribed, but coding was done for data management and reduction for responses to the first research question only. Saldaña (2021) defines a code as follows:

"A code in qualitative inquiry is most often a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data."

A middle-ground approach was taken for coding where an initial list of codes were formed with the help of theory, and then the list evolved during analysis. In the first cycle of coding, a descriptive coding approach was used where the basic topic of a passage of qualitative data was summarized as a word or short phrase. The code represented what was talked about (Wolcott, 1994; Miles & Huberman, 1994; Saldaña, 2021). A set of 34 codes were created in the first cycle when surfing through interview transcripts. This is shown in the figure **A-2** in the appendix.

In the second cycle of coding, some data was recoded because a better word or phrase was found that could describe the text. Codes that were made in the first cycle also seemed conceptually similar or infrequent, so they were merged and dropped respectively, which is shown in Figure 2-2 (Lewins & Silver, 2007).

Category	Codes
Drivers	Information overlay
	Visual documentation and process tracking
	Contextualized information
	Flexibility in training and communication
	Engagement with employees
	Standardized workflows
	Immersion experience and depth perception
	Cost-effectiveness

Figure 2-2: Codes to determine drivers of ARSGs

The relationships between codes as mentioned in interviews were analyzed and established in this cycle. Additionally, a pattern coding approach was adopted to categorize certain codes around a common theme (Miles & Huberman, 1994). This was repeated for categorizing the sub-codes as well and is shown below in Figure 2-3.

Category	Codes	Sub-codes
Barriers	Technological	User interface
		Interactions
		Field of view
		Computation and performance
		Display technology
		Adjustment to darker or brighter than usual environments
		Audio issues due to noisy environment
		Connectivity
	Organizational	Privacy issues
		Safety
		Mindset changes
		Cost
	Ergonomic	Heavy on the head
		Visual discomfort
		Overall comfort and wearability

Figure 2-3: Codes to determine barriers of ARSGs

2-4 Research quality

Yin (2018) describes four tests and relevant tactics to judge the quality of the case study design. These tests include construct validity, internal validity, external validity, and reliability. The quality of the case study conducted for this thesis will be evaluated based on the tactics associated with each of these tests.

- *Construct validity:* Yin (2018) necessitates using multiple sources of evidence and maintaining a chain of evidence during data collection and having key informants review the case study report during composition stage as three tactics to ensure construct validity. This study uses multiple sources of evidence and a chain of evidence is maintained as the actions of the research are well explained. The key informants will also have an opportunity to review the report and comment on the findings. Furthermore, the literature review will aid in identifying the right constructs.

- *Internal and external validity:* A test for internal validity does not seem to be applicable for this study as it is not causal research. However, to strive for external validity, the research questions framed and theories that will be reviewed would be such that the findings can be generalizable beyond this study. This study aims for analytic generalization (Yin, 2018). Generalizability of findings is further addressed in 6-2.

- *Reliability:* Reliability is defined as consistency and repeatability of producing the case study's findings (Yin, 2018). This means if another researcher follows the same procedures and conducts this study again, they should be able to arrive at similar findings and conclusions. For this reason, all procedures that are going to be followed in this research will be documented and explicitly mentioned.

Chapter 3

Literature Review

3-1 Augmented reality

Augmented reality (AR) can be defined as the technology that superimposes digital, computer-generated information on the real environment to enhance user experience. For augmented reality, it is important to emphasize that the surrounding environment is real augmented with useful information. In comparison, virtual reality (VR) involves a completely digital or computer-created environment (Berryman, 2012). Milgram et al. (1995) developed a Reality-Virtuality Continuum that indicates a spectrum of mixed reality technologies that can lie between the real environment and virtual environment. Distinctively, augmented reality by definition is closer to the real environment whereas in virtual reality, users are completely immersed in a synthetic world without seeing the real world and therefore, this lies closer to the virtual environment side of the spectrum. This distinction is illustrated in Figure 3-1.

Figure 3-1: Milgram's reality-virtuality continuum. Reprinted from Milgram et al. (1995)

Alternate realities

- *Mixed reality*

  People often tend to interchangeably use the terms augmented reality or virtual reality with mixed reality. However, as indicated by Figure 3-1, mixed reality is a broader term that constitutes various technologies. Mixed reality technologies blend capabilities of AR and VR, bringing the physical and digital world together to create an environment where physical and digital objects coexist and interact in real time (Wigmore, 2019).

- *Virtual reality*

  In Virtual Reality (VR) systems, the users are fully immersed in a synthetic environment. VR systems have the ability to fool participants in believing that their interactions are real and for this purpose, systems do track the location and orientation to create a point of view, but are not grounded to specific locations. Users cannot see the real world around them and sense of immersion and presence are vital to virtual reality systems (Azuma, 1997; Craig, 2013). Examples of devices that are in the market include Oculus Rift and HTC Vive. Applications of virtual reality exists in the domains of health, exploration (tourism, travel, archaeology, digital museums, heritage projects), and presentation and entertainment (construction, engineering, security and planning, gaming, and other entertaining systems) (Berntsen, Palacios, & Herranz, 2016).

(a) Augmented Reality **(b)** Virtual Reality

Figure 3-2: View of user in different environments. Reprinted from Perillo (2017) and Oculus Blog (2021)

Functionality

Augmented reality is characterized by its ability to combine real and virtual objects, is interactive in real-time, and is registered in three dimensions. It can be applied on markers, faces, 3D objects, and flat surfaces (Azuma, 1997). An AR system must be able to determine the current state of the physical and virtual world, and then proceed to display the virtual world in registration with the real world such that the user senses these virtual world elements as part of their physical world. This process then repeats as the environment changes (Carmigniani & Furht, 2011).

Principles

The basic principles governing the functionalities of augmented reality systems that are depicted in Figure 3-3 can be described as follows:

- **Tracking**

  For tracking, an augmented reality system may use a type of computer vision named video tracking that usually comprises of two stages, tracking and reconstructing (vision-based) or just sensors (sensor-based), or a combination of both (hybrid). In sensor-based

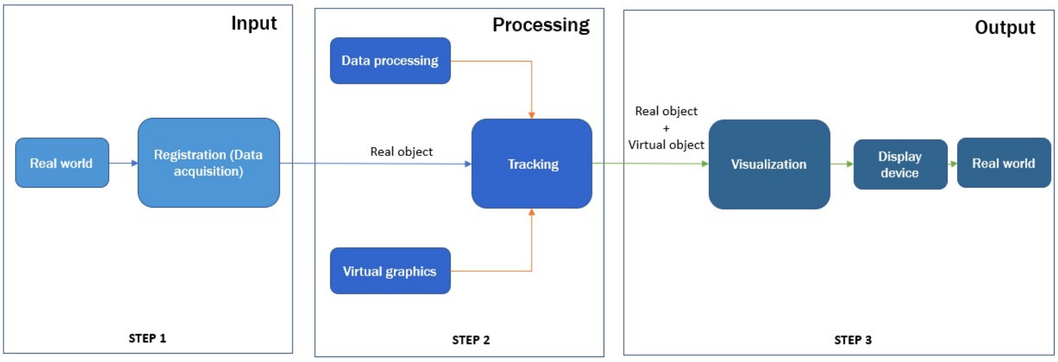


Figure 3-3: Working of an AR system. Adapted from Rodriguez (2020)

tracking, sensors are used to calculate the users' or devices' position relative to the real world exclusively using sensors. It does face a few challenges such as interference, shielding, and noise (Chatzopoulos, Bermejo, Huang, & Hui, 2017).

Vision-based tracking (computer vision) uses images captured by a camera to calculate users' or devices' position relative to the real world. The techniques by which this can be done are either marker-based or markerless-based techniques. Marker-based techniques utilize artificial markers such as references to calculate the camera pose, similar to QR codes (Carmigniani & Furht, 2011; Craig, 2013).

If the physical features of the object have to be used to calculate the camera pose, they are referred to as markerless-based techniques. These can be classified as model-based (static model) or feature-based (dynamic model). Model-based tracking makes use of the CAD models or 2D templates of the tracked objects' features. Feature-based tracking identifies the connection between the 2D image features and their 3D world frame coordinates. If the AR system follows a feature-based tracking and the entire scene is not known beforehand, Simultaneous Localization and Mapping (SLAM) is used to map fiducial markers or 3D models relative positions. If the 3D geometry of the scene cannot be assumed, for example, if the AR device is mobile and is designed for an outdoor environment, the Structure from Motion (SfM) method which consists of two parts, feature point tracking, and camera parameter estimation is used for tracking. The challenge for a camera moving in an unfamiliar environment is to reconstruct the motion of the camera and structure of the scene using the image and sensor data sequences (Carmigniani & Furht, 2011).

- **Registration**

  Registration is defined as how well the virtual world aligns spatially with the real world. A tracking system creates the need to manage several coordinate systems that need to be reconciled with each other in order to ensure the right overlay of virtual objects on tracked physical objects. It is one of the most challenging aspects of augmented reality as this process needs to seamlessly meld the real and virtual world. The registration depends on the accuracy of the tracking system. Poses received from the tracking system are converted to the coordinate of the rendering application. This process is also necessary for aligning the rendering camera with respect to the tracked display. Few terms associated with this process also include latency and calibration. For precise registration, several components of smart glasses need to be calibrated. Latency is defined as the amount of time the virtual world lags behind when it should occur ideally. It is essential to note that there is no way to eliminate latency in AR systems as it is present in any system that involves processing or communication. One should analyze if the lag in the system is sufficient to render the AR system useless for that particular application (Schmalstieg & Höllerer, 2016; Craig, 2013).

- **Visualization**

  Once the AR device maps and localizes your surrounding and your position relative to the surrounding, or receives an input from a sensor, it activates the processing unit. Within the processing unit, the data received from the AR input is interpreted using different hardware and software resources. Based on the user input and the software that has been developed using tool kits for that particular application of AR technology, the corresponding virtual graphics to overlay on the physical world is readied. Finally, once the real and virtual graphics are congruent, the resulting output is displayed with the help of a display device (Berryman, 2012; Craig, 2013; Chatzopoulos et al., 2017).

Components

The different hardware and software resources (components) that perform tasks and contribute to the effective functioning of an AR system are listed below.

- **Software**
  - *Software involved in the application directly*

    The software involved in the application directly includes functional components such as environmental acquisition (sensors), sensor integration, application engine, and rendering software. These are often available bundled together in AR libraries (Eg.: ARToolKit, Vuforia, ARKit). Environmental acquisition software act as an interface between the sensors used to gather information about the real world and AR system. It helps if the system is able to gather information from the camera or audio information from the real world quickly (Craig, 2013).

    In the process of sensor integration, the signals from the sensors are processed and integrated to make them appropriate for the AR application, for example, the use of camera data to provide tracking information to the AR application. The information from the camera must be merged, ideally, with another sensor like GPS to indicate to the application where the camera must be. The combined signals from multiple sensors is useful in identifying the camera location and pose accurately and speedily (Craig, 2013).

    The core structure and framework for the AR application that participants interact with is the application engine. This engine is responsible for collecting inputs from the sensor integration elements and users and creating the information that will be provided to the renderer to create signals for the display device. This engine can also be taken care of by a computer game engine such as the Unity Development Tool or can be written from scratch using programming languages (Craig, 2013).

Finally, the rendering application is responsible for converting the information from the AR application into signals to drive the AR display. There are rendering software for graphics (visual output), sound (audio output), haptics (tactile and force output), and other sensory outputs (Craig, 2013).

- *Software used to create the AR application*
  Creating an AR application is similar to curating an media-intensive, interactive application. Tools such as software compilers, software development environments, and debuggers are used to develop AR applications (Craig, 2013).

- *Software used to create the content for AR application*
  Different software can be used by content creators to create and edit three dimensional graphics, two dimensional graphics and sound. Though there exist tools for fully curating multimedia content in one package, creators many times prefer to use tools built and optimized for creating one type of content (Craig, 2013).

- **Hardware**
  - *Input devices*
    Input devices such as sensors are used for data acquisition and to respond to stimuli from the environment. This would encompass different types such as optical (cameras, infrared), magnetic (compasses), inertial (accelerometer, gyroscope), and others like GPS, Wireless networks or Bluetooth (Craig, 2013).

  - *Output devices (Displays)*
    The types of displays used in augmented reality devices can be categorized into multimodal and visual displays. Multimodal displays utilize other sensory modalities such as olfactory, audio, and haptics to augment the real world with information. Since humans intrinsically experience the physical world in a multimodal way, AR displays supporting multiple augmentation modalities is reasonable. However, in this thesis, we will focusing on visual displays. Based on the distance of the visual display from the eye, they can be classified as near-eye (head-mounted, wearable), handheld display, stationary display, and projected display. Within visual displays, two important distinctions need to be made between optical see-through and video-see through displays and between bi(n)-ocular and monocular displays (Schmalstieg & Höllerer, 2016).

    Optical see-through combines optical elements (half silvered mirrors) that are half reflective and half transmissive, allowing sufficient light from the real world to pass through and projecting computer-generated on the mirror through a display component placed overhead, which creates a perception of the combined world. Video see-through devices first capture the reality through cameras and transfer this to a graphics processor real-time. The graphics processor combines the video image feed with the virtual content and displays it on the screen. While bi(n)ocular displays presents images to both the eyes, either the same image (biocular) or each eye gets a separate view (binocular) and monocular displays presents images only to one eye and there is a single for channel for viewing.

Head worn display devices are mounted on the head of the user or a helmet and the images of the real and virtual environment are added to the users' view of the world. Hand held displays employ sensors and computing devices with a device that the user can hold in their hands and video see through techniques that can overlay graphics on the real environment. Smartphones, tablet PCs, and personal digital assistants are examples of handheld portable display devices that are commercially available. Stationary displays are, as the name suggests, displays that do not move during typical use (fixed location) but people have to go to the display to use it. Graphical virtual information can also be directly projected on physical objects with the help of projectors, optical elements, holograms, radio frequency tags, and tracking elements, making augmentations co-planar with the surface onto which they project, completely dependant of user and integrated into the environment. This allows for users to collaborate with each other and scale up groups of users. This is known as Spatial Augmented Reality (SAR) and has interesting applications in museums, education in universities and labs and art communities (Bimber, Raskar, & Inami, 2007; Carmigniani & Furht, 2011; Craig, 2013).

- *Data processing and Storage (CPU's, GPU's)*
  For processing of images captured, an AR system needs to backed by powerful CPU and sufficient RAM storage (Carmigniani & Furht, 2011). A processor acts as the brain for the AR system by coordinating and analyzing sensor inputs, storing and retrieving data, carrying out the tasks of the AR application program, and generating the right signals to display (Craig, 2013).

3-1-1 Augmented reality smart glasses (ARSG)

Augmented Reality Smart Glass (ARSG) (e.g. *Microsoft* Hololens 2) is a type of wearable (head-mounted) augmented reality device drawing attention from academia and industry due to foreseeable opportunities for development. Technologies such as GPS, camera, microphones etc. are used to capture physical information, which is then digitally processed, and finally virtual information collected from the internet/memory device of the ARSG is used to augment the physical surrounding, accomplished mainly through location-, object-, facial-, and image-based recognition technologies. The virtual information is shown in a real-time display which is a transparent screen in front of a user's eye(s). Both the real and virtual world is now visible to the user's eye(s) through the display (optical see-through) (Ro, Brem, & Rauschnabel, 2018). Different hardware components of a basic prototype smart glasses are shown in the figure below. The applications for this specific technology will be identified in the thesis.

3-1-2 Alternatives (non-ARSG)

Augmented Reality Smart Glasses (ARSG) can be differentiated from a range of other products that lie in the same realm. Sometimes, terms used to describe ARSGs are often inter-

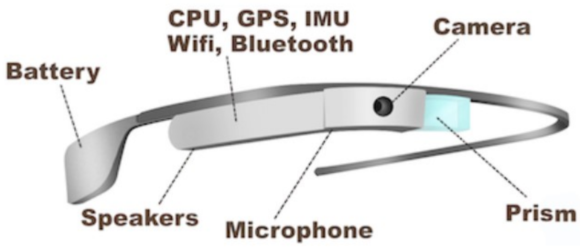


Figure 3-4: Hardware components of a smart glass. Reprinted from Al Delail and Yeun (2015)

changeably used. This section highlights the alternatives to ARSGs that are not the main focus of this thesis.

Assisted reality

Assisted reality are devices that are wearable and users can view the screen within their immediate field of vision, hands-free. It provides the right set of information and offers situational awareness to the user. They do differ from augmented reality as information is not overlaid with real world view. The experience offered by the technology is said to be reality first and digital second, which translates to allowing the user to have access to information, but without distractions or much hampering of vision (Realwear, 2021). Examples of such devices include RealWear HMT-1, represented in Figure 3-5.

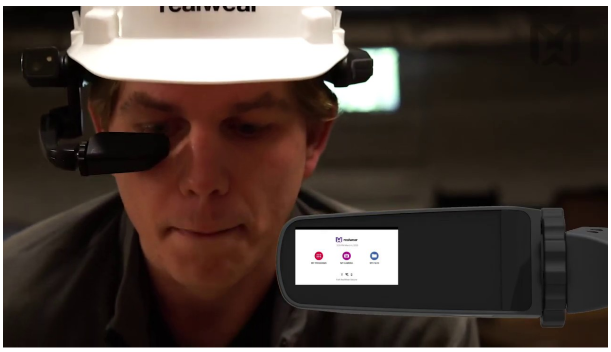
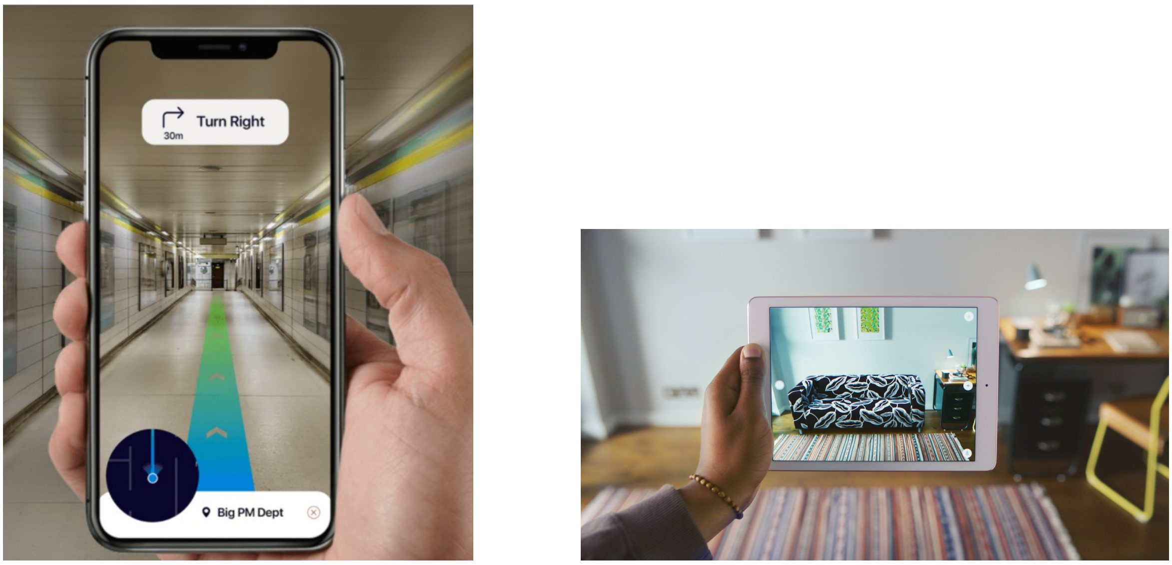


Figure 3-5: Assisted reality device. Reprinted from Realwear (2021)

Smartphones and tablets

From literature covered so far, based on the desired application of smartphones and tablets, they can serve as both assisted reality and augmented reality devices. If they are used as a means to just provide information to enhance the real environment, they would act as assisted reality devices. On the other hand, if software and hardware in the smartphones or tablets and the surroundings are designed to support information overlay, they would be categorized as augmented reality devices. A drawback when it comes to smartphones or tablets with respect to augmented or assisted reality devices is the fact that they are not hands-free and



(a) Smartphone

(b) Tablet

Figure 3-6: Augmented reality demonstrations on smartphones and tablets, for indoor navigation and furniture visualization applications, respetively. Reprinted from Makarov (2018) and Joseph (2017)

in some cases, not wearable. The output display of smartphones are also video see through, similar to assisted reality but different from augmented reality optical see through devices. **An extensively illustrated mindmap has been built to explain and understand augmented reality and can be found in the Appendix *(A-5)*.**

3-2 Market adoption

Diffusion of a technology refers to gradual adoption of an innovation in a market segment or society. A model that can be used to describe the diffusion of a technology over time based on the percent of adoption is the S-shaped diffusion curves. According to this model, a given innovation that enters the market initially has lower number of adopters that can be attributed to either complexity of knowledge underlying a new technology or lesser availability of complementary resources that enhance the value of the technology. This tool could be used as a prescriptive tool to guide organizations to understand if the technology is reaching its limits or to recognize new and upcoming technologies that can benefit the firms' performance. However, this model has been critiqued by authors. Christensen (1999) argues that S-curve as a prescriptive tool for managers is limited because it is rare that true limits of a technology are known in advance and there could be disagreement among firms on this issue. Additionally, the shape of S-curve is subject to change, especially if unexpected changes in the market, complementary technologies, or component technologies arise that could lead to shortening or extension of the life-cycle of the technology. Sometimes, new development approaches or reconstruction of the architecture design of the technology undertaken by organizations can influence and stretch the S-curve.

Also, according to Ortt and Schoormans (2004), early stages of a diffusion process are not well captured by the S-curve as it does not show the relevant developments just after the invention of a technology. It also does not provide information on the erratic patterns that are observed after introducing a breakthrough communication technology based product or service. To overcome the limitations of this model, they created a pattern of development and diffusion by observing how breakthrough communication technologies evolved and extending the S-curve to fit its evolution. Their study took into account the intricacies such as beginning and end, market actors and factors that play a role, and the average length of three distinguished phases, namely innovation, adaptation, and stabilization. Figure 3-7 illustrates these phases with respect to the percentage of adoption.

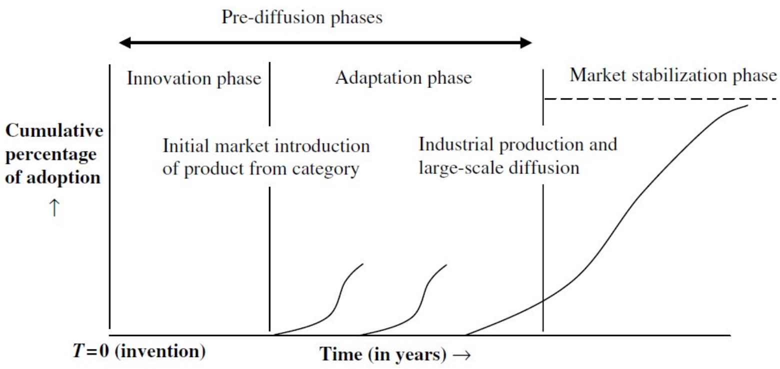


Figure 3-7: Pattern of development and diffusion of high-tech products. Reprinted from Ortt (2010)

The first time a technical principle of a category is demonstrated and mastered, it is defined as the invention of a high-tech product category. The technical principle is the functionality that enables the product category, especially the physical and chemical processes that is underlying the product category (Ortt & Schoormans, 2004; Ortt, 2010). The invention of smart glasses can considered to be when the augmented reality system was first demonstrated. Though in 1966, Ivan Sutherland invented the head mounted display, it was not until 1968 he created an augmented reality system using an optical see-through head mounted display. Following this, researchers at Boeing coined the term augmented reality when assisting the workers to assemble wires and cable for an aircraft in 1990 (Berryman, 2012).

Introduction of a product is the date on which it is available for sales or can be transferred to users. It is done so for testing and pilot studies for actual use (Ortt & Schoormans, 2004; Ortt, 2010). In 2011, a prototype for Google Glass was created by Google (GlobalData Thematic Research, 2020). Later that year, Epson introduces Moverio BT-100 to the public market in Japan (market introduction) (Toto, 2011). Currently, augmented reality smart glasses can be speculated to lie in the market adaptation phase. This is derived from the fact that:

- Several market introductions and re-introductions of multiple products for different applications has occurred. Organizations like Google relaunch iterative versions of their product catering to different markets and acquiring smaller companies like North (GlobalData Thematic Research, 2020; Etherington, 2020).

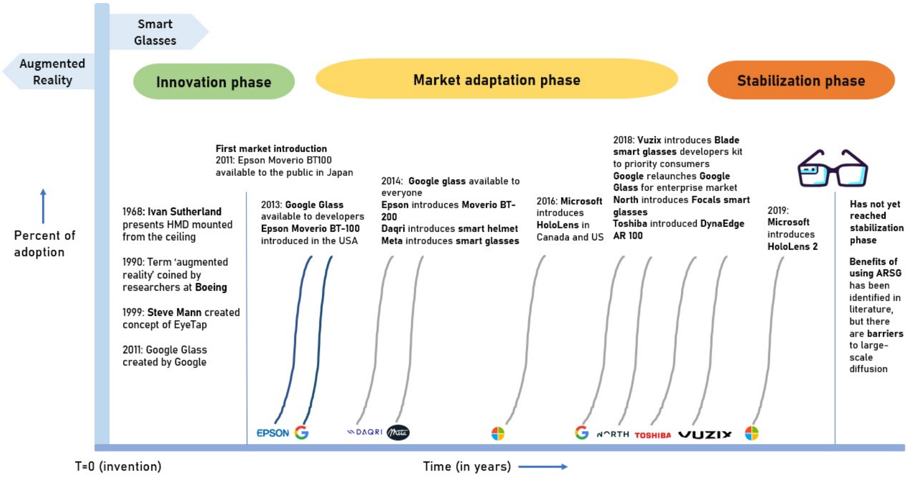


Figure 3-8: Pattern of development and diffusion of augmented reality smart glasses. Adapted for ARSG from Ortt and Schoormans (2004)

- In contrast, companies like DAQRI and Meta entered markets early but were forced to shutdown due to technical limitations their device faced in comparison to ones in the market (Wheeler, 2019; Robertson, 2019; GlobalData Thematic Research, 2020). It is also in the adaptation phase when companies become extinct in the struggle to produce the fittest products (Olleros, 1986).
- Now, Microsoft, VUZIX, Epson, and Google seem to be having a fair share of the market (Burns, 2013; Vuzix Corporation, 2017; Bohn, 2019). The competition amongst smart glass manufacturers exists as many companies are working on a similar technology. This is shown in the figure above.

The pattern of development and diffusion can give adopters an idea of what device alternatives exist in the market for purchase and which companies are still thriving despite strong competitive markets. Besides, it is also possible to see to what extent the speculation holds true based on the type of barriers the technology is facing which are described in market characteristics. More importantly, the market characteristics subsection is for adopters to be wary of and understand what challenges they might encounter as well as the value drivers that can be realized.

3-2-1 Factors affecting ARSG adoption

Barriers

Looking into recent papers to discern the challenges augmented reality smart glasses as a technology is facing led to categorization of barriers on the basis of technological, organizational, ergonomic, and social and political (Rejeb, Keogh, et al., 2021). Information that was gathered from other papers were also grouped into these categories.

- **Technological**

  According to Ro et al.(2018), from a technological perspective, limited number of applications, short duration of batteries, missing standards, and lack of ubiquitous high-speed internet connection were some factors that affect the growth of ARSGs. Likewise, a literature review on potentials and challenges of augmented reality smart glasses in the field of logistics and supply chain management showed technical challenges such as visualization of of objects due to small displays of ARSGs could be an obstacle to comprehensive coverage of information and transfer of knowledge (Niemöller et al., 2017; Rejeb, Keogh, et al., 2021). Furthermore, cameras inability to adapt to low light environments (contrast levels) that may affect the operators abilities, detection of physical characteristics of objects in the workspace that may require the support of powerful computation and hardware, lack of fast storage and processing capabilities, short battery longevity, weight of the devices, complicated graphic user interface interactions, heat generated by power sources, and performance issues due to transmission latencies were identified as major challenges (Seneviratne et al., 2017; Fraga-Lamas, Fernandez-Carames, Blanco-Novoa, & Vilar-Montesinos, 2018; Chang, Chen, & Chiou, 2018; Berkemeier, Zobel, Werning, Ickerott, & Thomas, 2019; Kim, Nussbaum, & Gabbard, 2019; Rejeb, Keogh, et al., 2021).

  Addressing similar issues, Danielsson, Holm, and Syberfeldt (2020) in his article on understanding usage of ARSGs in assembly operations provided a technological maturity perspective that indicated the lack of readiness levels of ARSG-accompanying technologies. The technology readiness level is a scale of maturity levels developed by the European Commission to discover the risk of adopting a certain technology. There was a need to improve the enabling technologies and individual components required for the functioning of ARSGs. Augmented reality smart glasses have a technology readiness level of 9, but tracking processes, user interfaces, and interaction technologies have a lower readiness level of 5. This could be attributed to its low maturity in certain applications, lack of widespread adoption, and restrictions within shop floor usage (Lacueva-Pérez et al., 2018), which leads to the upcoming points on organizational challenges.

- TRL 1 – basic principles observed
- TRL 2 – technology concept formulated
- TRL 3 – experimental proof of concept
- TRL 4 – technology validated in lab
- TRL 5 – technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
- TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
- TRL 7 – system prototype demonstration in operational environment
- TRL 8 – system complete and qualified
- TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

Figure 3-9: Technology readiness level scale developed by the European Commission to judge the maturity level of a technology. Reprinted from European Commission (2015)

- **Organizational**

  Organizational challenges arise because of the novel nature of the technology and lack of experience of firms in using smart glasses. Availability of expert opinions alone is also not enough to drive adoption as end users will need to be made aware of the technology to waive off their uncertainties about ARSGs and develop associated capabilities (Wang, 2015; Rejeb, Keogh, et al., 2021). Since the technology in itself is relatively immature, further validation of its effectiveness, tangible benefits, and maturation would be required that would be able to strongly justify the need for wide-scale adoption (Rauschnabel, Brem, & Ivens, 2015; Kong, Luo, Huang, & Yang, 2019; De Keyser, Köcher, Alkire, Verbeeck, & Kandampully, 2019).

  Technology acceptance is described as the success of implementation of technology in terms of using a technology at different organizational and individual operator levels, which is a critical driver for adoption of AR (Hein & Rauschnabel, 2016; Berkemeier et al., 2019). For ARSGs, it is unclear if the public will be ready to accept it. In fact, even though smart glasses contributed to achieving improvements in task completion time and reduced error frequencies in a certain application, workers were not willing to acknowledge these benefits and underestimated their performance (Fraga-Lamas et al., 2018; Murauer & Pflanz, 2018). Also, due to privacy concerns, lack of awareness, fear of external control, and the insufficiency of actual usage as an indicator for future usage have acted as barriers to adoption (Rauschnabel et al., 2015; Berkemeier et al., 2019). The personality traits, gender of participants, and their perceived complexity of the device also raises skepticism (Sedighi, Ulman, & Nussbaum, 2018). Cost of the devices and availability of financial resources and infrastructure were also found to be inhibitors (Chen, Zheng, Chen, Sun, & Chen, 2017; Basoglu, Ok, & Daim, 2017).

- **Ergonomic**

  Ergonomics emphasizes the the role for humans in the system regardless of their functionality and importance of their health and safety (Drury, 2000). Though process improvements are achieved, safety concerns regarding their long-term usage is raised (Rejeb, Keogh, et al., 2021). Studies provide evidence of visual problems such as acuity, fatigue, discomfort, dizziness and, cognitive overload caused by resolution constraints and size (Wang, Tsai, Lu, & Wang, 2019). The weight of the glasses may cause headaches and an imprint on the nose caused by inflexible and narrow temples that are not desired by users (Tsai & Huang, 2018). Logistic operators also provide negative feedback such as the troublesome and distracting nature of the device, principally when there is a need to switch focus from different displays or work in conditions of decreased visibilities (Grabowski, Rowen, & Rancy, 2018). Due to the above concerns, using smart glasses for full shifts in logistics and other industrial scenarios is still unsuitable. The management needs to make a decision on how they plan on balancing the usage time and safeguarding the health and safety of their employees (Kong et al., 2019; Rejeb, Keogh, et al., 2021).

- **Social and Political**

  Wearing ARSGs might make users less social and reduce their interactions with colleagues. There are also certain sensitive or highly protected and private areas in localities or even within plants. There could arise legal issues if smart glasses are operated in and around those areas. For the same reason, countries or organizations may also have an intent to ban or limit the usage of augmented reality smart glasses due to privacy concerns (Ro et al., 2018).

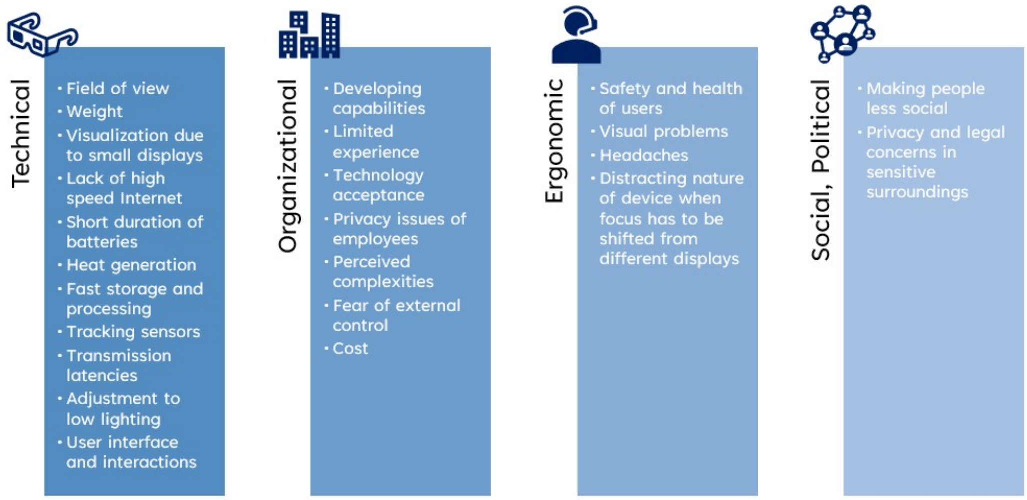


Figure 3-10: Drawbacks of ARSG technology

Despite facing challenges, companies are urged to have augmented reality strategies as ARSGs were said to have wide-ranging implications for all manufacturers. It was also foreseen to have an integral impact on the firms' strategy and change the way they compete (Porter & Heppelmann, 2017). So what are the advantages of using this technology? Why do companies find ARSGs desirable?

Value drivers

Ro et al. (2018) claims that ARSG is a possible means to create corporate value for businesses and society as a whole. ARSG is shown to improve process efficiencies by displaying relevant information, increasing accessibility to information, and combined with technologies such as big data and IoT, information can be enriched. ARSG also provides hands-free assistance, giving workers greater flexibility. Firms value is created by helping them do things better (faster, safer, higher quality, etc.) and doing things cheaper.

Pfeiffer, Hellmers, Schön, and Thomaschewski (2016) stated that smart glasses could be used to document all actions of the users and track users' gaze orientation with a camera, providing more information and visibility in comparison to external camera recordings. They could make use of voice control or touch screen to additionally capture videos or photos through interactions. It is also shown to be simplistic and convenient to use and are perceived to be powerful, efficient, and comfortable to wear. In learning and training situations smart glasses are useful as they provide increased autonomy to users' by possessing an interactive nature that supports self-exploration and self-direction.

Smart glasses also have the ability to collect and project data on a screen within the user's field of vision, assisting them in visualizing the next manufacturing step better whilst providing the necessary information. Demartini et al. (2018) describe how AR applications could be used for maintenance activities if supported with suitable collaboration tools to allow remote experts to create AR-based instructions to assist on-site technicians who may need assistance. Workflows are being standardized through virtual instructions, which could be provided to workers to complete their activities. Smart glasses then would be very useful in industries that have seasonal labor changes or for complex, rapidly changing tasks. Fitzgerald, Cook, DeMarinis, and Smetana (2018) summarize what have been discussed above as value drivers of smart glasses: *contextualized information, hands-free assistance, enhanced training and communication, visual documentation and enhanced process tracking, greater employee engagement, and increased workflow standardization.*

Subsequently, in the domains of manufacturing, logistics, field services, inspection and operations, hands-on testing and usage of technology is prominent.

3-2-2 Applications of ARSGs in supply chains

Logistics

In the logistics sector, the usage of smart glasses by DHL is a well known case. DHL said to utilize ARSGs for warehousing operations, transportation optimization, last mile delivery, and enhanced value-added services such as assembly and repair and customer services (Glockner, Jannek, Mahn, & Theis, 2014; Paksoy et al., 2020). Apart from these primary activities, ARSGs can also be used in support activities such as human resource management (training) and infrastructure (planning and design) (Rejeb, Keogh, Wamba, & Treiblmaier, 2020).

Business Category	Logistics Operations
Warehousing Operations	Pick-by-Vision: Optimized Picking Warehouse Planning
Transportation Optimization	Completeness Checks International Trade Dynamic Traffic Support Freight Loading
Last-mile Delivery	Parcel Loading and Drop-off Last-meter Navigation AR-secured Delivery
Enhanced Value-added Services	Assembly and Repair Customer Services

Table 3-1: DHL's use of AR in business operations. Reprinted from Paksoy et al. (2020)

Manufacturing

Kohn and Harborth (2018) in their paper explore use cases for augmented reality in the manufacturing industry. They could be used for production operations (assembly), inspection (diagnosing faults) and maintenance (Sanjiv, 2016). It is shown to increase work speed by decreasing production times and improve accuracy by reducing number of errors. A list of companies and the business processes they have digitalized using smart glasses is shown the

Phase	Company	Rendering Technology	Improvement quantifications
Prototyping	Volkswagen, Audi, Ford	Display	Not quantified
Training	Bosch	Oculus Rift headset	Not quantified
Training	UNIDO	Tablet	Not quantified
Production Operations	Lockheed Martin	Smart glasses	Increases engineers' accuracy to 96%, increases work speed by 30%
Production Operations	Airbus	Google glasses	Cut production times by one-fourth, cut error rates by half
Production Operations	Boeing	Microsoft HoloLens	Not quantified
Production Operations	Volvo	Smart glasses	Not quantified
Maintenance	Mitsubishi	Smart glasses	Not quantified
Inspections & Maintenance	Bosch Automotive Service Solutions	Tablet or smart glasses	Increases speed by 10-15%
Inspections & Maintenance	BMW	Smart glasses	Not quantified
Inspections & Maintenance	Volkswagen	Tablet	Not quantified
Inspections & Maintenance	ThyssenKrupp	Microsoft HoloLens	Not quantified
Inspections & Quality Insurance	Porsche	Tablet	Not quantified
Inspections & Error Prevention	Airbus	Tablet	Time reduction of 80%
Inspections & Error Prevention	Newport News Shipbuilding	Mobile devices (e.g. tablet or smartphone)	Time reduction from 36 hours to 90 minutes

Table 3-2: Overview of augmented reality use cases in manufacturing. Reprinted from Kohn and Harborth (2018)

table below. The most common rendering technology seems to be head mounted devices and handheld displays (tablets). Customers are desiring variations in product and operators and manufacturers may need to have access to critical information regarding the desired configuration to modify the existing processes. Since the augmented reality technology can assist in delivering such information wherever and whenever needed, it is slowly gaining significance (Kohn & Harborth, 2018).

Business customers utilizing ARSGs in their operations are crowded in markets such as manufacturing, entertainment, education, and tourism but certain markets like food industries are still under-researched (Juan, Charco, García-García, Mollá, et al., 2019; Rejeb, Rejeb, & Keogh, 2021).

Food Manufacturing

Caria, Sara, Todde, Polese, and Pazzona (2019) suggested the use of augmented reality smart glasses in farming which could allow farmers to visualize information regarding the crops, animals, machinery, or feedstock and provide real-time data and guidance through video calls. Since farming is labor intensive and requires one to be hands-free, a device like smart glasses that could provide instant and regular information to the farmer would be useful in increasing efficiency of their manual tasks. ARSGs would streamline several activities real-time consulting, data sharing, data collection, and remote assistance.

ARSGs could also be used in the tractor guidance monitoring system where layers of Geographic Information System (GIS) could be superimposed over the field of view of the farmer to locate treated zones. This would enhance the cognitive capabilities of the tractor driver as they can visualize the real plot through the glasses (Santana-Fernández, Gómez-Gil, & del Pozo-San-Cirilo, 2010). Smart glasses could also be used to improve precision farming especially in dynamic indoor planting in conjuction with Internet of Things (IoT). The data generated using IoT could be superimposed over real objects, allowing for visualization of crop coordinates to see where the crops have grown or where there is disease damage, for example (Phupattanasilp & Tong, 2019).

Training of employees to empower and elevate their educational standards could also be carried out with the help of smart glasses. Using smart glasses for training is shown to increase the commitment and involvement of employees in the training process, improve their cognitive abilities, and enhance their problem solving skills. According to Clark, the way food safety training is performed is going to be transformed by head mounted augmented reality devices (Chow & Lui, 2001; Clark, Crandall, & Shabatura, 2018).

A use case that has come to light in the food safety sector is that of remote inspections and auditing. Due the COVID-19 pandemic, travel restrictions and lockdown procedures have obstructed the movement of food certification bodies to conduct audits and regulatory checks onsite and issue certifications to supply chain actors. Auditors have not been able to travel, conduct checks and confirm compliance to ensure consistency of food safety systems (Rejeb, Rejeb, & Keogh, 2020). Augmented reality could be used for remote participation where a food safety manager/food auditor would be able to share the same visual field as employee and collaborate on process improvements. Employees would receive timely actionable responses from experts who need not travel long distances (Parker & Hitchcock, 2020). Though different technologies like CCTV cameras, smart glasses, wearables, and handheld devices were used, companies were said to lack the technical expertise, infrastructure, and insights to safely perform such audits. The pandemic has exposed this sector to new challenges for monitoring food safety and delivery of safe food products (Rejeb, Rejeb, & Keogh, 2020).

Food industry is already regarded as a sector with low research intensity (Demartini et al., 2018). Infact, when Bottani and Vignali (2019) studied the applications of augmented reality technology in the last decade, they identified that the food sector is researched the least and found only one review paper. This was attributed to the fact that the cost-effectiveness, benefits, and scalability of AR solutions in this context requires more evidence (Weidenhausen, Knoepfle, & Stricker, 2003). Subsequently, a proposed research direction by (Rejeb, Keogh, et al., 2021) was to study how smart glasses could add value to food safety and quality. Therefore, in section 3-3, food safety and quality processes would be discussed in detail to later identify potential applications for ARSGs.

So far, the barriers, value drivers, and applications of the technology have been discussed. Clearly, there are certain technological barriers that need to be tackled before the device can be widely adopted. The following subsection will lay an emphasis on the future of the technology, what can be expected in terms of improvements in complementary disciplines or supporting services that could potentially help in overcoming the barriers of smart glasses.

3-2-3 Future of ARSG

Gartner's hype cycle is a framework that assists in the analysis and forecasting of technologies during their early period of development. This model was developed by Gartner Inc. in

1995 to showcase the path a technology can take over time, in terms of expectations or visibility of the value of the technology. According to this model, technologies advance through consecutive stages, starting with a peak, followed by disappointment, and then recovery of expectations. Though this model has received a lot of attention from practitioners, in the academic world, its dissemination is relatively limited with increasing interest from technology and innovation management (TIM) researchers and literature. The hype cycle is composed of two curves: the bell curve of expectations and hype based on a sudden, overtly positive, and irrational reaction on introduction of a new technology and the S-curve that describes the technological maturity based on the technical performance (Fenn & Raskino, 2008; Dedehayir & Steinert, 2016).

The bell-shaped curve observed during introduction of new technology could be attributed to attraction to novelty, social contagion, and heuristic attitude in decision making. Over-enthusiasm regarding a particular technology due to above mentioned attributes, in combination with big stories from media lead people to perceive a certain potential for the technology which also results in collective hypes and increases the number of supporters. Decision-makers in organizations are inclined to follow the trend rather than assessing the potential of the technology themselves, which is dangerous because the sharp peak of enthusiasm of a new technology is followed by disappointing early results. Since the technology was still in its first generation of applications, the hype suddenly ebbs and collapses into a trough. The S-curve is the second equation that forms a hype cycle. This pattern has already been discussed in section 3-2 (Fenn & Raskino, 2008; Dedehayir & Steinert, 2016).

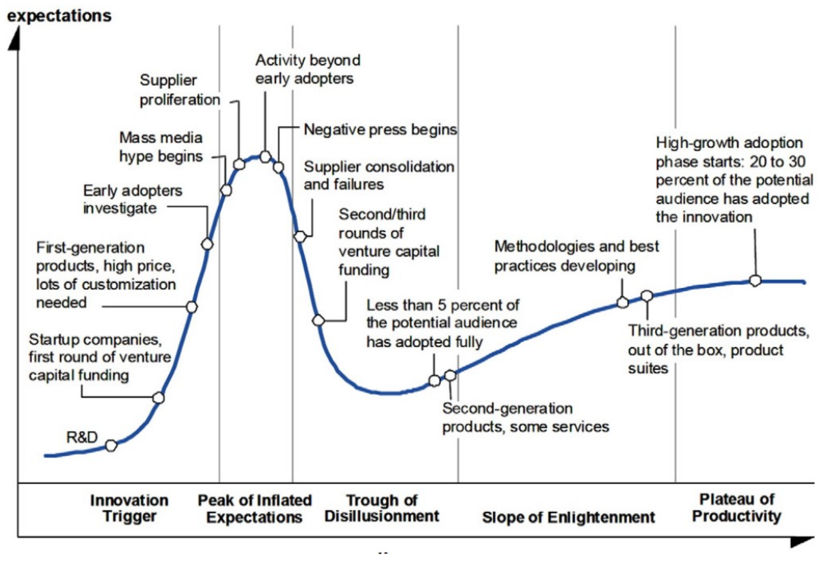


Figure 3-11: The hype cycle and its stage indicators. Reprinted from Fenn and Raskino (2009)

The hype cycle is divided into five distinguishable phases known as innovation trigger, peak of inflated expectations, trough of disillusionment, slope of enlightenment, and plateau of productivity. Innovation trigger is when a public demonstration or announcement triggers the cycle and awareness amongst consumers about the technology begins to spread. As it attracts media coverage, venture capitalists and other companies wishing to the adopt the technology try to gain first-mover advantages. Following this is the peak of inflated expectations, where a bandwagon effect can be observed. Due to boosted expectations and media hype, companies invest without having a clear strategy or sound business cases. The trough of disillusionment occurs because commercially adopted technologies fail to meet performance or revenue expectations. The public is now disappointed and the media spreads this negative news, and hypes it up as well. This phase occurs due to over-enthusiasm and hyped investments. Slope of enlightenment is the penultimate stage when the technology gets socialized as early adopters who continued to work with the technology start experiencing net benefits and have the motivation to work with the technology. The performance of the technology also increases due to increasing investments and growth of contextual understandings of the technology. The final phase is the plateau of productivity where a realistic value can be placed on the technology and with successful marketplace demonstrations, adoptions accelerate (Fenn & Raskino, 2008; Dedehayir & Steinert, 2016; Gartner Representative, 2021). This is illustrated in Figure 3-11. Based on the information available to us, in the upcoming pieces of text we will be trying to identify in which stage augmented reality smart glasses are.

ARSG on the hype cycle

ARSGs were explicitly not a part of the hype cycle as it features only broader spectrum of topics and not individual applications, but AR was last mentioned on the hype cycle in 2018 in the trough of disillusionment phase. Specialists discerned that AR needed 5 or 10 years more to pass through slope of enlightenment and finally reach maturity in the plateau of productivity phase. It has since then disappeared because Gartner's firm believe the technology is not longer emerging, but is rather is becoming important and getting incorporated in business and IT (Skarredghost, 2019; Herdina, 2020).

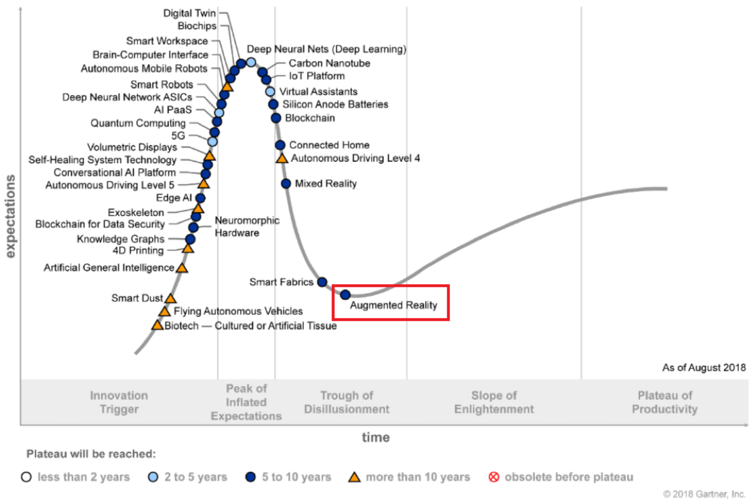


Figure 3-12: Hype Cycle for Emerging Technologies, 2018. Reprinted from Panetta (2018)

From recent literature, ARSG seems to be a fast growing innovation with increasing publicity. The emergence of Industry 4.0 technologies and the radical transformation of manufacturing systems are providing the digital support required at plant control level and making way for an increased focus on smart wearables (Rejeb, Keogh, et al., 2021). Looking at market valuations, BIS research, a global leading market intelligence company that studies emerging technologies reported that the enterprise AR market was worth 3.5 billion US dollars and will reach 200 billion US dollars by 2025 growing at a compound annual growth rate (CAGR) of 65.1% from 2018 to 2025. The report also mentions that the sales of AR smart glasses could amount to 52.9 million US dollars (BIS Research Representative, 2018; Rejeb, Keogh, et al., 2020).

In an article titled 'Why every organization needs an augmented reality strategy' in HBR, authors discussed how AR is being applied in consequential ways in both consumer and B2B settings. AR is said to open up multiple avenues for product differentiation and enable efficiencies that every company must explore. Organizations that produce commodities could focus on operational efficiencies across the value chain and must prioritize AR-driven cost-reduction efforts in line with their strategic positioning (Porter & Heppelmann, 2017). By collecting information from close to 600 organizations that are implementing and exploring AR and VR, Capegemini reports that within the next three years, AR would become mainstream in 41% of the organizations. AR was more relevant and widely implemented in comparison to VR and on average, early achievers were said to derive higher benefits such as efficiency, safety, and productivity increases and complexity reduction (Cohen et al., 2018). Finally, PwC touches upon the fact that AR and VR are contributing over 46 billion US dollars to global GDP and there is no reason for organizations to sit and wait (Dalton & Gillham, 2019).

Few factors that are considered to be influential for the growth and success of ARSG are as follows:

Role of 5G

ARSG as a technology is still evolving rapidly and has not reached operational maturity. Organizations should expect integration challenges and understand how they will leverage data for critical use cases (Fitzgerald et al., 2018). With the advent of 5G, there can be expected reductions in transmission latency that would allow the user to have a smoother and richer augmented reality experience (Rejeb, Keogh, et al., 2021). With the help of 5G, ARSGs need not rely on built-in processing or storage, which may decrease the costs and enable more user-friendly designs. The processing and storage activities would then take place on the cloud (Dalton & Gillham, 2019). AR Cloud is defined as the soft (digital) copy of the real world (Open AR Cloud Representative, n.d.).

Role of AR Cloud

AR Cloud is a machine-readable, 1:1 scale models of the world are continuously updated in real-time. They contain billions of datasets that are machine-readable, point clouds, and descriptors aligned with real-world coordinates. It is said to drive the next generation of immersive experiences (Open AR Cloud Representative, n.d.). Currently, no vendors seem to provide AR cloud as a comprehensive solution. It is an amalgamation of existing technologies and processes, as shown in the figure below (Raza, 2021).

According to Gartner, by 2025, 15% of organizations with over 1 billion US dollars in revenue would use AR cloud to monetize the physical world through new interactions and business models. It was also featured as an emerging technology in the 2019 in the hype cycle along with 5G, that was in the peak of inflated expectations phase (Huy Nguyen, 2021). The

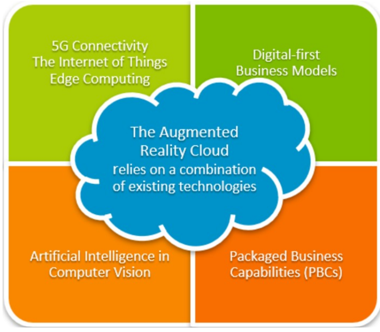


Figure 3-13: AR Cloud is a combination of the above technologies. Reprinted from Raza (2021)

hype cycle and meanings of these phases was already discussed in more detail in subsection 3-2-3.

Role of interoperability

Apart from focusing on the immersive experience the standalone device can offer, with the development of Industry 4.0, the interoperability of smart glasses with other complementary technologies such as IoT, cloud computing, AI, and blockchain may help businesses achieve their objectives (Rejeb, Keogh, et al., 2021). In fact, integrating AR/VR solutions with the companies' enterprise resource planning (ERP) or product lifecycle management (PLM) systems is said to yield higher benefits. This could bring about process changes and a foreseen investment, but alongside that due to the novelty of the technology, companies should keep in mind security and privacy. Security and privacy concerns maybe a hindrance to adoption, but could be controlled with the right built-in security and privacy framework, to avoid exposure of sensitive and proprietary information (Cohen et al., 2018).

3-3 Food safety and quality

Consumer perceptions show an increasing concern about the safety of food and the specifications of what they buy and eat. Even though information is available on labels, it does not translate into more confidence. Consumer confidence should be restored and enhanced by the food industry brands. Subsequently, quality assurance has become the cornerstone of food safety policy in the food industry and quality management systems have become the center of attention (Trienekens & Beulens, 2001; Beulens, Broens, Folstar, & Hofstede, 2005). To assess the safety and quality of food that include on-farm production, manufacturing practices, sanitation, and hygiene, internal and external food safety audits are conducted. The introduction of this practice can be dated back to the industrial evolution when companies realized a need for developing mechanisms to detect fraud and establishing financial accountability (Powell et al., 2013). Once the British Retail Consortium (BRC) Global Standards began in 1996, retailers expected legal, technical, and financial advantages. The retailers had to protect the health of the consumers by fulfilling their legal obligations and take reasonable precautions to avoid failure. This included verification of the technical performance of food manufacturing facilities of retailer-branded products. Food producers now have to handle requests for audits from buyers in the food supply chain and have categorized their audits into first-party, second-party, and third-party audits (Kotsanopoulos & Arvanitoyannis, 2017). Next, both food safety and quality, and auditing practices will be described.

Food safety and quality assurance and management systems

At the outset, it is necessary to differentiate between food safety and quality. According to FSSAIfoodlicense(2019), food safety is "the assurance that food will not cause harm to the consumer when it is prepared or eaten according to its intended use" and food safety assurance involves reduction of risks which may occur in food. Food quality is related to characteristics of food that are acceptable and/or required by consumers such as shape, color, texture, flavor, etc. Food safety could also be considered as a component of quality as public authorities are pressing the food and feed industries into developing quality management systems that are aimed at improving food safety, restructuring inspection systems, and enhancing the information provided to customers. Such systems may vary based on origin, but they do share common features such as their reliance on documentation of production processes and practices and third-party auditing and certification (Kotsanopoulos & Arvanitoyannis, 2017; FSSAIfoodlicense, 2019).

In 1993, Hazard analysis and critical control points (HACCP) was recommended by FAO-WHO Codex Alimentarius Committee as the most effective system to maintain assurance of safe food supply. Soon after 1993, HACCP-based control systems also became a legislative requirement within the European Union (EU). Several EU food hygiene directives were implemented and food retailers, manufacturers, and caterers were required to perform hazard analysis to comply with the Hygiene of Foodstuffs Directive 93/43/EEC. HACCP is a science-based system that allows the maintenance and introduction of a cost-effective ongoing food safety programs. It is a program that gives emphasis on identifying and managing risks in food chains (farm to fork approach) and allows food businesses to establish a higher degree of safety that cannot be achieved by just following basic hygiene practices by allowing them to determine if their food operations can consistently produce safe food. If all stages of food production and preparation needs to be systematically assessed, then implementing HACCP would allow the producer to identify and control stages of production that are critical to the safety of the product (Mortimore, 2000; Humphrey & Memedovic, 2006; Kotsanopoulos & Arvanitoyannis, 2017). The main principles of HACCP system are described by Mortimore and Wallace (2013) as follows:

- *Conducting a hazard analysis:* A detailed process flow diagram consisting of all processes taking place in the plant when converting raw material to finished product can assist in identifying the hazards in each step. Once these hazards are identified, their likelihood of occurrence, the severity of the effect to the consumer, and preventive measures for their control need to be described.
- *Determining critical control points (CCPs):* Once hazards and control measures are described, the employees working on HACCP can decide the points where control is critical to the safety of the product.
- *Establish critical limits:* For the control measures that have been identified, there should be a limit that differentiates between safe and potentially unsafe product at the CCPs.

These critical limits involve a measurable parameter and are also known as safety limit or absolute tolerance for the CCP.

- *Setting up a system that monitors control of CCPs:* The HACCP team should also work on creating monitoring actions along with monitoring frequency and responsibilities to maintain the CCPs within its limits.
- *Establishing the corrective actions during monitoring when identified CCPs are not under control:* In order to bring the process back to control and work on dealing with the unsafe products that would have been manufactured when the process was out of control, corrective action procedures and responsibilities for implementation needs to be created.
- *Setting up procedures to verify if the HACCP system is working efficiently:* More than developing HACCP systems, greater effort is required to keep continuously auditing and verifying a HACCP system. Robust Pre-Requisite Programs (PRPs) must be in place to support HACCP and may include supplier assessment, suppliers' level of accreditation, specifications, analytical control programs, internal audit schedules and inspections, traceability and recall systems, training, water and air quality control, and Good Manufacturing Practices (GMPs). Procedures must be in place to both validate that CCPs will control the hazards of concern and verify if the system is working day-to-day as planned.
- *Organizing documents associated to all procedures and records appropriate to these principles and their application:* To supply evidence when needed on safe products being manufactured at the plants, records must be maintained that show how HACCP is operating under control and appropriate corrective actions are taken when deviations from critical limits were observed.

In a plant environment, sources of hazard could be related to either the raw material, process, or work environment. While HACCP focuses on the safety of raw material, product, and manufacturing processes, PRPs focus on hygienic operating environment which include the facility, people, and programs. PRPs are just as important for food safety and are required prior to and during implementation of HACCP to ensure that HACCP systems are focused on actual CCPs that are essential for control of hazards. Another definition that needs to be made in the PRP area is that of Operational Pre-Requisite Programs (OPRPs). According to ISO, "OPRPs are PRPs defined by the hazard analysis as essential in order to control the likelihood of introducing food safety hazards to and/or the contamination or proliferation of food safety hazards in the products or processing environment". If OPRPs are used along with CCPs to help in management of significant hazards, then it is formally a part of overall HACCP. Failure of either an OPRP or CCP will result in a high likelihood that a product may contain a food safety hazard. Once the PRPs, HACCP system (including the CCPs and OPRPs) are drafted, the next thing to take into consideration are Quality Management Systems (QMS) (Mortimore & Wallace, 2013).

A formal QMS is based on external references and unique to a company to ensure that the company meets its objectives for food safety and quality. Such systems would help in preventing and detecting non-conformities during production and distribution of product to the customer. Preventive and corrective actions can be taken to ensure the defect does not

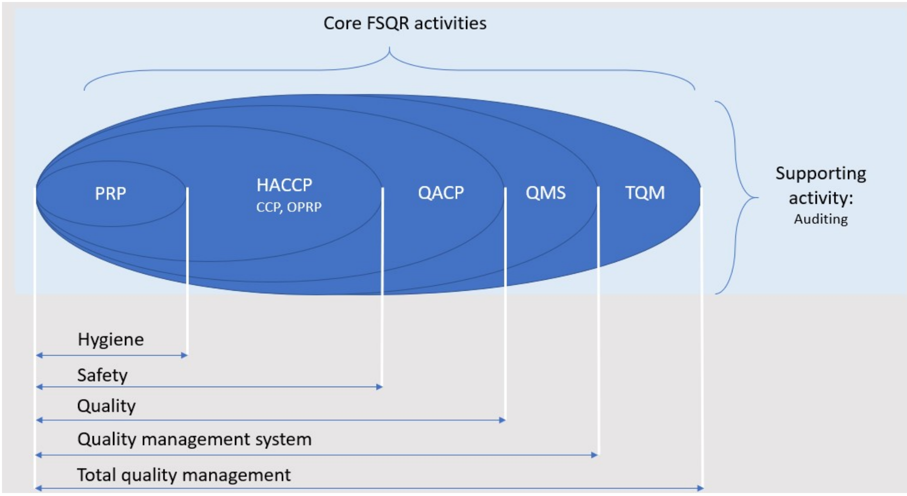


Figure 3-14: Relationship between food safety and quality parameters. Adapted from Sikora and Strada (2005)

occur again. Quality management is often done voluntarily by the organization based on what the customers expect. Working with a formal QMS will allow the manufacturer to meet the specifications required 100% of the time, but problem arises when the product specifications described are unsafe. This is where the QMS needs to work in synergy with HACCP, otherwise you would be producing the unsafe product every time. Quality Assurance Control Points (QACPs) are the counterparts of CCPs in a HACCP system for a QMS system. QMS usually consist of quality assurance and quality management. Quality assurance relates to the product itself and all the safety systems (PRPs, OPRPs, HACCP) and the QACPs. Quality management corresponds to the overall organization of the firm, including the product quality and safety, QMS, and Total Quality Management (TQM) (Sikora & Strada, 2005; Mortimore & Wallace, 2013).

Auditing

Food safety audits and inspections are activities used to verify if the food producer or individual is following specific guidelines, requirements, or rules. They could also be organized to obtain certifications to certain food safety and quality standards, evaluate incidents occurring at other facilities or organizations, or for some commercial objectives (Powell et al., 2013; Kotsanopoulos & Arvanitoyannis, 2017). Audits involve a "systematic and independent examination to determine whether quality/safety activities and related results comply with planned arrangements and whether these arrangements are implemented effectively and are suitable to achieve objectives" (European Commision, 2006). Around the world, food inspection and quality control systems are evaluated and reorganized to better their efficiency, account for human resources, and introduce risk analysis-based approaches.

ANZFA differentiates between inspections and audits by stating that inspections evaluate "conformity by measuring, observing, testing, or gauging the relevant characteristics" whereas audits are inspections supplemented with microbiological and quality assurance product testing and process inspections by regulatory authorities or industry to assist in making sure that regulations and manufacturing practices are adhered to (Australia New Zealand Food Authority, 2001; Powell et al., 2013). To collect information on food production and processing practices being followed, an audit of food safety practices, facilities, documentation, and written procedures of a producer is conducted. The reports of audits serve as the "eyes and ears" for an organization that buys its food from a producer (Weise, 2010). There are three types of audits: self/internal audits performed by the organization itself which are usually led by quality assurance teams. If methods followed in these audits are those outlined in widely accepted codes and risk assessment guidance documents, these audits have a potential for reducing risk. Second-party audits are those checks conducted by a downstream company or buyer that performs an audit on their supplier. Third-party audits are conducted by an outside firm or independent auditors who focus on verification or standard implementation to ensure that the buyers' rules are being followed. Their speciality is examining the compliance with laws and codes of practice and providing "an insight into management controls and supervision" (Costa, 2010; Safefood 360 Inc, 2013; Kotsanopoulos & Arvanitoyannis, 2017). Third-party audits have increased in popularity as organizations develop private food safety standards for food safety governance, shifting away from the government regulation and inspection (Busch, 2011).

An audit program is a resource intensive, carefully planned system of audits conducted on a scheduled basis with a clear scope for a particular plant, scheme, group, and regulatory frame of objective. The objectives need to be met with minimum cost and maximum benefit. Large companies often have their own internal audit programs in place, along with those conducted by food retailers who have their own supplier audit programs based on technical standards. Regulatory agencies would operate national and international programs covering specific acts and bills on food safety. A typical audit program and implementation process has the following steps: planning the audit program, conducting the audit, monitoring and reviewing the program, and finally improving the program. During the planning stage, areas such as the objectives, scope, frequency and schedule, risk classification, program responsibilities, program resources, and program procedures needs to be developed. When the audit is being conducted, the steps that are implemented are as follows: initiation, preparing, conducting, reporting, and completing. Using the information collected during the audit, a summary report can be prepared that would aid in providing directions for monitoring and renewing the program, as well as identifying areas of improvement of the audit program (Safefood 360 Inc, 2013).

3-4 Organizing resources for Augmented Reality

A firms resources can be defined as all assets, capabilities, organizational processes, firm attributes, information, knowledge, etc. controlled by a firm that enable the firm to conceive of and implement strategies that improve its efficiency and effectiveness (Daft, 1983). To understand how firms achieve sustained competitive advantage, Resource Based View (RBV) analyzes and interprets the internal resources of the organizations. The competitive advantage is said to occur only if the underlying assumption that the resources possessed by the organization is heterogeneous and immobile is fulfilled (Barney, 1991). By resource heterogeneity, Barney(1991) indicates that resources are different across firms and firms with same external forces can have different resources and outperform others. Resource immobility refers to resources not being able to move from company to company in a short-term, and competitors not being able to quickly replicate their rivals' resources or strategies (Barney, 1991). Additionally, the difficult-to-imitate attributes that are Valuable (V), Rare (R), costly to imitate (I), of resources and firms being Organized to capture the value of the resource (O) are also said to be the sources of superior performance and competitive advantage. These attributes are known as the VRIO criteria, which if satisfied by resources, along with them being heterogeneous and immobile, can provide the said performance and advantage (Hesterly & Barney, 2014; Rothaermel, 2018). Further explanation of VRIO criterion is as follows:

- *Valuable*: Resources owned by an organization would be considered to be valuable if it can provide strategic value to the firm by helping them exploit market opportunities or reducing market threats (Barney, 1991; Hesterly & Barney, 2014; Rothaermel, 2018).
- *Rare*: Resources owned by an organization would be considered to be rare if it is difficult to find among existing and potential competitors of the firm. This would help the organization in designing and executing a unique business strategy in comparison with other competitors (Barney, 1991; Hesterly & Barney, 2014; Rothaermel, 2018).
- *Costly to imitate*: Resources owned by an organization would be considered costly to imitate if they cannot be developed by other firms or buy the resources at a reasonable price. Firms that do not own the resources should not be able to acquire them for delivering temporary competitive advantage to the organization in picture (Hesterly & Barney, 2014; Rothaermel, 2018).
- *Organized to capture value*: Resources owned by an organization that are valuable, rare, and costly to imitate, in combination with the organization structured to capture value, would form the basis for achieving a sustained competitive advantage for the organization. To be able to exploit the competitive potential of the firms, competencies, resources, and capabilities, the organization should have an effective organizational structure, processes, and systems in place (Hesterly & Barney, 2014; Rothaermel, 2018).

According to RBV, a firm is a culmination of physical resources (physical, technological, plant, and equipment), human resources (training, experience, insights) and organizational resources (formal structure) (Barney, 1991). They could also be classified as tangible or intangible and this is represented in Figure 3-15. Tangible resources could be defined as those that have physical attributes and are visible.

On the other hand, intangible resources are invisible, and do not have any physical attributes (Rothaermel, 2018). Some argue that tangible assets have a clear market value but the value of intangible assets is open to subjective assessment. It is challenging to account for the value of certain types of intangible resources but they need to valuated as they are a source of potential revenue (Xaxx, 2019; Murphy, 2021). Intangible resources were also categorized as those that constitute customer capital, human capital, innovation capital, and process structural capital by Günther and Beyer (2003). Authors mention the increasing importance of intangible resources in western economies and tried to identify measurement objects that could aid in reporting the value of such resources. Not only does this paper signify the importance of intangible resources and especially human capital, but it also provides examples of what could potentially be classified as an intangible resource.

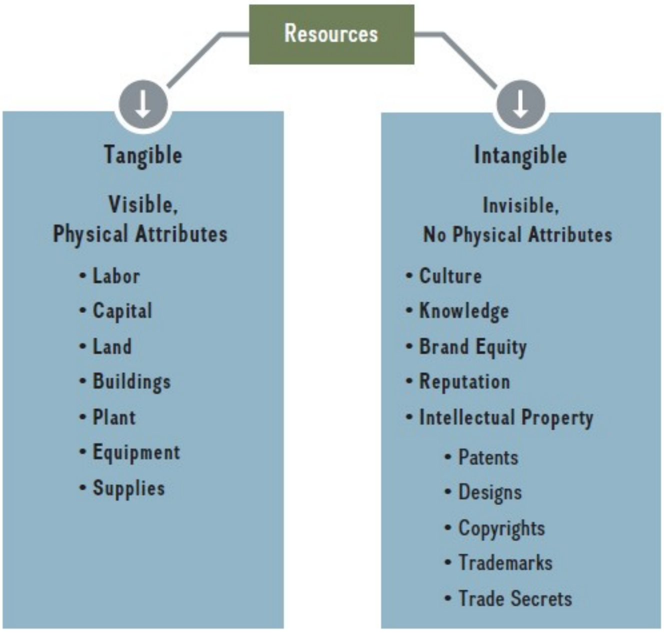


Figure 3-15: Examples of resources classified as tangible or intangible. Reprinted from Rothaermel (2018)

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These resources possessed by a firm that cannot be easily transferred or purchased, require an extended learning curve or a major change in the organization climate and culture are said to be difficult to imitate by competitors as they would be unique to the organization. Utilizing such resources, companies must develop a value-creating strategy that competitors are not using to create superior performance relative to its rivals, which is known as sustained competitive advantage (Madhani, 2010). By sustained competitive advantage, Barney(1991) means non-duplicatable advantage, which does not mean it will last forever. Rather, Barney(1991) suggests it is something that will not be competed away or easily duplicated by the efforts of others. If there are unanticipated changes to the economic structure, what remained as a source of sustained competitive advantage, may not longer be a source of advantage. A few isolating mechanisms that would act as barriers to imitation of resources, capabilities, or competencies that can help firms sustain their competitive advantage include better expectations of future resource value, path dependence, causal ambiguity, social complexity, and intellectual property (IP). A combination or one of these isolating mechanisms may help a firm strengthen its basis for sustainable, competitive advantage (Lippman & Rumelt, 1982).

One such barrier to imitation or isolating mechanism that could provide a sustained competitive advantage to organizations, in the case of AR, is path dependence (Arthur, 1989; Rothaermel, 2018). Path dependence is a situation in which the options one faces in the current situation are limited by decisions made in the past. Since firms cannot compress time at their will and need to catch the train of capability of development, learning and improvements must take place over time and existing competencies must be constantly upgraded and nourished (Rothaermel, 2018). Even though it is known that early adoption of Industry 4.0

Customer capital	Human capital
Brands	Technological know-how
Customer relations	Education
Company name/image	Process know-how
Structure of sales and distribution	Experience
Cooperation	Innovations
Franchise partnerships	Adaptability, Corporate culture

Innovation capital	Process and structural capital
Patents	Information systems
Copyrights	Corporate culture
Technological know-how	Networks
Brands	Locations
Protected labels	Investor relations
Licences	Process know-how

Figure 3-16: Examples of intangible resources. Adapted from Günther and Beyer (2003)

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technologies like AR may lead to high transition costs and capital expenditures, the competitive advantage and associated benefits is shown to far outweigh those costs (WEF and McKinsey Company, 2019).

The inside-out view of the firm taken by RBV can help in understanding why certain organizations fail or succeed in the marketplace (Dicksen, 1996). However, marketplaces now are much more competitive and change rapidly due to the globalized environment (Madhani, 2010). Firms' resources and capabilities need to change over a period of time to ensure they relevant to changing market condition. The dynamic capabilities approach insisted that managers of firms need to work on developing capabilities embedded in the firm which are based on sequences of path dependant learning in order achieve periods of competitive advantage (Teece, Pisano, & Shuen, 1997; Eisenhardt & Martin, 2000; Miller, 2003).

Additionally, it was recommended to have timely strategies, flexible infrastructures, and an ability to utilize resources and capabilities in coupled and innovative ways (Teece et al., 1997). So, what are the resources, capabilities, and competencies required to make AR a source of sustained competitive advantage for organizations? This would be addressed next. Other actions and resources that are required with respect to adoption and implementation of AR, that could possibly also be sources of sustained competitive advantage will be subsequently examined.

3-4-1 Resources, competencies, and capabilities needed to embrace AR

According to a global alliance manager at Upskill, a Boeing- and GE-backed up start-up, the best way to discover a use case within the organization is to focus on the operational impact, and think about how a little digitization using AR/VR could help the employees do their job better. A certain level of resistance from employees towards the novel technology is expected, but companies could overcome this by encouraging employees to apply and embrace augmentation. The research also reported the need for conducting demonstrations to employees on how the new technology could support daily work and make workplace more productive and safer. Instead of directly focusing on the technology, it was recommended that the organization focus on the use case, and then arrange for information handling and data so that the right information is delivered to the technology. Overall, organizations could make a rational decision on investing for predetermined use cases where a potential would lie for their business, considering user usability and ergonomics together with it (Cohen et al., 2018).

Technology infrastructure

Complexity in execution seems to be a barrier for adoption for about 61% of organizations exploring and implementing AR/VR and more than half of the respondents blame lack of data and technology readiness (Cohen et al., 2018). Authors Porter and Heppelmann (2017) identified five key considerations for firms to deploy AR. Firstly, an organization needs to identify which development capabilities would be required, which would be based on the application. If it is for the purpose of providing instructions, such applications would be more difficult to build and use as they require the capacity to develop and maintain dynamic 3D digital content. Organizations could also use less-mature technologies like voice and gesture recognition in conjunction with smart connected products (SCPs) to develop apps, but it is a challenging task. To achieve a greater strategic impact, it was suggested that firms move from static visualizations of 3-D models into dynamic instructional experiences. Secondly, companies need to look out for ways to create digital content that requires specialized expertise, particularly when more-complex, dynamic contextual experiences must be built such as business-instruction applications. Also, instead of building the content themselves, companies could partner with experienced vendors who can deliver AR/VR solutions, on a case-by-case basis or available turnkey options (Cohen et al., 2018). Sometimes, complex AR experiences may also need to tap real-time data streams from enterprise business systems, SCPs, or external data sources and integrate them into content. A recommended starting point for organizations to broaden their AR portfolio is to take an account of their current 3-D digital assets in CAD and other spaces, and then invest in digital modeling capabilities. Ensuring content availability such as system specifications, performance metrics, statistics of machines and other relevant information when combined with AR/VR systems could be a powerful enabler. Though converting workers' tribal knowledge into a database and preparing data for immersive technologies is a challenging task, automating processes and standardizing data is the need of the hour. This information could be stored in a repository of content that would also enable well-functioning AR/VR systems (Porter & Heppelmann, 2017).

Following this, AR applications need to be able to recognize the physical environment and shape recognition technologies would be capable of performing this operation. Organizations need to use them to have high-value AR applications. When it comes to hardware, ARSGs were said to be widely available and affordable in a few years and companies were urged to develop a cross-platform approach to be able to deploy AR experiences across multiple devices (smartphones and tablets), and be ready for smart glasses. Lastly, a choice needs to be made between a software-development or a content-publishing model for delivering the AR experience. The authors discuss how initially several reliable, high-resolution AR experiences were delivered through stand-alone software applications that were downloaded, complete with a digital content to a handheld device. These applications made by firms did not require internet connectivity but a major drawback was a change to the AR experience required the software developer to revisit the app code and rewrite it, which is an expensive assignment (Cohen et al., 2018). As indicated in subsection 3-2-3, AR cloud could be used to host AR content that was created on a commercial AR-publishing software. This experience could then be downloaded on demand on a general-purpose app running on an AR device, and the AR content could be updated or supplemented without changing the software itself, similar to website alterations. This would be beneficial if lots of content changes and large amount of information is involved and content-publishing models would become more common as products and machines require real-time AR interaction and control. For scaling up AR, such a content-publishing capability would be of significance. Furthermore, AR/VR technologies also necessitate high network availability and the bandwidth, and for some use cases, this could be a deal breaker. For use cases that can work without network connectivity, computing power is mandatory as these technologies make use of graphics and real-time rendering (Cohen et al., 2018). As mentioned in subsection 3-2-3, these issues could be overcame with the help of 5G and AR Cloud.

Talent acquisition and training

One of the top three barriers to growth identified by respondents who participated in a survey was the lack of in-house talent and expertise to develop AR/VR since the technology is new. The technology has to percolate through the organization and upskilling of the employees is still needed. Early achievers are investing in agile and in-house teams of expert. They recruit people with AR/VR expertise and are found to conduct specialized in-house training. For expanding AR initiatives, organizations also adopt strategies such as investing in R&D teams or innovation centers and partnering with academic institutions to leverage outside talent and technology. Outsourcing subject matter experts with direct experience in immersive technology apart from building internal capabilities would also be a suggested alternative. This study also reported the fierce competition for talent faced by companies, who are losing competitive advantage because of shortage of digital talent (Porter & Heppelmann, 2017; Cohen et al., 2018; Dalton & Gillham, 2019).

Setting up a centralized governance structure and building awareness

For the technology to improve and flourish, it is necessary to establish a governance structure with the help of committed teams. It was noted that early achievers have either dedicated teams or innovation centers that work on AR/VR activities. Also, There is a need for influencers who can build awareness throughout the organization, but it was advised that the overall planning and execution could be led through a centralized unit to improve governance and make the best use of resources (Cohen et al., 2018).

3-4-2 AR as a source of sustained competitive advantage

Rothaermel(2018) believes that intangible resources and capabilities are said to drive competitive advantage rather than tangible resources and capabilities. From what is discussed above and the classification defined in Figure 3-15, up skilled employees after the right talent acquisition and training, and centralized governance structure and innovation teams would be the intangible resources that could contribute more to competitive advantage (knowledge). This, combined with an isolating mechanism of path dependence that arises when an organization chooses to adopt a technology earlier than others might bring about sustained competitive advantage to the organization. In conclusion, the combination of both tangible resources such as technology infrastructure needed for the identified use cases, and intangible resources such as trained employees, could be valuable, rare, and costly to imitate and with innovation teams, and centralized governance structures, the firm would also be organized to capture value. Though the tangible resources could be easily accessible and transferable, in combination with intangible resources and capabilities, the resources owned by an organization would be heterogeneous and immobile. If this is the case, according to the RBV framework, the organization with the help of the aforementioned resources for AR, could enjoy a sustained competitive advantage (Barney, 1991; Rothaermel, 2018; Porter & Heppelmann, 2017; Cohen et al., 2018; Dalton & Gillham, 2019).

3-5 Conclusion

The literature review section was focused on exploring the technical aspects of augmented reality smart glasses in the beginning. Augmented reality was differentiated from virtual and mixed reality, and its functionality and working principles were defined. Later, smart glasses and their alternatives were also distinguished. These distinctions are important to narrow the scope and focus of this study. The different components required to perform value-adding activities using augmented reality systems were identified. When studying market adoption, it was found that ARSGs face technological, organizational, ergonomic challenges and social and political concerns. The technology readiness level of complementary services and technologies was much lesser in comparison to smart glasses. The applications and business customers of smart glasses were also concentrated in certain industries and sectors like food are less aware of the applications. Both organizations and users may be hesitant to shift their current way of working and practices due to these reasons and the device not being the norm for usage in certain applications (socio-cultural aspects). All these aspects may be negatively influencing the large-scale diffusion of the product (Ortt, Langley, & Pals, 2013). It is possible from this narrative that augmented reality smart glasses **could still be in the adaptation phase** in the pattern of development and diffusion of technologies and have not entered the market stabilization phase (due to several barriers faced to large scale diffusion/stabilization). Nevertheless, there are sufficient value drivers and the future of the technology and market valuations seem to be promising. It was urged that companies take action to utilize the value drivers of the technology.

The focus for potential applications of smart glasses was centralized to food safety and quality processes as it was a suggested research proposition and there was a lack of publications addressing this. The food safety system of HACCP was explored in detail and the main principles were described. Food quality is more of a customer requirement and is done voluntarily by organizations that have a formal quality management system and preventive and corrective actions in place for the same. To ensure that food safety and quality practices are being followed, activities like auditing are carried out. An audit program is quite comprehensive and is prepared days in advance of an audit. Information presented in this section could serve as a foundation for understanding the business processes within the food safety and quality domain in food manufacturing organizations.

Finally, to figure out and classify the resources (tangible and intangible) required to bring about a sustained competitive advantage to the firm, resource-based view theory was chosen. Since firms cannot compress time at their will and need to catch the train of capability development, learning and improvements must take place over time and existing competencies must be constantly upgraded and nourished (Rothaermel, 2018). It was identified that for embracing AR within organizations, companies might need to invest in purchasing and upgrading necessary technology infrastructure, acquire the right talent and train the existing employees, and build a centralized governance structure that can plan and monitor the usage of ARSG. Also, sufficient awareness amongst employees needs to be created to embrace AR. ARSGs could be viewed as a source of sustained competitive advantage by having the right resources, capabilities, and competencies in place in combination with a few isolating mechanisms.

In the next Chapter, interviews will be conducted with different stakeholders to verify if the findings are in line with or different from what is reported in the literature. These interviews will be part of a case study performed at Cargill, a multinational organization specializing in food, agriculture, financial, and industrial products and services. Their food safety and quality processes would be studied in detail to identify potential applications for smart glasses. The benefits and risks of these potential applications would be discussed. Lastly, resources that are required for the adoption of smart glasses would be covered. An implementation plan for aiding food manufacturing organizations in the adoption of smart glasses would be a concluding outcome based on the case study conducted.

Chapter 4

Evaluating the present setting

4-1 Introduction

In this Chapter, we describe the empirical findings collected from semi-structured interviews and information gathered through archival documents and records and direct observations as a part of the case study at Cargill. These responses provide an insight into the present setting.

To seek answers on the **first research question**, questions posed in the interviews were focused on the value drivers, barriers, and future of augmented reality smart glasses technology. To evaluate the responses, the interviews were transcribed and coded using qualitative data analysis software, *Atlas.ti*. The coding procedure is explained in Project Methodologies (2-3-2). The participants were grouped based on their work and usage in relation to augmented reality smart glasses technology.

Questions posed in the interviews for partially answering the **second research question** revolved around the edible oils supply chain, the core food safety, and quality activities at Cargill's refinery and packaging plants, and the support activity of auditing. These interviews were also transcribed. The interview guide and corresponding questions can be found in the Appendix (A-2).

4-2 Stakeholder perceptions on Augmented Reality Smart Glasses

As seen in Figure 4-1, the sample of participants who were interviewed consisted of external augmented reality developers and researchers and internal Cargill AR smart glass end-users and managers of AR smart glass end-users. The motivation behind this is that the perception of those who are in the academic field like researchers and developers, could be different from those in the industry who are more into the practical application side. The end-users in this study were employed in the Food Safety, Quality, and Regulatory (FSQR) department in the organization.

Interview #	Role
Interview #1a (TU Delft)	**Developer** working on augmented reality and virtual reality projects for academia
Interview #2a (TU Delft)	**Developer** working on augmented reality and virtual reality projects for academia
Interview #3a (TU Delft)	**Developer** working on general support, programming, and creation of augmented reality and virtual reality applications
Interview #4a (External, UvA Amsterdam)	**Researcher and lecturer** on Informatics, Computational science, and scientific visualization
Interview #5a (Cargill)	**End-User**, FSQR Coordinator
Interview #6a (Cargill)	**End-User**, FSQR Manager
Interview #7a (Cargill)	**Manager of End-User**, Plant Systems and Manufacturing Operations Manager
Interview #8a (Cargill)	**Manager of End-User**, Process and Operational Intelligence Packaging Leader
Interview #9a (Cargill)	**Manager of End-User**, Technology, Governance, Regulatory, and Compliance Lead for Compute and Collaborate

Figure 4-1: Infographic of interview sample for RQ1

To understand if the technology is suitable for an organization like Cargill, the barriers and drivers to the adoption of the technology, and the future of the technology needs to be known. This information would help us in answering the first question and determining if there is an actual need for the technology. If the barriers, for example, are too many and cannot be overcome, the organization could look into substitute technologies and take up ARSGs when these barriers considerably reduce. Also, if the future seems promising, the organization could try to come up with appropriate measures to overcome the barriers.

Barriers

Before dwelling into the fact there are barriers to the adoption of the technology, there must be someone who reports the existence of these.

> *"So it is something typically Cargill, we are cautious when it comes to adopting new technologies. Augmented reality smart glasses is an example of such a technology. This is because new technologies give rise to new risks and those need careful handling."*

-Participant 7a (Manager of End-User)

The risks that are faced could be attributed to various factors that would pose as barriers to adoption. Our initial assumption that such barriers probably exist for smart glasses is confirmed. These barriers have been further classified as technological, organizational, and ergonomic based on the information collected from interviews.

- **Technological**

  An important feature of the smart glass that seemed to be a challenge was that of the user interface. Most participants reported that they faced issues with the user interface (UI), especially when trying to arrange the application windows they opened on the device. Few participants recalled their issues of losing the virtual windows they opened in spatial space.

> *"We don't really know how to design a user friendly, augmented reality interface yet."*

-Participant 1a (Developer and researcher)

Along with the user interface, interactions that help users navigate through different windows and applications present on the device were also found to be tricky. These interactions often involve pointing and clicking, especially when they would want to join applications for remote calls, access and use the keyboard, and for general usage of the applications installed on the device. This activity would require practice to get used to, and might be difficult for older people.

> *"But also, there needs to be a lot of improvement in terms of the interaction that we're going to do with these devices. So hand interactions is probably going to be very important."*

-Participant 4a (Developer and researcher)

Amongst developers and researchers (participants 1a, 2a, 3a, 4a), the main limiting factors of the device included the field of view and computation and performance. Certain smart glasses right now have fields of view that are so narrow that the experience is comparable to having a screen floating in front of view at a distance, which is not pleasant. Narrow field of displays would also affect what a third party sitting in a remote location can or cannot see and would not be favourable for applications like auditing, where auditors would like to view a chunk of the surrounding without having to instruct the user to change their viewpoint frequently. Increasing the field of view is quite complicated because when you have a screen that contains a humans' field of view atleast, there might be issues with being able to focus on the screen (display technology). Waveguides is a type of display technology being experimented with right now, but they have a tendency to distort color as they contain layers of displays and producing it rightly requires a few trial and errors that may lead to waste. This display technology thereby, has not performed and adjusted well in darker or brighter than usual environments and sometimes may lead to a disturbing rainbow haze around the real objects which are viewed through the the smart glass. But not only does the display technology affect how the device performs in dark or bright environments, the type of sensors that are used for data acquisition also have an influence on whether the device is able to measure and estimate parameters correctly.

When it comes to producing high quality images for overlays, computation and performance of the device plays a significant role. For ARSG this seems to be quite limited because you want the device to be compact and portable. Increasing the computing power of the standalone device needs to be balanced with battery life. Sometimes, to do serious work you might need external rendering or computing power. The issues related to battery, however, seem to be application dependant as an end-user (Participant 5a) found the battery to be good for remote auditing purposes.

> *"But then the technical barriers, I think most of it is computation performance. The amount of performance required to produce the images is quite high. And because with AR you want it to be wearable, it needs to be very compact, whereas with VR, we can have a big chunky device that has a very strong processor in it or it is connected to computer. With AR, you don't want that. Second thing is cooling, actually, with the displays being that big and high resolution just in front of your eyes, being able to cool the displays to a comfortable temperature requires active cooling. And that's a barrier that we see with VR already. And with AR that will be even more obvious because then it needs to be see through as well."*

-Participant 3a (Developer and researcher)

When smart glasses for communication purposes in plants, end-users faced certain audio issues due to noisy environment. Participant 5a (End-User) states:

> *"The device has difficulties and a right solution needs to be found for the audio. There is a lot of background noise in the production environment and for communicating, you need to be able to understand someone in a such an environment."*

On the same topic, Participant 6a (End-User) who had used a smart glass for remote auditing said:

> *"When we go through the production environment, the audio was not as good because it was behind the head. And we could not hear the auditor requirements really well with the production noise."*

Employees working at Cargill are required to login to the smart glass device application with their Cargill digital ID. This ensures that they have limited and controlled access and the devices are not misused. To be able to do that and use applications installed on the smart glass, one would require WiFi internet connectivity or 4G/5G/mobile data hotspots. Based on where the plant is located and the facilities available, connectivity may be a barrier to adoption. Participant 5a asserted that they did not have any issue with connectivity in their plant when they connected the smart glass to a 3G/4G data hotspot.

On the other hand, Participants 6a (End-User) and 7a (Manager of End-User) were skeptical about using mobile data and WiFi.

> *"We could not connect the smart glass to the WiFi. So we were depending on the data from our mobile phone to make the connection and the workaround. This is an issue because sometimes you empty your data from your mobile phone and also the speed that you are going to have because of the signal can affect the audio, for instance."*

-Participant 6a (End-User)

This issue of not being able to connect to the Cargill network acts as a good segue to the organizational concerns that companies have when they make use of smart glasses.

> *"If you start walking (inside the plant), then you have all kinds of technology issues and loss of connectivity. The other big concern is at Cargill we do not allow smart glasses to get connected to the Cargill network. Meaning, lots of functionality is not available."*

-Participant 7a (Manager of End-Users)

- **Organizational**

  Because not all personnel in the organization will understand the potential risks that can arise when a smart glass is connected to the Cargill network, they protect themselves by connecting the device to other networks. Some functionalities that can be performed on the device, like opening multiple windows of information and files for quick access that are stored on the Cargill network would not be possible. So security concerns are a prevailing problem in the devices that the participants have interacted with, and they are eager for alternatives that can solve this and guarantee information protection.

  Within Cargill plants, some regions or plants are marked as ATEX locations. Essentially, what this means is that there is a possibility of explosion under certain operating conditions in such atmospheres and the minimum safety requirements are more stringent. If smart glasses are not ATEX-safe certified, they cannot be used in such regions or plants. Respondents were unsure if such smart glasses exist in the market that do not compromise on the safety of the user and can be used in ATEX zones. Additionally, according to Cargill safety standards, participants mention the need for a spotter, a person who accompanies the smart glass wearer because the glasses could be distracting.

  > *"Because according to Cargill requirements, the people wearing the glass could not go alone because you can be distracted now with a glass, so this person had to go with another person."*

  -Participant 6a (End-User)

  The organization places utmost emphasis on the safety of their employees and have the necessary precautions that must be taken. Ensuring the safety of employees also extends into the next point, where certain aspects of the device that make it uncomfortable or affect the health of the employees is discussed.

  > *"In Cargill, we cannot use smart glasses without having a spotter, that is without having somebody that is taking care of the user. The safety component is still questionable, how safe it is to walk with these glasses?"*

  -Participant 8a (Manager of End-Users)

  Ultimately, this technology is going to be changing the way in which people do their daily jobs. A mindset change needs to take place to be able to adopt smart glasses for regular usage. Participant 3a (Developer and researcher) explains:

> *"The main business thing is getting people to change their workflow, especially if they have more than five, possibly 10-20 years of experience in their fields, just being able to have them do it completely differently that's very difficult."*

Adding on, Participant 1a (Developer and researcher) said:

> *So I think a barrier which is both organizational and social, is that there is a lot of backlash from people who are not used to the technology, who are very skeptical about the use cases. I think a lot of people at the top of companies are very hard to convince that this is an actual, useful technology instead of a gimmick. Yeah, it's very hard to convince them. Also, because the ergonomics take some getting used to it's not very intuitive.*

Their concerns were rightly expressed, as Participant 7a and 8a from Cargill (Manager of End-Users) respectively stated:

> *"All of them (augmented reality devices) will be different, not only from a user functionality point of view, but also from a user acceptance point of view. Typical other thing we learned is that plant operators will never use their smart glasses. That's just not what they want to do, because it's not safe."*

> *"I mean, our operators are not using smart glasses, they are using the phone much more."*

Cost of purchasing the device was also declared as expensive by a few participants, but on the contrary, the employees at Cargill felt that for a multi-national corporation, it would not be really considered as expensive. More about this would be addressed under drivers next.

- **Ergonomic**

  The most explicit concern was the device being heavy on the head, especially when worn for long periods of time. But it still seems to be a concern for all participants across the board. Participant 9a (Manager of End-Users) said:

  > *"The weight of the device is an ergonomic challenge because we obviously in our plant locations need to have it integrated into a hardhat. So the device itself I think weighs about three and a half pounds. So what's that? A little over a kilo and a half, almost two kilos."*

  However, Participant 5 (End-User) did mention that they got used the weight over time and did not find the device and helmet heavy. Participant 6a (End-User) also resonated with the fact that the device combined with the helmet was not heavy.

  Participants 5a (End-User) and 6a (End-User) also cautioned the visual discomfort that might arise for the viewer who is watching the video stream. The person wearing the device broadcasting it to people in other locations must make sure they move smoothly and slowly.

> *"The only thing I need to pay attention for myself is to move more like a robot and not move too fast. So I also mention it (to the auditor), tell me if I need to slow down."*

-Participant 5a (End-User)

> *"I think the smart glass was much better than the mobile, and we have to be careful not to make the person in the other side sick, so move in a vertical or horizontal slow way."*

-Participant 6a (End-User)

All in all, few interviewees felt that the overall comfort and wearability of smart glasses is still not up to the mark. Customisation to the device that allows the user to adjust the smart glass according to the size of their face, or incorporate the lenses power of their normal prescription glasses, are examples of features that still need to be configured. Participant 1a (Developer and researcher) claimed:

> *"The form factor of AR smart glasses is not really ergonomic as they are still large and heavy."*

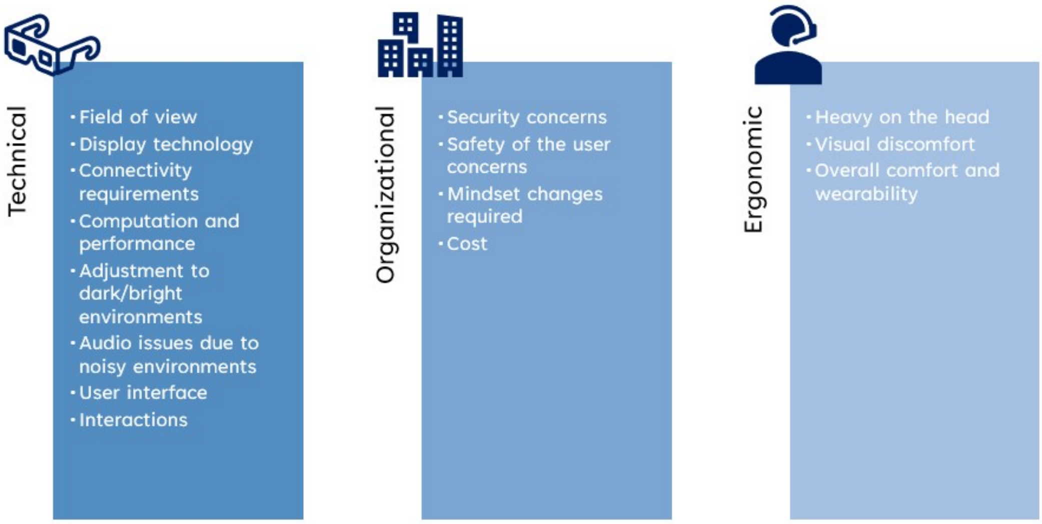

Figure 4-2: Barriers to adoption of ARSG technology collected from interviews

From the above excerpts, it is clear that there are countable number of barriers to overcome. These may have persuaded a respondent to say:

> *"But the concept that smart glass is the Holy Grail, I do not acknowledge that. I know like an alternative it's a different way of looking at information. But its totally different, so there is no real benefit. Some people will like it. It's like a color, what do you like retro green? Some people will like red, some people will like green, but there's no good or bad and I see the same with a smartphone versus a tablet versus a smart glass"*

-Participant 7a (Manager of End-User)

The next few paragraphs will explore the extent to which the above statement holds true and if smartphones or tablets are comparable alternatives in terms of what they can offer. We would see if participants know of benefits of smart glasses and what are the unique value adding components to AR smart glasses that are not present in the counterpart devices such as tablets or mobile phones where AR could be used as well.

Drivers

The initial question was to find out in general, what were the benefits of smart glasses. Participant 3a (Developer and researcher) had some thoughts on how useful AR smart glasses are for information overlay which are as follows:

> *"So in terms of AR, the ability to overlay on the real world, there's so much benefits that you can have from that, because you don't have to create a virtual world, you can make use of the entire environment that we already have and add to that. In case you want to do anything on all of the other platforms (VR) I mentioned before, you need to recreate reality, whereas with augmented reality, you don't have to be quick. So it's kind of a very efficient way of incorporating data into our lives."*

The possibility of information overlay also leans into another value driver of smart glasses, which is enabling visual documentation and process tracking. According to Participant 1a (Developer and researcher), this ability of smart glasses can reduce the operators dependancy on physical resources. They said:

> *"Augmented reality reduces your dependency on physical resources. So let's say if you want a workspace, well, normally, you're limited by the amount of monitors you have. But in augmented reality, you could just plan, let's say, a whole grid of interactive monitors. So yeah, it allows you to do more with less resources."*

Along similar lines, Participant 3a (Developer and researcher) combines the benefits of information overlay and visual documentation and process tracking with another perceived value driver of smart glasses, which is being able to provide contextualized information. They described:

> *"Let's say you have an instruction set, being able to project instructions onto something real, being able to detect this step that you're in and then adapt instruction sets, being able to train using AR being able to see things that you cannot normally see, all of that is basically just the growth of this technology."*

> *"I think that the biggest added value is just to have data at your fingertips. You don't have to go out of context."*

-Participant 2a (Developer and researcher)

Participant 7a (Manager of End-User) also agreed that augmented reality can be used to provide additional information to people not only in the plants, but also in the office.

AR smart glasses gives more room for exploration and discovery about 3D objects, how they are made, and for marking comments without having to hold a phone in your hands.

Participant 5a (End-User) was impressed by the flexibility in training and communication it offers. They said:

> *"If you want to see production, at this moment, I'll just grab the smart glass and go into production, it's very easy. The good thing is on the device, it's easy to communicate with the auditor. If you want, you can also see him during the live tour because sometimes face expressions tell a lot. You can call directly on a MS Teams call, it's very easy. You can also share the tour together with other people besides just one."*
>
> *"We had a certification audit on the refinery and the auditor was not on site. It was a remote audit and they wanted to see something. So we made an agreement for a second audit and I used my smart glass, so they can see whatever they want to. That's what I mean with the flexibility."*

Participant 6a (End-User), a colleague of the previous participant at Cargill shared similar views on the device and the flexibility it offers for training and communication. They claimed that:

> *"The experience (of using AR smart glasses for remote audits) was super good. Also the fact of being able of putting circles or marks in the screen to see things that the auditor wanted to go further or wanted to later on to go back now. This is very good."*

On training, Participant 8a (Manager of End-User) was enthusiastic and hopeful. They expressed:

> *"So, we believe that the next step of trying to train our personnel in operating our line is to do it digitally."*

> *"It's (smart glasses) also creating an easy way to communicate with experts."*

The above quote indicates how smart glasses could enhance engagement with employees, which could be a beneficial feature of smart glasses. Participant 5a (End-User) was also excited about these possibilities. They explained:

> *"It (smart glasses) can be useful to share knowledge between different Cargill locations to see how other plants look like and to share experiences."*

Some employees within Cargill are already digitalizing their standard operating procedures. According to Participant 8a (Manager of End-User), AR smart glasses could be used to host the standardized workflows and provide digital instructions through information overlay to operators.

When respondents were asked about what they think was the value adding feature of smart glasses alone that is not provided by the counterpart devices where AR can be used such as smartphones or tablets, their responses were quite varied. The key benefit according to Participant 3a (Developer and researcher) was still the ability of smart glasses to provide information overlays. They asserted:

A similar question was posed to Participant 1a (Developer and researcher) who stated that the immersion experience and depth perception is superior when it comes to smart glasses. They claimed:

> *"If I'm looking at a smartphone, it doesn't feel like I'm actually looking at it. Because there's no awareness of the spatial components, what you're looking at. You're seeing the real world which is 3D, as a 2D projection and you're automatically losing information."*
>
> *"This (stereoscopic display) allows you to see something in distance and allows you to feel like you're actually there. Also, smart glasses allow you to interact with augmented reality inside of the augmented reality. If you're interacting on a smartphone, you're again interacting on a 2D surface with 3D objects. Smart glasses allow you to interact with them in 3D already."*

Similarly, Participant 4a (Developer and researcher) commented that smartphones are limiting in terms of binocular disparity. Smartphones are being used with their camera for a see through augmented reality picture, but most smartphones have only one camera, so the view is limited to a monoscopic view that does not have depth perception. This would also mean that one cannot interact with objects that have a depth perception necessity. Participant 7a (Manager of End-User) pointed out that the only reason to use smart glasses over smartphones is your ability to be hands-free when performing activities. Participant 2a (Developer and researcher) also strongly agreed to the above the statement.

Apart from these drivers of the technology, Participant 3a (Developer and researcher) made a striking remark on how cost-effectiveness would be one of the deciding factors that could drive adoption in organizational settings:

> *"I think with any technology, there are always organizational barriers, because people need to be trained. We see it with with VR as well, there's a difference between younger people and older people, how they react to the content and how they react to wearing the device, a different way of interacting with stuff. So there's going to be training involved, there's going to be serious investments involved. And I think for adoption to succeed in that sense, it needs to be proven that business wise, it's cost effective, including the training, including all of the courses, including the storage and everything."*

They also derive insights from research on VR that prove that VR devices are cost-effective, especially for employee training. They add:

> *"So if it's top down, it needs to be cost effective, then usually there can be top down and from bottom up, either it's going to be very disruptive, so completely new companies coming in or I do not really see it being adopted."*

Select employees at Cargill were affirmative on smart glasses being cost-effective for their business. They were familiar with using the technology for remote audits, and despite the challenges were quite amazed by the abilities of the device. They were convinced that it compensated for one time expenses of travel and accommodation for auditors, and so in the long-run, it would definitely be profitable to use the device as a replacement for on-site

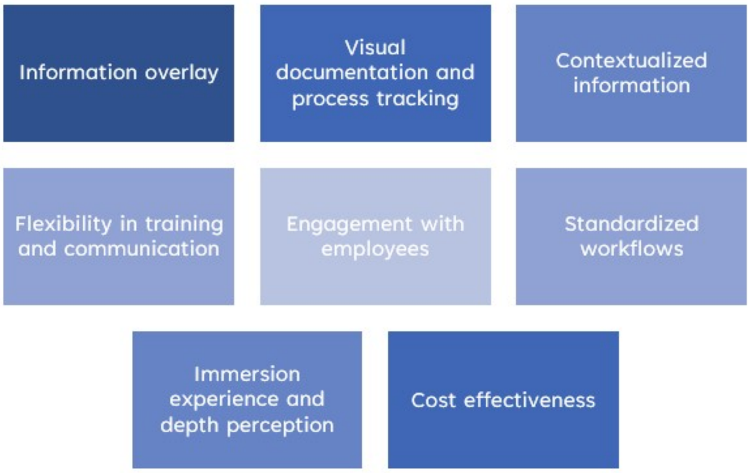

Figure 4-3: Value drivers motivating technology adoption collected from interviews (Authors' own interpretation)

auditing. Not only did they hint on cost-savings, they were also positive that it saved a lot of time.

> *"You see, auditors are asking questions regarding the system (augmented reality smart glasses setup) next to the audit part they need to do, because they are really interested in it. For them, it's also saving a lot of their time. Most of them are done from external countries, the last one (auditor) was from England. If that person needs to travel to Belgium (Cargill plant) and book a hotel, you have a lot of time they spend just on traveling."*

-Participant 5a (End-User)

COVID-19 was also a major influence in adopting these devices as countries had their own travel restrictions, and organizations were also trying to limit people from working on-site. During these times, employees felt using these smart glasses were very helpful. Though the auditing experience was not exactly the same, using smart glasses for remote auditing served as a good alternative. In the end, Participant 9a (Manager of End-User) felt the costs of the device were justified and claimed:

> *"I mean, the devices are averaging what, three to five thousand US dollars. So if you're a smaller company, I'm sure cost is an issue but from a large corporate standpoint, cost isn't an issue. And in the long run, the cost savings justifies the cost, if nothing else, like for PLC support (a smart glass use-case), right. If I don't have to have the technician come from Germany, to France, or Germany to the UK, I've essentially saved. The devices paid for itself."*

Future of the technology

> *"The only question that I have is, what is the next step? Because as I mentioned, what is interesting for us is the application on augmented reality, not only the smart glasses. I mean, our operators are not using smart glasses much, they are using the phone more."*

-Participant 8a (Manager of End-User)

Cargill, an organization active in the food industry could also be considered as a late adopter of AR in comparison to other industries such as manufacturing. Accordingly, AR as a domain seems to have attracted attention at the beginning of COVID-19 crisis at Cargill. They were introspecting the use and need for ARSG in the organization back in early 2020 already. Within the context of the organization and the hype cycle, this phase could be noted as the innovation trigger phase. Subsequently, the innovation trigger phase was also crossed as the crisis acted as an external trigger and created a growing interest in ARSGs for the use case of remote auditing (plant visits). During COVID-19, companies were functioning with lesser employees on site, and due to strict travel regulations it became difficult to arrange for food audits in plants. Some enterprises like edible oils within Cargill started experimenting with ARSGs for providing a view of the plant site and operations to auditors and leaders in the organization who were stationed at far away locations. Through word of mouth and success rate of audits they had conducted, and with COVID-19 accelerating adoption, a general hype for AR exists within the organization. Including above characteristics, others such as the device suppliers of ARSG to Cargill being able to provide a few cases of ARSG, Cargill purchasing from high-end suppliers, and the innovation team within the organization conducting workshops on the technology goes to show how AR is surpassing the peak of inflated expectations.

Currently, Cargill is looking to derive meaningful value from the ARSG device beyond just using it for remote audits. They are also evaluating between different AR devices and suppliers. The organization is doubting the potential of ARSG and has entered the trough of disillusionment. Referring to the hype cycle, in this stage, AR failing to meet the high expectations and over-enthusiasm can be anticipated.

Participant 1a (Developer and researcher) feels that when it comes to AR smart glasses, overcoming certain barriers may automatically resolve a few others. In addition, they believe that smart glasses would be an enabler for human-robot interactions in the near future. Participant 2a (Developer and researcher) predicts that field of view and battery improvements would contribute in increasing ergonomic value. They also conveyed that most computing processes might take place on cloud, and 5G would play a role in solving the connectivity issues. Further, they mentioned that a good UI experience would also be essential to accelerate adoption. According to Participant 3a (Developer and researcher), Moore's law would facilitate resolution boosts and devices would get smaller, especially display technologies which are quickly adapting. Adding on, Participant 4a (Developer and researcher) hinted that a lot of work needs to be done, in the realms of speech recognition and producing sounds to give information in an audio fashion, and also held similar opinions as Participant 2a on how cloud technologies for computing and 5G for wireless communication is going to be transformative for the AR smart glass experience. Participant 4a is very positive and confident that AR smart glasses are going to become an indispensable part of our daily lives.

Almost all four developers and researchers in the sample pool expressed their anticipation and eagerness for an optimal pair of smart glasses that is yet to be released in the device market. Two of them feel that certain organizations are carefully observing other smart glasses being subjected to scrutiny and taking their time to introduce a smart glass device that are significantly better, especially in terms of guaranteeing more privacy. One participant in this pool was also certain that the devices would be more expensive, but would provide the much needed friendly UI. Amongst developers and researchers, an average estimate of 5 years would be required for the release of an optimal version of the technology and a much more mature technology.

So far, the challenges, value drivers, and future of the technology was explored. In the upcoming section, interviews were conducted with employees at Cargill to understand the food safety and quality processes, and potentially identify use cases for smart glasses that can utilize the value drivers of the technology.

4-3 Studying the food safety and quality processes at Cargill

The first course of action was to understand edible oils Food Safety, Quality, and Regulatory activities, manufacturing processes, and where do the edible oils activities take place within refinery and packaging plants at Cargill in Europe. For this, a set of six people working in these domains were interviewed. Their profiles are as follows:

Interview #	Role
Interview #5a (Cargill)	**FSQR Coordinator**, Packaging
Interview #6a (Cargill)	**FSQR Manager**
Interview #1b (Cargill)	**FSQR Coordinator**, Refinery
Interview #2b (Cargill)	**FSQR Lead**, Refinery
Interview #3b (Cargill)	**FSQR Auditor**
Interview #4b (Cargill)	**Regional Supplier and External Manufacturer (S&EM) and Audit Leader**
Interview #5b (Cargill)	**IT Management Trainee**

Table 4-1: Interview sample for RQ2 and RQ3

To learn if there was a differentiation between food safety and quality, participants were questioned on the same. Participant 5a (FSQR Coordinator) mentioned how food quality, for the specific edible oils areas reviewed, was aimed at the upkeep of color, solid fat content, melting points of product, etc. that are qualitative indicators and if there is a deviation from standards in any of these indicators, it could not possibly harm the consumer. These deviations are not preferred however, because there are certain customer requirements that need to be met. When we speak about food safety, parameters of interest are concentrations of pesticides, dioxides, and other contaminants that could actually harm consumers. Participant 1b (FSQR Coordinator) and 3b (FSQR Auditor) also agreed that food quality indicators are more aligned on meeting customer specifications which have an impact on how the finished product looks or taste, for example. Whereas food safety focuses on eliminating foreign objects, bacteria, pathogens, or other chemicals that may have a significant impact on the health of the people, and can sometimes even lead to death. For ensuring food safety within plants, Cargill uses HACCP as a foundation. Participant 5a (FSQR Coordinator) said that PRPs or pre-requisite programs are the basics of a food safety system, which is regarding the maintenance of equipment used, training that needs to be given, pest control, personal hygiene that needs to be maintained, state of the building, and glass and wood policies. They also explained about OPRPs which stands for operational pre-requisite programs and CCPs which stand for critical control points and the difference between PRPs and OPRPs, CCPs. If something goes wrong at OPRPs or CCPs, it will most definitely lead to an incident on food safety. Along different points in production and packaging, they have set OPRPs and CCPs in place that ensure that the food they manufacture is safe for consumption packaging they utilize does not affect the food quality. Participant 5a (FSQR Coordinator) stated the following as a distinction between OPRPs and CCPs, to which Participant 1b (FSQR Coordinator) also agreed:

> *"The CCP is fully automatic control. For example, if the temperature of a tank is critical during a process, you have an automatic measurement of the temperature. You can set different levels (standards) and if it goes over that temperature or underneath, an alarm will go off. This is a CCP. If an operator needs to go every hour and measure it (the temperature), there is a certain procedure behind it, then it's an OPRP."*

The quality of the product, along with additional safety is controlled by performing checks on the sample at the laboratories. The parameters of interest to the customer are measured at the appropriate in the laboratories to ensure they are satisfying the order specifications.

Edible Oils Supply Chain

Participants 5a (FSQR Coordinator), 2b (FSQR Lead), 4b (Regional S&EM and Audit Leader), and 5b (IT Management Trainee) provided an overview of typical edible oil supply chains at Cargill. At Cargill, the seeds from farmers are collected and transported to a buying station. The feed that arrives to the buying station could also be acquired through brokers or middlemen who have more contacts with farmers. The collected raw seeds feed is then sent to a crushing mill for extraction of crude oil. Inside the crushing mill, the seeds are cleaned and dried, and foreign objects are removed from them. The seeds are separated from the hulls and then crushed. The hulls may be gathered to be used as feed for animals. The crushed crude oil is then exported via ships to the refinery. Additionally, if there is an increased demand for a certain type of oil, Cargill may also buy these crude oils from select vendors or third parties and those are sent to the refinery as well. Within the refinery, the crude oils undergo an extensive set of chemical processes that transform the raw crude oils to refined oils. These refined oils are then sent to packaging units through pipelines where they are bottled based on the quantity requirements of the customers. There is also a possibility to create blends by adding additives in the packaging unit based on the requests placed by customers. Again, there is a possibility of Cargill purchasing refined oils from other vendors or third parties who transport the oils through trucks to their packaging units for blending and bottling. These bottled units are then sent to the storage facilities, where orders are picked in time and distributed to purchasers.

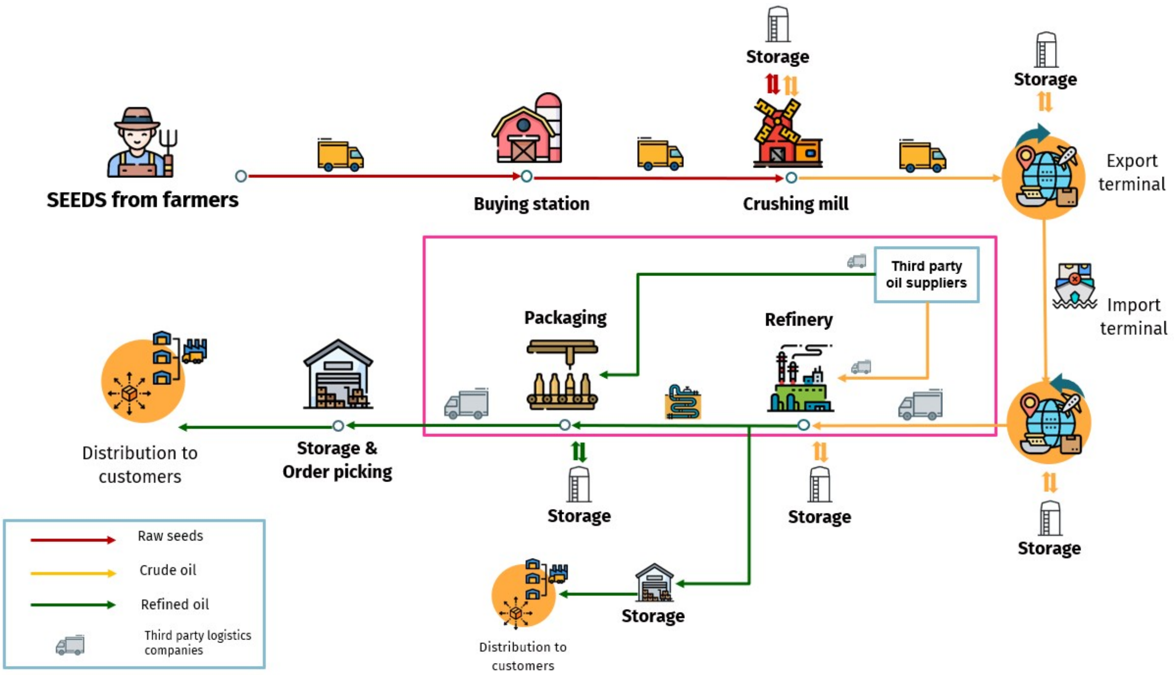

Figure 4-4: Cargill edible oils supply chain (Authors' own interpretation)

Moving on, based on the explanations of Food Safety, Quality, and Regulatory, activities and manufacturing and production processes above, Participants 1b (FSQR Coordinator), 2b (FSQR Lead), and 5a (FSQR Coordinator) who were active in the Cargill oil refinery and packaging plants at a location in Europe were interviewed on the FSQR interventions. The focus was limited to these refinery and packaging units and the FSQR interventions in these plants due to ease of access to information and the ability of participants to respond in time. Also, this supply chain and participants at this location had previous experience with smart glasses and were familiar with the technology. They had tested the device for certain applications like auditing frequently. They had meaningful interactions about the pros and cons of the technology already and were actively participating in discussions regarding smart glasses to resolve their issues. It would have otherwise been difficult as the technology is quite novel and requires some basic training and getting used to. Since they were familiar with the technology, they also had a positive outlook and mindset when it came to brainstorming about the use cases. Their contributions are therefore, very relevant.

FSQR activities in the Refinery plant

Samples of crude oils that arrive in trucks are sent to labs for conformity checks. Additionally, trucks are also inspected unloading the crude oil in storage tanks. The crude oil is then subjected to a series of chemical processes such as neutralization, bleaching, deodorization and is finally cooled before it transforms into an edible oil. This oil may also be blended with additives. Refined oil is loaded into trucks or sent to packaging units via pipelines based on the demands of the customer. Relevant PRPs, OPRPs, and CCPs are present along the refining process to ensure that the safety and quality of the final product is maintained. If there are deviations in the PRPs, OPRPs, or CCPs the operators would notify this to their managers. A more descriptive version of these activities can be found in the confidential appendix.

FSQR activities in the Packaging plant

Once again, sample of refined oils that arrive in trucks undergo conformity checks in the labs. The trucks are also inspected before the oil is sent to storage tanks. In the packaging unit, the bottles are arranged in the assembly lines and oils are filled in. The bottles are capped, labelled, and transferred to boxes and stored in warehouses. At the right time, the orders in boxes are picked and transported to the customers. Relevant PRPs, OPRPs, and CCPs are present along the bottling process to ensure the safety and quality of the final product is maintained. If there are deviations in the PRPs, OPRPs, or CCPs the operators would notify this to their managers. A more descriptive version of these activities can be found in the confidential appendix.

Auditing

Apart from food safety and quality management systems, there are other processes such as food auditing where inspectors visit plant sites to monitor their practices, PRPs, OPRPs, and CCPs. Though food safety and quality is ensured through HACCP and laboratory testing, Participant 5a (FSQR Coordinator) illustrated the need for auditing practices that help in keeping a check on food safety management systems at plants and work on continual improvement of practices. They claim:

> *Food Safety and Quality is set up and maintained but local business audit is something like a support. Imagine if you have a picture of a mountain, and you have a ball rolling up, that's on how more developed you get on your food safety and quality. If you don't put something behind it, the ball will fall down. Audits are done each time putting some plates behind the ball to make sure the standard is keeping on track and there is a verification. We have therefore our internal audits, external certification audits, and customer audits, as support and to see things from a different perspective. In the best case, they help us see gaps we missed and reach the next level.*

Above is Figure 4-5 that represents Participant 5a's (FSQR Coordinator) opinion on the process auditing which is treated as a support activity. In addition, Participant 4b (Regional S&EM and Audit Leader) who is experienced in the domain of auditing also gave their inputs on the responsibilities of auditing teams and employees. As FSQR auditors, they are responsible for approving the suppliers of materials (ingredients, additives, food contact material and others) that are being used in the production and packaging facilities. They are also responsible for approving external manufacturers who support Cargill in producing an end product they would sell in the market. They go over the food safety and regulatory aspects

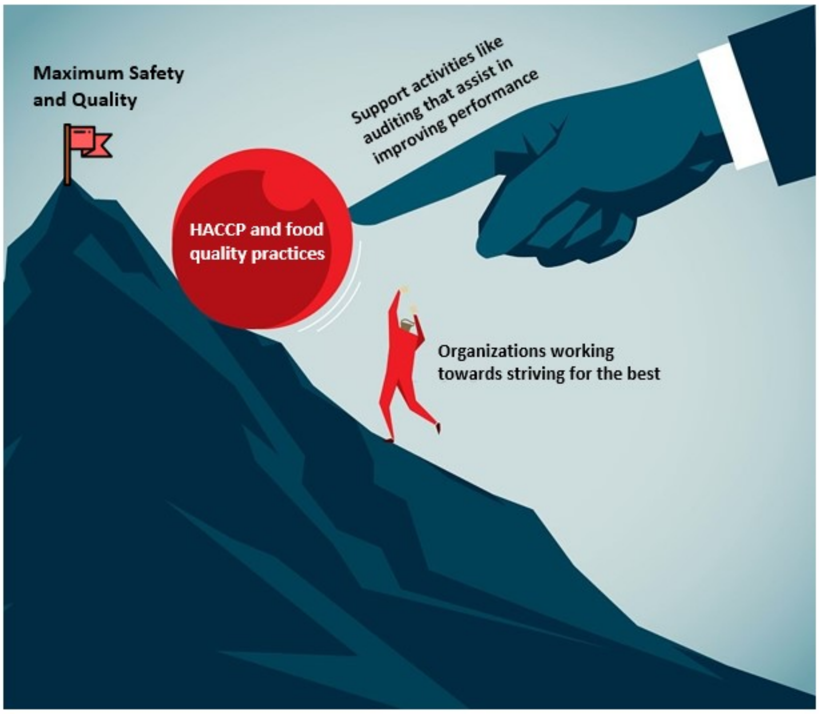

Figure 4-5: Need for auditing practices to maintain food safety and quality (Authors' own interpretation)

during approvals and check if the products, suppliers, and processes are compliant. Suppliers and materials are categorized as low-medium-high risk products and suppliers. Based on the combination of risks, the auditing team decides on the frequency of audits (risk-based approach). This is one type of audit that Cargill conducts on its suppliers. Another type of audit is when the production facilities and packaging units of Cargill need to be audited by the customers of Cargill, also known as customer audits (second-party audits).

In principal, audits could be carried out all along the Edible Oil Supply Chain, but they are based on risk assessments that indicate if audits are required in the first place or not because it is close to impossible to audit the large multinational supply chains of Cargill. To manage the risks, they try to analyze the problems as early as possible to prevent propagation and magnification of the risk, basically nipping the problem at the bud. The auditing process usually follows three steps: pre-reading of documents, documentation review, and physical audits. The auditor pre-reads documents that contain information on previous audit findings and management review, organizational charts, HACCP program, etc., for example, two to fifteen days before an audit. Following this, an auditor has to also review detailed technical documentation on contaminants monitoring, customer complaint, quality policies and plans, fraud assessments, etc. and go over questions they have from the pre-read documents. This step usually happens two to three times with each session lasting for two to three hours. Finally, a physical audit takes place where the auditor tours the plant for a maximum of half a day. There is also additional factory inspection and items to be checked on-site in some cases if auditor feels that they may have to revise the topics discussed during the pre-read or documentation review stages.

4-4 Conclusion

This chapter consisted of semi-structured interviews and information gathered through archival documents and records and direct observations as a part of the case study at Cargill. The aim was to evaluate the present setting on what participants perceive of augmented reality smart glasses. Additionally, understanding the edible oils supply chain and the food safety and quality business processes (including auditing) at Cargill was also vital.

To discover answers to the **first research question**, the sample pool consisted of external academicians and developers from universities in the Netherlands and internal employees from the organization of Cargill. Participants answered questions on their perception of augmented reality smart glasses, what from their experience and research constituted as barriers and value drivers that influence the adoption of the technology and about the future of the technology. The barriers identified through interviews were categorized as technical, organizational, and ergonomic based on how it was already classified in literature. A few unique value drivers that are unique to having an augmented reality experience in smart glasses and may influence the adoption of the technology include the immersion experience and depth perception it offers and the ability of the device to overlay contextualized information. Few developers and researchers also felt that the optimal version of smart glasses that provides customers an opportunity to experience the value drivers without being skeptical about the barriers has still not been released in the market. Though developers and researchers were positive and believed in the potential of the technology, those in the industry felt COVID-19 heavily influenced the adoption of the technology and were eager to recognize more use cases. This led to the review of Cargill documentation and archival records and the next set of interviews with employees from this organization to understand their edible oils supply chain and FSQR business processes. The motivation for this was explicitly mentioned.

Cargill's edible oils supply chain proceeds by purchase of seeds from farmers that are transported with the help of trucks to the buying station and then to the crushing mill where they are stored and ultimately crushed to extract the crude oil. This crude oil is then transported through through trucks again to a export terminal. From the export terminal, the crude oil is shipped to a location where a corresponding refinery of Cargill is present. At the refinery, crude oil from third party suppliers may also processed. The crude oil gets converted to a refined oil through a series of chemical processes and is sent to the packaging unit where it is bottled based on the customer requirements. If the refinery and packaging units are located close to each other, pipelines are used to transport the refined oil. Finally, the bottled units are stored, orders are picked, and distributed to the customers. The FSQR business processes within the refinery and packaging units (manufacturing environment) were explained in great detail through interview inputs and relevant documentation and records. Thereby, answers to the **second research question** was also found.

In the upcoming section, opportunities for digitalization within the FSQR business processes in the refinery and packaging units and associated benefits and risks would be explored, along with the resources required. An implementation plan for adopting smart glasses for food organizations will also be drafted.

Chapter 5

Imagineering use cases for digitalization

5-1 Introduction

In this chapter, based on the discussions on the technology, Cargill's edible oils supply chain, and relevant FSQR business processes identified in the previous chapter, potential use cases for digitalization will be suggested and validated for feasibility by Cargill employees. These findings will complete the answer sought for the **second research question**. Subsequently, to answer the **third research question**, unstructured interviews will be carried out to discover benefits and risks associated with each use case. These benefits and risks are process-related, that is, when augmented reality smart glasses are used for the use cases, the possible ways in which it could affect the process is of interest. The barriers and value drivers that influence the adoption of smart glasses were established in the previous chapter already.

Following this, resources (tangible and intangible) required to adopt smart glasses for implementing recognized use cases will be addressed. Semi-structured interviews will be carried out for the same and the responses would account as findings for the **fourth research question**. The interview guide that consists of the questions posed to interviewees can be found in the Appendix under A-2.

A value complexity matrix will be utilized to categorize the use cases described previously based on their business value and implementation complexity, for which a few assumptions were made. Finally, an implementation plan will be created that provides a roadmap to adopt the technology for organizations (especially food manufacturing) that are in the early stages of technology assessment and use case ideation.

5-2 Possibilities for digitalization using smart glasses and its implications

> *"Talk to the user in the early phase. Do not assume that you understand what the user wants but ask the user what he wants, voice of the customer is very important in this."*

-Participant 7a (Manager of End-User)

Based on brainstorming workshops with Participants 5a (FSQR Coordinator), 1b (FSQR Coordinator), 4b (Regional S&EM and Audit Leader), and 5b (IT Management Trainee) on the current food safety and quality processes, six potential use cases for ARSGs for enhancing FSQR and FSQR-related activities were identified. These use cases were also reviewed for feasibility and verified by Participant 6a (FSQR Manager) who had a similar job profile to previous participants 5a (FSQR Coordinator) and 1b (FSQR Coordinator) but is employed at a different production site. They had also made useful contributions and shared their knowledge on these use cases. In the coming paragraphs, a description of these use cases, along with *process-related* benefits and risks when ARSGs are used to improve FSQR activities will be provided. An important thing to note is that most of the benefits (drivers) and risks (barriers) that arose because of the usage of the *technology* have already been covered in section 4-2.

Use Case #1: Workflow Sign-off

When the trucks arrive at the refinery or packaging location, they have to be authorized and inspected. In this process, operators have a checklist of items they need to inspect about the truck, jot it down on paper and forward it to FSQR to keep records and also notify them if there are any issues with the truck and the materials in it. Certain information about the truck specifications also has to be captured and registered on paper. Before a truck is loaded with the end products and transported, similar truck inspection processes are conducted. This process could be carried out with the help of smart glasses where in the operator is able to view the required checklist on the device, enter the required data, and store a soft copy of the document with the information. Additionally, videos of the operators performing these job duties could be recorded for future reference purposes as proof to see if regulated steps were followed.

The benefits of using smart glasses for workflow sign-offs (checklists and documentation entries) were identified.

They included the fact that there would be no loss of filled paperwork as most of this would be done with the help of smart glasses on a file that could possibly be stored online or on the device. It would also become easier to track electronic copies of documents when compared to paperwork and using the keyboard on the smart glass to enter data would prevent confusions that arise due to bad handwriting. The ability to record the actions carried out by the operator during this process would ensure that accountability is maintained. These recordings would be a supplementary, nice-to-have feature as currently no such videos are taken. Since all employees would be following the same way of working assisted by a smart glass, they would not be able to skip any checks (if they are forgetful, then their chances of skipping checks exist). This uniformity would reduce possible mistakes and rework.

Participants shared their views on the possible risks of using smart glasses for workflow sign-offs (checklists and documentation entries)

Since a considerable number of operators need to make use of smart glasses, they could misuse, mishandle and damage, or lose the device. If the device falls off from the head of the operators when they perform checks, it is not favourable. They would also need to keep an eye out for real-life danger, which would not be possible if they are completely immersed in the augmented reality experience. Operators becoming too dependant on the device was also a risk that was recognized. Storing very long recordings of all the trucks that are inspected would require a lot of storage space and when operators are continuously shifting between inspections, the entering of information with glasses should also be agile.

Use Case #2: Quality and safety checks in labs

Once the barge with crude oil arrives, a sample of it is taken to assess the quality parameters within the lab. For these assessments and other sample checks along the manufacturing and packaging process, there are standard operating procedures (SOPs) that lab technicians and quality analysts must follow for testing the sample. These procedures and possessed tacit knowledge could be converted into instructions with help of a software (custom-made guides). These instructions could be viewed from the smart glass in front of the users eyes through an application that would guide them through preparing the sample for different tests and conducting the tests. They would be able to track their process and execute their tasks in a sequential manner. Further, the laboratory information management system that is currently being used could be installed on the smart glass either directly, or using a compatible application that would provide access for storing data on the test results.

The benefits of using smart glasses for quality and safety checks in labs were identified.

Not having to look to written notes and SOPs on how an analysis is to be performed and instead be guided through the process was perceived as a huge benefit. Sometimes, one might need to refer to old documents or papers that have information on the how-to's, especially for processes that do not happen frequently like equipment calibration or creation of solvents. If smart glasses are used to view and access these documents or papers, it would reduce the user's dependence on physical copies of documents that may be difficult to refer to when preparing or testing a sample. They would also be able to access the information much faster. Even when employees join, they could adapt to this and make lesser mistakes. Intuitively, it would be easier to view the document on a screen in front of you and simultaneously and carry out the operation. There are also chances of spillage or accidents happening in the lab due to which documents and the workplace might get destroyed, which could be potentially avoided.

Participants shared their views on the possible risks of using smart glasses for quality and safety checks in labs

Few people might get distracted due to the device that could affect their quality of work. The concern that employees would become dependant on the smart glass for feeding them with instructions was also recognized as a risk.

Use Case #3: Remote assistance

With the help of a video calling software that could be installed on the smart glass, employees and operators at the plant could get in touch with experts across the globe. Both the audio and video capabilities would allow workers to interact with other colleagues to seek assistance on complex issues, such as problems with higher concentrations of contaminants for example, or get support from suppliers when they face some technical issues on the equipment in the lab. They would be able to provide a visual scenario of what is happening in any location, showcase the sample results to discuss on what actions need to be taken if there abnormalities, get in touch with colleagues if the shipment that has arrived in trucks have certain defects. The possibilities of using the device for remote assistance within plant environments are many, but for FSQR, some examples have been highlighted above.

The benefits of using smart glasses for remote assistance were identified.

Getting a second opinion when needed and being able to flexibly troubleshoot were few of the advantages of using smart glasses for remote assistance. Additionally, the costs of having an expert travel to the plant location may also be saved.

Participants shared their views on the possible risks of using smart glasses for remote assistance

The risks reported for this use case were close to none, apart from making sure that the user does not get too distracted or immersed within the smart glass environment such that they are not able to keep an eye out for danger in their surroundings. Their safety should be considered, especially if they are going to make use of it in plants where there are a lot of buttons, sharp edges, or sensitive/high-risk equipment.

Workflow sign-off (truck inspections)

Workflow sign-off	
Benefits	*Risks*
No loss of paperwork, tracking and tracing of documents is easier	Misuse/Mishandle/Damage the device, Device might fall off from the head during movements
Recording the actions of the operator	Keeping an eye out for real danger might not be possible, operators might become too dependent on the device
Digitized workflows provide a uniform way of working	Requiring large amounts of storage space

Quality and safety checks in labs

Quality and safety checks in labs	
Benefits	*Risks*
Ease of access to information while performing tests	Distractions due to the device may affect the quality of work
Reduction of user dependence on physical copies of documents	Increased dependence of user on the device for instructions

Remote assistance

Remote assistance	
Benefits	*Risks*
Ability to collaborate when needed and flexible troubleshooting	Distractions due to the device
Cost efficient as technical experts need not travel distances	Keeping an eye out for real danger might not be possible

Instructional training

Instructional training	
Benefits	*Risks*
Align duties of operators and create awareness	When technical issues arise, the training might come to a halt
Comprehensive understanding and overcoming cognitive barriers	Keeping an eye out for real danger might not be possible

Figure 5-1: Overview of benefits and risks for use cases of workflow sign-off, quality and safety checks in labs, remote assistance, and instructional training (Authors' own interpretation)

Use Case #4: Instructional training

Within the refinery and packaging plant, there are certain tasks such as cleaning and changing of filters or preparing additives for blending for which on-demand training videos could be accessed from the smart glass. Augmented reality information would then overlay their real world and help in making the tasks more interactive. Additionally, if these step-by-step training videos are guiding the operators, one could also connect these to a software that would provide workflow analytics. If smart glasses are used this way, then organizations would also have the ability to identify process improvement opportunities.

The benefits of using smart glasses for instructional training were identified.

Smart glasses used in this context would align all operators their duties and create awareness. The managers would also develop more trust in them as each step would be done properly. A visual aid during training will help employees overcome cognitive barriers and provide comprehensive understanding to the operator.

Participants shared their views on the possible risks of using smart glasses for instructional training

Again, the risks reported for this use case was close to none. Participants were worried that tasks may get delayed or take more time if the smart glasses do not switch on due to technical issues, especially if operators are dependant on these. And of course, operators should be more careful while making use of these in plant environments and keep an eye out for danger else accidents could occur.

Use Case #5: On-site inspection

Within the packaging plant, towards the end of the production line, the bottles get capped, labelled, and boxed. During these stages of packaging, the operators have to ensure that the reference number on the cap, label, and the bottle are the same as the numbers on bill of materials. Operators could use augmented reality smart glasses to view the bill of materials through the display in front of them. Another potential possibility is to have a barcode printed on the packaging that could be detected by the device. In the back end, the information on the bill of materials could be stored into a document that is associated with the printed barcode. Once the smart glass detects the barcode, it could automatically inform the operator if the details are correct or if there is an error.

The benefits of using smart glasses for on-site inspection were identified.

By using the device, there is a proof that the end-of-line checks in packaging has taken place. There is currently a manual intervention to perform this verification and cross-check, which could lead to errors if the operator is distracted or makes a mistake. It makes the duty of the operator easier.

Participants shared their views on the possible risks of using smart glasses for on-site inspection.

If this arranged system of barcode linkage to the database is not correct, it could lead to problems. Apart from this, no other process related risks exist.

Use Case #6: Auditing

Within auditing, there are two sub use-cases, one of which is in-plant audits. When in-plant audits are conducted, there are documents that auditors need to pre-read and review. When an auditor arrives at the plant location, they could utilize smart glasses to access their documents of interest or refer to regulatory standards. They could also additionally make notes of their observations and comments on the device directly. Since they would have certain structure to their evaluation, with a help of a software, this structure or form could be viewed on a screen directly in front of the auditor with the help of smart glasses. They could

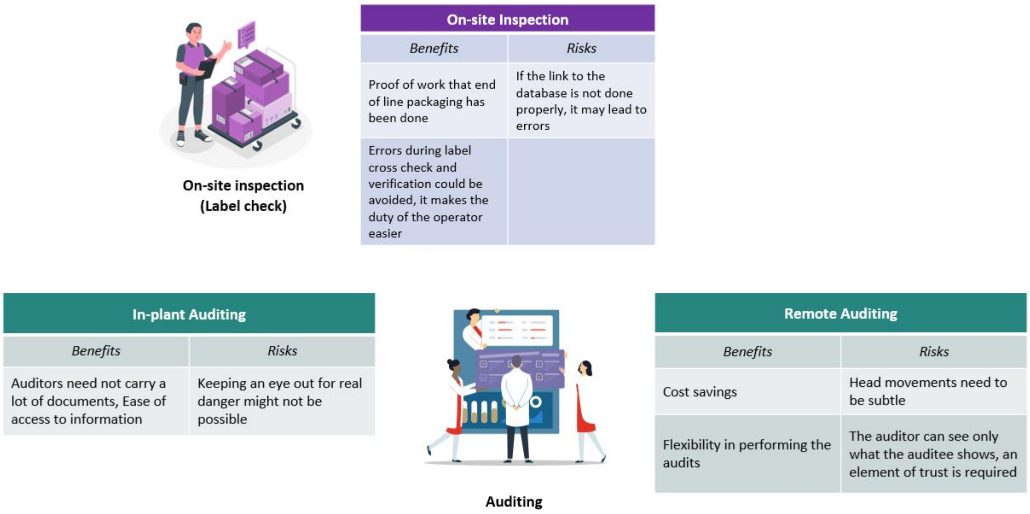

Figure 5-2: Overview of benefits and risks for use cases of on-site inspection, in-plant auditing, and remote auditing (Authors' own interpretation)

also have guides prepared that could be loaded on the device and would help the auditor execute their tasks in a sequential manner. Secondly, in remote auditing, an employee in the plant wears the device and shows around the areas of interest to an auditor who is situated far from the plant location.

The benefits of using smart glasses for auditing were identified.

For in-plant audits, the auditors may have ease of access to information and they need not carry a lot of documents. The case of remote auditing would save a lot of travel and accommodation costs of the auditor for the organization. Auditing becomes a more flexible process as one could split the auditing into different sections and conduct it according to convenience and availabilities of both parties. Finally, it provides the auditor a quick way to see something.

Participants shared their views on the possible risks of using smart glasses for auditing

During in-plant audits, keeping an eye out for real danger might not be possible. During remote auditing, the auditee must make sure they are not moving too fast or moving their head abruptly. The fact that the auditor can see only what the auditee is showing is a risk that cannot be ignored. This could be solved if the auditor is provided a map of the plant or has seen the plant before, but if they are auditing a plant for the first time, plants are quite big and complex to understand. There are chances of auditors overlooking some details because the auditee is not transparent enough. An element of trust plays a huge role in such processes. If smart glasses are being used for in-plant auditing by an auditor, they should make sure they are not distracted and keep an eye out for danger else it could lead to accidents.

Based on the value drivers identified in the previous section, through discussions and deduction with Participants 5a, 1b, and 5b, they were associated to the derived use cases. The shaded yellow boxes represent the value drivers applicable for the use case. It is important to note that the cost-effectiveness value driver was difficult to estimate quantitatively without implementation. It has been indicated as a value driver for the most obvious use cases like

Value drivers	Employee engagement	Visual documentation and process tracking	Enhanced training and communication	Contextualized information	Workflow standardization	Information overlay	Cost effectiveness
Workflow sign-off							
Quality and Safety Checks in Labs							
Remote Assistance							
Instructional training							
On-site Inspection							
Auditing 1. Onsite Auditing							
Auditing 2. Remote auditing							

Table 5-1: Value drivers attributed to the discovered use cases (Authors' own interpretation)

remote assistance or remote auditing where the expert or technician does not have to travel.

5-3 Determining resources, competencies, and capabilities required for adoption of smart glasses

To seek answers to research question four on what were the resources (tangible and intangible) required to make the implementation of the technology a success, Participant 9a, 1c, and 2c were interviewed. They had gathered experiences and learning from deployment of the device for other applications. Their responses revealed how the resources needed might vary depending on the extent of adoption of ARSGs within an organization.

Interview #	Role
Interview #9a (Cargill)	**Senior Technology Risk Analyst,** Technology, Governance, Regulatory, and Compliance Lead for Compute and Collaborate
Interview #1c (Cargill)	**Service Owner,** Operations and Supply Chain
Interview #2c (Cargill)	**IT Advisor,** Smart Manufacturing, Operations and Supply Chain

Table 5-2: Interview sample for RQ4

During the early stages of adoption, if there is a need for ARSG from the plant, instead of directly procuring the device, they must first approach the right technology governance in-charges. They could also report to their need to responsible colleagues at Supply Chain Operations. Issues in communication in this stage might arise if companies are not organized to handle these requests. It is imperative that if the business, plants, and technology governance bodies note multiple requests arriving for the need of this technology, they work together to have everything covered from a procedure standpoint so that employees can follow this process. They would also need to devise a plan on how they would evaluate the devices based on the company's priorities for security, data management, and other parameters of interest. A similar process should also be simultaneously set up for approval of software and value-added services that could be used on the smart glass. To operationalize the process, a report could be prepared focusing on the line of communication and use instructions that needs to be followed when a smart glass is required, along with a list of relevant software and infrastructure that needs to be arranged. This document could be shared on a common platform among employees who are interested in adopting the device.

Phase	Tangible	Intangible
Early stages of adoption	Smart glasses AR Software Network connection	1. Orchestrate standard procedures for placing requests and placing purchase orders for smart glasses and relevant software (Process know-how) 2. Adapt device and relevant software evaluation and assessment procedures (Process know-how) 3. Set up Communities of practice (CoP) where employees would share their knowledge, experiences and organize mini workshops to create awareness (Knowledge) 4. Set up Technology governance teams (Knowledge) 5. Encourage positive shift in organizational culture and mindset initiated by above discussions and workshops (Culture) 6. Managerial talent will be required to motivate business units to adopt and test new technologies (Leadership skills)
When base of users increase	Smart glasses AR Software Network connection Extend storage capabilities	1. Update standard operating procedures, usage instructions, device and relevant software evaluation and assessment procedures, and vendor management systems (Process know-how) 2. Set up Center of Excellence (CoE) – Employees involved in tasks such as building custom AR software, training users, troubleshooting, handling requests/support (Intellectual property, Knowledge) 3. Organizing decommissioning teams that would be responsible for post purchase decision analysis, device replacements or recycling, etc. (Process know-how) 4. Hiring talent who are specialists in AR or AR developers (Knowledge)

Table 5-3: Summary of tangible and intangible resources, competencies, and capabilities required as collected from findings (Authors' own interpretation)

> *"As it's (ARSG technology and related services) getting stood up, we are right now receiving some pretty basic questions from users that are learning about the devices because they're new to them. But right now, a center of excellence, probably not. A community of practice is more likely. But as we start to get more advanced, and additionally use cases that require custom development get brought forward, then the answer may change."*

-Participant 1c (Service Owner)

Other resources and capabilities that would be required is the development of Communities of Practice (CoP) consisting of end-users, managers, and employees from IT infrastructure and technology governance who can guide and help each other troubleshoot and answer queries on a shared platform. These CoPs could also include representatives from smart glass manufacturers who would find it advantageous to learn and receive feedback from the users and at the same time try to resolve issues faced by the purchasing organization. There would also be a need to organize mini workshops to provide small scale training and create awareness among colleagues. These discussions would also act as a catalyst for bringing about a shift in the mindset of employees and creating an organizational culture open to innovation and change. Further, the managerial talent of plant managers, manufacturing and process leads, and other supervisors managing end-users would be tested and play a role in identifying use cases within their business/enterprises and advancing adoption of smart glasses. Certain technology governance teams might also have to undergo a shift in responsibilities from enterprise/business/product based to technology based.

Once the technology starts picking up pace and garnering a large base of users, technology governing authorities must prevent from being overwhelmed with requests. They should use their internal capabilities to formally plan and collaborate with employees working in supply chain and operations and business relationship managers to evaluate a range of devices. Intangible resources such as target architecture, appropriate usage instructions, and vendor management systems must be established. From a procedure standpoint, information on approved vendors, how to acquire devices with the right security configuration and the warnings for each device must be updated. The operations teams might have to focus on two arenas: one would be on deploying the technology, and one would be on assessment of vendors. There is also a need to develop a stronger relationship between vendors and purchasers so that the organization is well informed on the new developments and releases of the technology and are able to quickly align their procedures. As the number of users increase, a need for Center of Excellence (CoE) dedicated for AR was suggested.

> *"It would be nice to have a center of excellence. It would also be nice to have a specialist that understands the technology. The current support team had to learn (how to use and approve ARSGs) on the fly plus, we had to figure out how to slot it into Cargill's existing processes."*

-Participant 9a (Senior Technology Risk Analyst)

Previously, AR software solutions were required for basic use cases and could be made available/procured when necessary. Participant 9a and 1c said as ARSGs integrate into daily operations and the complexity of use cases increases, internal capabilities for building AR software and a requirement for custom development would arise. This could pose as a unique differentiator for the organization as the capabilities for employees to innovate and capacities of organizational innovation increase. This would also mean hiring talent such as AR technology specialists or AR software developers (full-stack developers) would become essential, who would all be a part of CoE. Contrastingly, Participant 2c dismissed the need for a CoE. Their perception of ARSG is that of 'walking computer' and stated that the human resources and innovation capabilities needed for it are already present in organizations. They expressed that services such as training and troubleshooting/requests handling/support, could be outsourced rather than having a dedicated CoE. But Participant 1c also claimed that even when such parties come into the picture, based on marketplace assessments, there would be a mixed bag of in-house software and purchased and approved third party applications that are utilized on ARSGs. Similarly, AR software-related development activities could be a combination of what is provided by the organization and outsourced. CoE could also hire talent for troubleshooting and providing support for users as the use cases become more intricate and problems require time to be analyzed and fixed. Training of employees who are part of different tiers such as executives, managers, and operators might be required, that would enable the organization to embrace change.

All these activities might change the organizational culture and approach to innovations with the company, based on the type of resources they choose to invest in and strategic initiatives they implement.

5-4 Implementation plan for food manufacturing organizations to adopt smart glasses

For categorizing use cases within the value complexity matrix, it is necessary to determine the implementation complexity and business value entailing each use case upon implementation. *Only tangible resources required as mentioned in literature (3-4-1) and gathered from case study findings (5-3) were chosen as a measure of implementation complexity as they have a clearer market value.* The value of intangible resources is often open to subjective assessment (Xaxx, 2019; Murphy, 2021). Based on the use case, the identified tangible resources are categorized as must-haves, nice-to-haves, and those that needed to be developed in-house. This has been illustrated in Figure A-3 and Figure A-4 in the Appendix.

The frequency, impact, and business value of each use case was deduced from the information gathered through literature review and the case study. *Assuming that the frequency and impact could work as a qualitative measure to judge business value and the tangible resources identified are all-inclusive and are a measure of implementation complexity, a value complexity matrix was created.*

The matrix comprises of four quadrants, each representing a recommendation for implementation of use cases, which are as follows: *deprioritize, pursue later, easy win, or strategic initiative.* Initially, the use cases were sorted into the four quadrants as those that should be deprioritized, pursued later, are easy wins, or require strategic initiatives, without taking into consideration the nice-to-have resources that may affect implementation complexities and business value. An indication in the form of arrows were also included in the diagram to showcase how the implementation complexities and business value of use cases may change if the nice-to-have resources are taken into consideration. This is shown in Figure 5-3

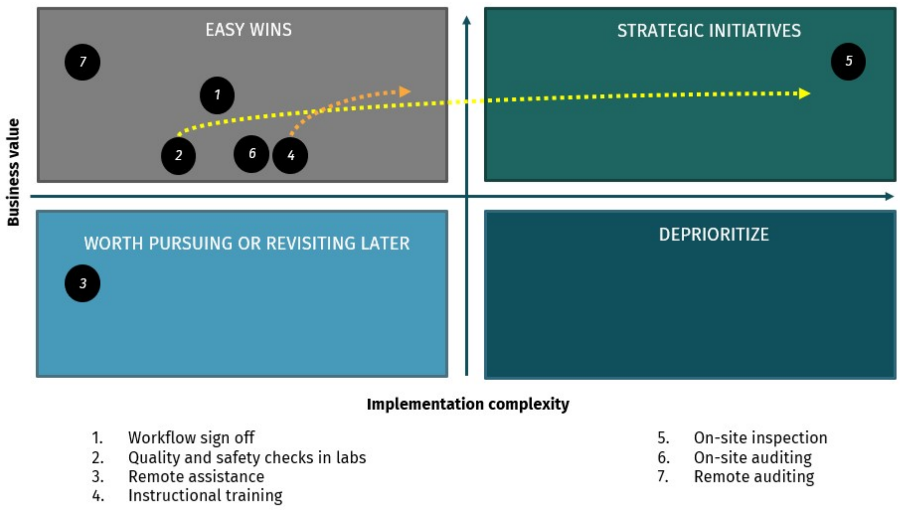

Figure 5-3: Derived use cases categorized in different quadrants in the value complexity matrix

Companies could start implementing the easy win use-cases, while simultaneously training and educating on how to use smart glasses for different applications and building a community of practice (CoP). They could start developing plans for strategic initiative use cases that would be required to implement them. As easy wins are being implemented, it is important to gather feedback from end-users and managers on their experience and learning from the first prototype testing and share these notes with the concerned employees. More of what is required in these early stages of adoption resources-wise have been discussed in detail in Table 5-3. For the derived use cases, boxes in green that are must-have tangible resources have been shown in Figure A-3, and Figure A-4.

Once the easy win use cases have been implemented, it is important to introspect and evaluate the business value of those (Review Stage 1). There are chances that the actual business value of the use case does not meet the standards expected. If the implementation complexity is also too high, such a use case can be deprioritized. Else, it can be pursued later. One might also find that they are not equipped with the right resources and require more infrastructure, support, and specialists who can aid in delivering a seamless experience to the end-users. They may also have to evaluate different device suppliers and choose the right ones based on the needs of the use cases.

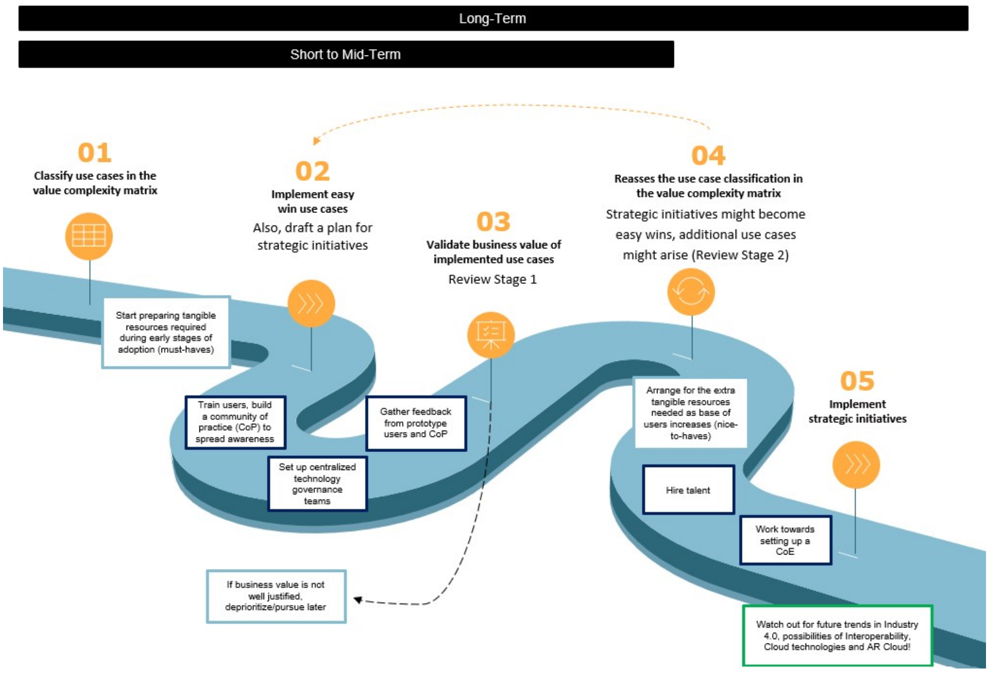

Figure 5-4: Short to Long-term Implementation Plan for organizations in the food sector (Authors' own interpretation)

It is also important to revisit the value complexity matrix and categorize the use cases again. Sometimes, certain resources would have already been arranged for as foundational requirements for other technologies and at that point in future, AR use cases that required strategic initiatives may become easy wins. Therefore, it is important to note which use cases still require strategic initiatives (Review Stage 2). The easy win use cases would also garner the most attention and the user base would slowly grow. This is could be attributed to the fact that it is less resource-intensive in comparison to strategic initiative use cases. But nevertheless, as the user base grows, the need for resources will also change. Implementing the strategic initiative use cases would bring about a greater business value and sustained competitive advantage to the organization over just implementing easy wins. So, once the use cases that still require strategic initiatives have been identified, organizations can work towards arranging resources for these applications. As technology scales up, it could also mean acquiring new tangible resources (refer to Table 5-3), hiring new talent, building centers of excellence, and training executives, leaders, and managers to embrace change brought about by incorporation of smart glasses. Firms should be able to anticipate the resources well in advance. For the derived use cases, refer to boxes in grey that are nice-to-have tangible resources shown in Figure A-3, and Figure A-4.

Lastly, the use cases that require strategic initiatives could be implemented and could also be fully integrated with current software and information management systems. Managers may have to look out for trends in other Industry 4.0 technologies like smart manufacturing or artificial intelligence for example, could come into the picture (interoperability). Smart glasses could then be integrated with those technologies to display and track valuable real-time information to operators. Additionally, cloud computing, 5G, and AR cloud will be transformative for augmented reality technologies. It will boost their performance and computation, reduce lag time, and make the experience more seamless. These trends might create further business process digitalization opportunities, which need to be taken into account while planning long-term beyond implementing strategic initiative use cases. All of the above is illustrated in 5-4.

5-5 Conclusion

Based on FSQR business process descriptions, seven possibilities for digitalization using augmented reality smart glasses were identified. These include workflow sign-off, quality and safety and checks in labs, remote assistance, instructional training, on-site inspection, and auditing (in-plant and remote). Now, to integrate smart glasses into these processes, either available resources and capabilities need to be mobilized or additional resources and capabilities need to be arranged for.

In the early stages of adoption, tangible resources like smart glasses, basic AR software, and network connection would be required. Standard operating procedures for placing requests and purchase orders, along with device and software evaluation and assessment procedures would be required. Additionally, communities of practice that could act as a platform for knowledge sharing and resolving basic requests could be set up. A change in organizational culture and mindset could be initiated by organizing mini-workshops that can raise awareness. These intangible resources and capabilities need to be spearheaded by managers who need to possess the right skills and talent. Finally, a governance team that is focused on governing the technology of AR needs to be set up.

When the technology picks up pace, the standard procedures, usage instructions, device, and software evaluation and assessment procedures, and vendor management systems need to be updated. A dedicated center of excellence that is aimed at creating custom software, training users, troubleshooting, and handling requests, and providing support could be set up. In these later stages, skilled people might need to be hired to support the large-scale digital transformation. Tangible resources like smart glasses, AR software, and network connection would still be required at this stage. However, the software might be more advanced as it may have to integrate with the current applications underuse. Storage capabilities may also have to be extended to store and share information smoothly.

An implementation plan for adopting smart glasses has been presented and explained in great detail in combination with the use case classification on the value complexity matrix. This could aid organizations in the food sector that are slower adopters to innovation and are assessing the technology and investigating use cases. Once the use cases have been identified, they can be categorized using the value complexity matrix where different parameters could be used as a measure for business value and implementation complexity. The steps in the implementation roadmap can then be followed to adopt the technology.

Chapter 6

Conclusion and Recommendations

6-1 Conclusion

This section will revert to the research questions of this thesis, and answer them briefly based on the information collected through the literature review and case study. The main research question to be answered in this thesis was ***How can augmented reality smart glasses be used to digitalize business processes in food supply chains and how can organizations be adequately resourced?***

Firstly, the purpose of the technology will be established which could essentially spark the interest of various stakeholders and give them an idea of the potential of the technology. This information could also provide a motive for organizations to purchase, invest, or assess the technology of augmented reality smart glasses. The drivers and barriers to the adoption of smart glasses will be covered here. In the subsection of delivery, we will look into the specific domain within organizational supply chains and business function of FSQR, and discuss the delivery of augmented reality smart glasses. Essentially, if organizations have similar business processes, they could refer to the derived use cases and know what to do with the technology, giving them an inspiration for where they could test and experiment. The benefits and risks related to using smart glasses to digitalize the process will be covered here. Finally, the last section will include a bird's eye view of resources that are required for the implementation of the derived use cases and to adopt augmented reality smart glasses in general. These resources would be both tangible and intangible ones. The resources listed could assist organizations in extracting value from the technology and deriving benefits from the process digitalization, whilst overcoming the barriers to adoption of the technology and reducing risks that arise due to process digitalization.

6-1-1 Purpose

The purpose of why the technology should be of interest to organizations is answered via the first research question:

RQ1: How has the technology of smart glasses evolved?

A combination of literature review and interviews was done to understand the technology of augmented reality smart glasses and answer the first research question. A distinction was made between augmented reality, augmented reality smart glasses and other technologies in the spectrum. This was accompanied with the explanations for the working principle and complementary hardware and software required for the operation of the technology. Market adoption characteristics were studied to understand which phase the technology is in, what are the barriers it is facing to adoption, and what are the drivers that are pushing the technology into the market, especially within B2B markets and specific industries such as manufacturing and food. Though the technology was invented 53 years ago, from the literature review and empirical findings, we can conclude that the technology is still in the adaptation phase and has not yet reached the stabilization phase (large-scale diffusion). The barriers to large scale diffusion found through interviews are in line with what was cited in literature.

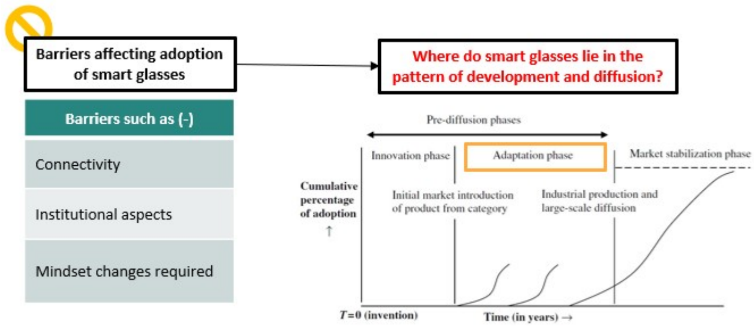

Figure 6-1: Impactful barriers to large scale diffusion of smart glasses

Dwelling into the specifics and viewing the barriers from an angle proposed by Rejeb, Keogh, et al. (2020), the major barriers to large scale diffusion that need to be resolved urgently as cited in literature and perceived from interviews are: *connectivity (technological), institutional aspects such as regulatory compliance and privacy concerns (organizational), and mindset changes required (organizational).* These three factors stand out the most because other technological barriers can be dealt with if alternative devices in the market indicated by the pattern of development and diffusion are purchased. But if there is no connectivity at all in the plant, purchasing the device goes out of question. If the organization feels that most of their information and happenings in the plant are confidential, then again, there would be an opposition that cannot be countered. Finally, even if the first two barriers do not exist, if the end-user is just not willing to use the device at all because of their general dislike towards the technology and change to their current ways of working, purchasing the device would not be beneficial. Another point to note is that though cost may seem to be a barrier for consumers, when it comes to multinational businesses, if the use-case is well justified and using smart glasses is cost-effective, cost is not a barrier of concern. Several drivers to the technology were also discussed, the highlights being the flexibility it offers for training and communication and the ability to overlay information within 3D space.

The future of the technology was studied with the help of the hype cycle and market figures from top consulting firms (Fenn & Raskino, 2009; Dedehayir & Steinert, 2016). The hype cycle indicated that currently the technology might be in the trough of disillusionment phase. Concurrently, positive figures were provided on the future valuation of ARSGs by

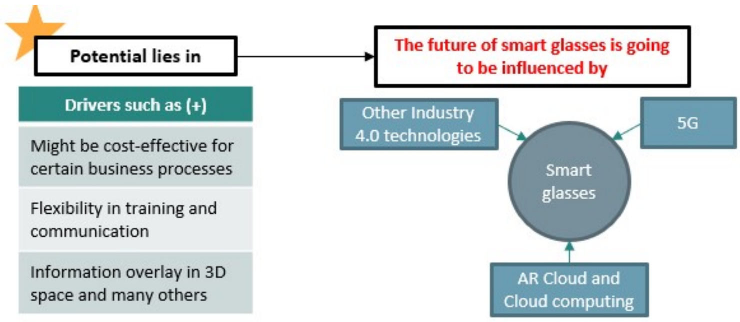

Figure 6-2: Impactful value drivers and factors affecting the future of smart glasses

consulting firms. They expect the technology to boom and change the ways of working in the coming years. The future of the technology is going to be influenced by advances in telecommunication networks, improvements in computation and performance if cloud experiences are involved, and other technologies within Industry 4.0 through interoperobility (ARSG might just be an enabling technology). Nonetheless, the technology is in the trough of disillusionment phase where uncertainties and negative opinions about the technology co-exist with perceived benefits, but it is important to look at how the technology might take off a few years from now (approx 5-6), and have use cases within organizations in place. The answer found for this research question through the course of this thesis has supplemented information to the existing literature on this topic.

6-1-2 Delivery

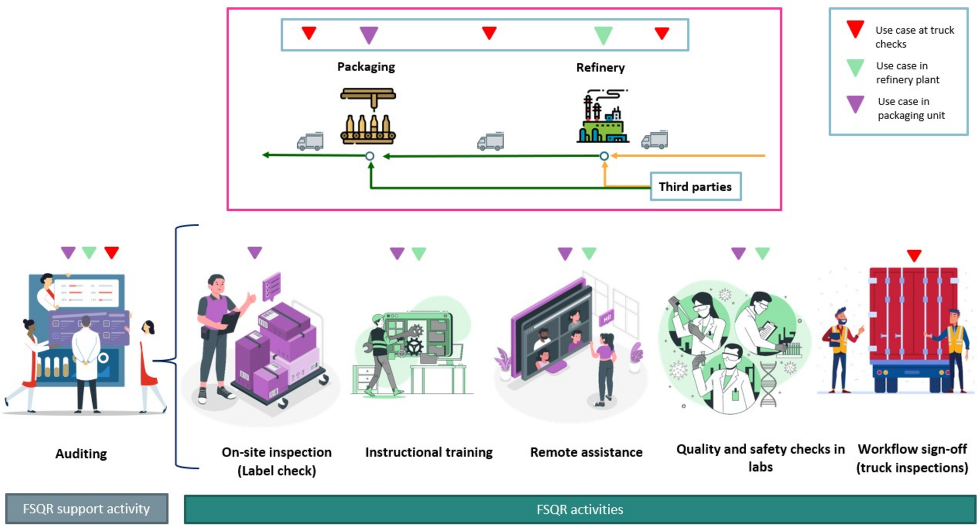

Figure 6-3: Intersection of use cases to the GEOS supply chain (Authors' own interpretation)

Organizations need to identify use cases where they can utilize smart glasses. Based on recommendations from papers and absence of published papers on how smart glasses could be used within food safety and quality, this domain within Cargill's edible oils supply chain was chosen. Two research questions that required answers were as follows:

RQ2: How can augmented reality smart glasses be used to digitalize food safety and quality processes along the supply chain?

RQ3: What are the qualitative benefits and risks of using smart glasses to digitalize food safety and quality processes?

For this purpose, processes in place to ensure food safety and quality were explored in detail, along with the support activity of food auditing that accounts for the outcomes of these processes. Within food safety and quality, seven opportunities/use cases for ARSGs were found, namely workflow sign-off (1), quality and safety checks in labs (2), remote assistance (3), instructional training (4), on-site inspection (5), and auditing (in-plant auditing (6) and remote auditing (7)). Figure 6-3 represents where these use cases take place along the edible oils supply chain of Cargill, especially close to and in the refinery and packaging units. The benefits and risks of employing augmented reality smart glasses to digitalize these processes has been described in detail. An overview of this is in Figure 5-1 and Figure 5-2. It is important to note that the benefits and risks were use case/process-related and not technology-related. Technology-related advantages and disadvantages were discussed as drivers and barriers in the previous section. The answers to these research questions were mainly found through the course of this thesis and may not be already present in literature.

6-1-3 Resources

Based on the derived use cases, resources might need to be allocated or arranged for if not already accessible. These resources should also aid in utilizing the drivers of the technology and optimizing the benefits of digitalizing processes (use cases), as well as overcoming the barriers of the technology and mitigating the risks that arise due to process digitalization. The resource based theory suggested that organizations require tangible and majorly intangible resources that cannot be replicated easily (heterogeneous and immobile) that satisfy the VRIO conditions, and a few isolating mechanisms to achieve a sustained competitive advantage (Barney, 1991; Rothaermel, 2018). For this thesis, the resource based theory by Barney (1991) was used as a foundation to answer the research question below:

RQ4: What resources do companies need to digitalize food safety and quality processes when using augmented reality smart glasses?

The technology infrastructure held by organizations might require some changes, upgrades, or additions. For the use cases identified, tangible resources such as the ARSG device itself, connectivity, built-in applications or third-party applications, and other AR software that can be used on the device are required for every use case, whereas, in some cases an in-house built application and system integration might be required. Regardless of the fact that some of these resources like in-house built applications or system integration might be nice-to-have accompaniments, organizations need to look into their overall technology infrastructure. The intangible resources recognized include communities of practice (CoP) or centers of excellence (CoE) where there would exist opportunities for employees to discuss, develop and innovate. CoPs and CoEs could foster an environment for collaborations, discussions, and innovation.

Another intangible resource includes the need for communication protocols for requests, standard procedures for purchase and device evaluation and assessment to be followed if a new device has to be acquired, and centralized governance structures. In addition, training the current employees and hiring the right talent increases the organizational potential for innovation and ability to embrace change. If the above resources are in place, organizations could adopt the technology in a streamlined manner and devise ways to utilize the drivers and optimize the benefits offered by the technology. Managers must ensure that they motivate their employees to embrace change and have a positive impact on the organizational culture. By developing these resources and capabilities, since the technology is still in the adaptation phase, there is room for path dependant learning in organizations. This would act as an isolating mechanism in the long run that could provide sustained competitive advantage to organizations (Porter & Heppelmann, 2017; Cohen et al., 2018; Rothaermel, 2018; Dalton & Gillham, 2019).

Having the above resources in place would aid in extracting value from the technology and deriving benefits of process digitalization. It is also necessary to address if any specific resources would be required to resolve barriers to adoption of the technology and minimize process risks. To tackle the barrier of connectivity issues, it would reel back to having the right technology infrastructure in place. The feasible solutions are to either make use of mobile hotspots or install WiFi networks across the plant. With the advent of 5G, connectivity is also expected to be faster. However, if none of the above options are possible and the device has to be used in plant locations, the best plan of action is to install software that could be used for offline for repetitive but impactful and high frequency use cases. Also, if the use case is highly valuable and the need for smart glasses is justifiable from various angles (financial included), organizations could always work together to find workarounds to make use of the technology despite the privacy/institutional concerns. They could selectively isolate confidential information if need be. Lastly, having regular training sessions to create awareness, setting up communities of practice or centers of excellence, and hiring the right talent would encourage the employees and operators to be more accepting of change. The training provided could not only be for end-users, but also executive leaders and managers who could proliferate tenets of change management, thereby creating strides towards overcoming the barrier of mindset change. Coming to the process related risks, a common risk across use cases is that of operators being distracted or not being able to keep an eye out for real life danger. For the chosen use cases, operators do not require devices that take up most of their field of view as in gaming. A smart choice needs to be made with respect to the device that is being purchased. It should not be very tinted, and at the same time occupy only the sufficient field of view to be able to see the real world and overlaid graphic information. Another frequently quoted risk was that of operators'/users' dependence on the device. This risk could easily be avoided if the standard of the hiring process and training given to employees continues to remain the same. An added bonus to their workflow would be the introduction of smart glasses, for which training is of course required but if the current standards for hiring is maintained and training is still given, this risk would not pose as a threat. The special risk that arises in the use case of remote auditing wherein the auditor is able to see only what the auditee shows could be handled if auditors are provided with a pre-recorded plant tour or the layout of the plant they are going to inspect. If this is done, they could intervene during the process of remote auditing and particularly ask the auditee to show areas that could have been neglected or not shown properly.

According to the RBV framework, a combination of above specified tangible and intangible resources could impart sustained competitive advantage to organizations as they are valuable, rare, costly to imitate, and are organized to capture value (Barney, 1991; Porter & Heppelmann, 2017; Rothaermel, 2018). The answers to this research question was partly present in literature, but it was enhanced by viewing the resources required with respect to the theory on resource based view. It has added to existing literature on resource based view and provided additional resources, competencies, and capabilities that will be required if smart glasses are adopted in organizations.

6-2 Generalizability

The answers to the first research question were sought through a combination of literature review and case study. Though the findings through the interviews may have limited generalizability as participants mostly had access to one major high-tech suppliers' device, during the literature review, a wide range of smart glasses were cited and taken into consideration. The findings on the components and working of the technology, drivers, and barriers to adoption, and future of the technology hold true across many but not all augmented reality smart glass devices. For the second research question, the answers were again sought through literature review and case study. The findings are limited as the food safety and quality processes may vary based on the food manufacturing organization. If a food manufacturing organization follows a HACCP framework similar to Cargill for assuring food safety and quality, some of the processes might be similar.

The findings for the third research question were curated based on the information collected on the food safety and quality processes at Cargill. The use cases could be applicable to food organizations that have a HACCP system in place or similar FSQR business processes. But some of the use cases for smart glasses are applicable for any manufacturing organization, not only food. These use cases can also be applied to other operations in the manufacturing environment like maintenance/repair or other industries for example automotive or chemical. However, the business value and implementation complexity of the use cases might change. It would become necessary to reassess the derived use cases and create an iterated version of the value complexity matrix.

Finally, for the fourth research question, again, the findings were sought through a combination of literature review and case study. The resources required are definitely applicable for Cargill. But it would be applicable to other food manufacturing organizations who would want to adopt smart glasses after they take into account the resources they currently possess. Similarly, after the derived use cases are categorized, the main steps one to five in the implementation plan can remain the same for any organization, but the resources needed at each step indicated in blue boxes are subject to change based on what is in possession of the organization. Ultimately, organizations can take inspiration from not only the use cases but also the approach, theories, and tools (2-2-1) followed in the thesis while digitalizing their business processes using augmented reality smart glasses.

6-3 Limitations

Four main limitations that were identified for this study are as follows:

- The literature gap was identified based on the lack of published academic literature. But in practicality, use cases and appropriate might already exist in the market. There could also be cases where the technology was adopted within organizations but has not been published. The literature review conducted was also based on a set of preferred keywords. The literature review could have been more exhaustive but due to stringent timelines, this was avoided.
- Moving on to the case study interviews, for the first research question, most users who were interviewed had experience in using a major high-tech suppliers' device and their opinions were based on the same. Interviewed participants lacked access to other AR devices as they are not sold in large scale to the consumer market. Those who worked at TU Delft had more experience with VR technologies and sometimes used that to guide their responses for ARSGs.
- When it comes to research questions three and four, employees within a single organization, working for the same edible oils supply chain, based mainly in the plants in north-west Europe were only interviewed due to time constraints (sample). With changes in the plant location, supply chains, and organizations, the responses to what are the different food safety and quality processes and how smart glasses could be used may differ. The list of benefits and risks that were discussed were not based on actual implementation but conceived from scratch (and imagination). On actual implementation, the answers could change.
- For the last research question on resources required, the interviewees were not part of projects that implemented all the use cases created in this thesis (sample). Their knowledge was based on deploying and being part of projects that involved smart glasses in other locations and for other use cases. If they were involved in the implementation of the use cases created through this thesis and deployment of smart glasses, the resources required could differ.

6-4 Recommendations

Future recommendations for my thesis are based on the gaps in knowledge from our literature review and findings and would benefit from further research.

- Identifying which smart glass is suitable for which application and industry is necessary. By the time this research was completed, there were many device suppliers in the market, however, they were lacking technology assessment and comparative studies.
- The FSQR processes that were studied to identify digitalization opportunities occur only within Cargill and their plants in north-west Europe. Researchers with a more general overview of the FSQR processes that are common across food supply chains and organizations could derive a more comprehensive list of use cases and accurate list of benefits and risks.

- Implementing the use cases through pilot projects would improve the list of qualitative process and technology related benefits and risks. There are several benefits of doing this. Firstly, the benefits and risks now gathered through interviews can be tested to see if they hold valid. Secondly, upon implementation, one can discover additional benefits or risks that initially were not discussed. This could even eliminate the use case from being a possibly enhanced with smart glasses. Capturing the quantitative aspects for evaluation of the use cases would also become feasible if the smart glasses are deployed.

- Identifying the IT architecture for smart glasses, which are defined by Gartner as "a series of principles, guidelines or rules used by an enterprise to direct the process of acquiring, building, modifying and interfacing IT resources throughout the enterprise" is also a future recommended topic that could be explored (Gartner Representative, 2012). The resources identified in this thesis could be strengthened upon systematically using already existing frameworks to develop IT architecture for the recognized use cases. In this process, recommendations could also be given on what software needs to be purchased or built.

- The value complexity matrix could be improved by conducting a literature review and interviews on what constitutes as business value (A) and implementation complexity (B) for people working in functions like FSQR and their managers. This could be a way to capture the measures of the variables A and B and learn how the value complexity matrix would change. A nice difference in how the use cases move across quadrants can be identified if qualitative measures versus quantitative measures are used to judge A and B. A cost benefit analysis, for example, could be a useful quantitative tool to assess the business value. Whereas a tool like Delphi method could be a useful qualitative tool to assess the business value. These changes could reflect in the implementation roadmap as well, with a more definitive timeline.

Chapter 7

Discussions

7-1 Implications

This Chapter will address the theoretical implications that would confirm if the findings are in line with the theories, and how this thesis has contributed to literature. The managerial implications include information on how managers within organizations can utilize the results of the thesis and what actions they might need to take to prepare for the future of augmented reality smart glasses.

Theoretical

The goal of this thesis was to study the technology of augmented reality smart glasses, find opportunities for the technology in food industries, and identify the tangible and intangible resources needed for successful implementation of it.

Firstly, this research contributes to existing theory on the market adoption of smart glasses. Studying the market characteristics of smart glasses provided information on the barriers and drivers to adoption of the technology. With the help of these barriers, it was attested that certain factors needed for large scale diffusion were not met (Ortt et al., 2013; Ro et al., 2018; Lacueva-Pérez et al., 2018; Danielsson et al., 2020; Rejeb, Keogh, et al., 2021). This was illustrated using the pattern of development and diffusion created by Ortt and Schoormans (2004). Additionally, it also provides a good overview on what are the different device alternatives present in the market. The drivers and advantages of using the technology were also studied, especially in manufacturing industries and briefly in food industries (Techcrunch, 2017; Chatzopoulos et al., 2017; Demartini et al., 2018; Kohn & Harborth, 2018; Noor Hasnan & Yusoff, 2018; Fitzgerald et al., 2018). These barriers and drivers to adoption of the technology were also validated using the empirical findings. They were found to be in line with what was stated in literature on many fronts.

Secondly, several use cases for ARSGs within food industries and food safety and quality processes in specific are presented in this study. Since existing literature did not already have information on this, the case study helped in identifying these possibilities (Penco et al., 2020; Rejeb, Keogh, et al., 2021). According to authors Feng and Mueller (2019) and Rejeb, Rejeb, and Keogh (2021), benefits of AR in literature have not been captured and comprehensively investigated. This study looked into the benefits and risks that could arise when ARSGs are implemented for these specific use cases. Consequently, the use cases discovered also add on to the existing list of use cases present in manufacturing and food industries.

Thirdly, this thesis contributes to literature on resource based view by Barney (1991); Madhani (2010); Rothaermel (2018). The resources (both tangible and intangible) required for organizations to achieve sustained competitive advantage by leveraging the potential of augmented reality smart glasses were described in this research (Porter & Heppelmann, 2017; Cohen et al., 2018; Dalton & Gillham, 2019).

Along the way, it was also discovered that food industries do not have a roadmap that can guide the sector through Industry 4.0 technologies (Akyazi et al., 2020). The technology roadmap developed for ARSGs as a framework for this thesis is contributing to literature on technology roadmap architecture by (Phaal et al., 2004). It has been customized for the technology of smart glasses and the use case of food safety and quality to derive benefits of the tool. This could be of relevance when researchers are looking to explore opportunities for other Industry 4.0 technologies within food industries, and specifically in food safety and quality (Phaal et al., 2004).

Managerial

The thesis research framework is useful for managers who are exploring technologies in the mixed reality domain and Industry 4.0. A similar framework could be developed for planning their strategies and long-term planning. The pattern of development and diffusion is a useful tool for technology manufacturers to understand where technical specification improvements need to be made in smart glasses. If they explore the topic further, they could also choose a niche strategy for themselves to push their device into the market. For technology adopters, they could foresee what obstacles they would encounter when they purchase and use smart glasses. They could accordingly prepare and plan workarounds when using the device.

Looking at the future of the technology as presented by the hype cycle and responses from interviews, it seems like smart glasses would take off approximately in the next five years. Managers could start planning on how to incorporate the device into their daily operations. Even if they are ready to purchase the best version of the device a few years from now, they need to start planning well in advance because there are certain organizational barriers that need to be overcome, which is no easy feat. Organizational barriers such as mindset changes of employees require training and change management strategies to bring about a shift in the organizational culture. Usually, automation is always associated to job loss but in the case of augmented reality without the end-user, the device has no meaning. Smart glasses enhance the real-world of the user and conversations like these need to happen to reduce the inertia employees have towards changing their usual ways of working.

Other concerns related to privacy, security and legal, and safety of their employees require discussions with employees and executives from different departments such as legal and technology governance, production and operations, IT, and human resources to name a few.

In general, all this is to do with the technology itself. Apart from initiating such conversations, managers need to be able to identify the right use cases to deploy the device in. This would lead to them discovering use case related benefits and risks. At this preliminary stage, they need to have an overview of what internal resources they possess and how they could utilize it for different use-cases. Based on their initial studies, they could develop a value complexity matrix similar to Figure 5-3 and categorize the use cases as ones that should be deprioritized, pursued later, implemented right away (easy wins), and worked implementation in the future (strategic initiatives) after analyzing the value it could potentially add to the business and implementation complexities.

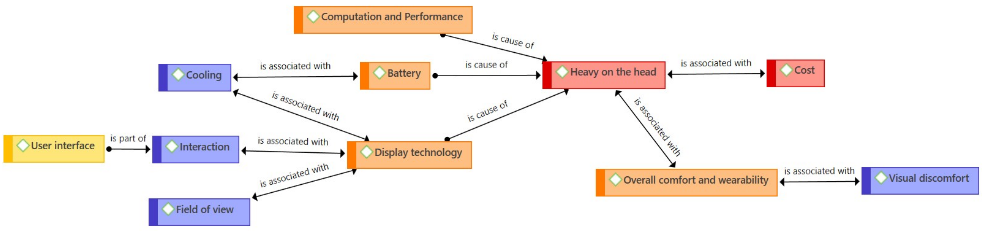

Figure 7-1: Factors that might affect the device being heavy on the head for operators

While choosing an augmented reality smart glass for digitalizing a business process, managers can consider the factors that influence the device being heavy on the head for the operators. This is shown in 7-1. These responses were collected from interviews conducted in the thesis, but of course, not all factors that influence the device being heavy on the head has been included because that was not an objective of this thesis. However, this can serve as a reference image before a device is purchased. As seen in the figure, a device being heavy could be because of the battery in the device, the computation and performance provided, the display technology used, or if overall comfort and wearability was an important aspect during the design stages of the device. These primary factors are associated to secondary factors that may also play a role. The strength of these relationships is yet to be determined, but participants indicated the influence. Before making a purchase decision, managers might have to make a trade-off between the computation and performance, battery, display technology, and overall comfort and wearability among other factors required for the particular business process being digitalized. Also, since an optimum device according to the participants is yet to be released, heavier devices may be inversely proportional to cost. But this relationship is not set in stone and is just based on interviewees responses at the time of the interview.

For AR to be leveraged as a source of competitive advantage, managers should be able to anticipate the above changes that are going to take place well in advance, prepare themselves and their organization, and work towards creating awareness amongst their colleagues, subordinates and leaders.

7-2 Personal reflections

Writing this thesis and having a defense seemed like an insurmountable task about six months back. There were so many crossroads along the way and a swamping list of to-dos at every instant. However, reflecting on this journey, the skills of time management, prioritization, and decision making were tested.

The motivation to choose the technology roadmap as an overall framework for this thesis was explicitly mentioned. However, the choice of research framework of technology roadmap could be critiqued. By itself, it seems very appropriate for consulting firms to suggest improvement directions for their customers and partners. Though its academic value was enhanced by using academic theories at junctures, a better option would have been to choose either a more complex technology roadmap that indicated the strategies to follow once the purpose, delivery, and resources needed to adopt a technology was identified or integrate the findings of this thesis (implementation plan and value complexity matrix) to create a customized research framework.

A case study seems relevant for this thesis and the justification for it was given under project methodologies. Initially, it did seem like there was a lack of rigor, a lot of effort needed, and it was not possible to generalize. This was tackled by approaching the case study in a systematic manner and aiming for analytic generalization based on the findings gathered.

The process of reviewing the literature was fairly simple due to the right choice of keywords. There were a lot of definitions of the technology and its working because it is a discipline that was discovered about 50 years ago. The key was to stick to definitions that explained the working and principles in detail and clearly. A trend observed while reviewing articles is how farther ahead and advanced manufacturing/automotive industries are in the adoption of smart glasses. A lot of use cases, consulting reports, and published literature belonged to case studies conducted in manufacturing/automotive firms. The lack of augmented reality smart glass use cases was a gap that was clearly bridged using this thesis. Practices to maintain food safety and quality also differed by country but the guidelines in Europe were well described. The resource-based view theory was helpful in providing overarching definitions and explaining how the resources of a firm could act as a source of sustained competitive advantage. However, the classification of resources as either tangible or intangible seemed very subjective and there was not much concrete evidence on how they could be differentiated. In terms of information on applications and usage of augmented reality smart glasses in scientific and published articles versus the market and consulting reports, a lot of statistics, lessons to be learned, and how companies can act on adopting such technologies were extensively available in the market and consulting reports. But the sample of industries selected and studied in such reports were limited to power/energy/utilities and automotive, so an evaluation had to be made before citing statements.

The experience of conducting a case study at Cargill was educative and fulfilling. Being part of an organization, gaining an understanding of their practices and daily activities, and working in a professional environment was a great learning experience. At least 30 interviews were conducted in total most of which proceeded smoothly and confirmed a lot of information discovered in the literature. The employees were friendly and accepting, but sometimes, did require reminders and prompts. Nevertheless, working in a disciplined and systematic manner to ensure that the time of participants is valued aided in the completion of the research objectives. The mentor and managers assigned were actively participating in thesis discussions and since the hype of the technology had spiked during COVID-19, interviewees were equally excited about prospects and cared about the quality and output of the research, which made the entire experience wholesome and worthwhile. If there was more time, I would have liked to prototype a few of the easy-win use cases to have a better comprehension of the benefits, risks, business value, and implementation complexity.

Having more participants always enhances the generalizability and quality of the thesis output, but with the given time constraints and COVID-19 restrictions, the case study findings seemed satisfactory. Hopefully, the conclusions and recommendations add value to academicians, AR developers, and organizations!

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Appendix A

Appendix

A-1 Management of Technology Relevance

This section will address the relevance of this thesis to MOT course programme.

The website of MOT describes the programme as: *"The programme in MOT educates students as technology managers, analysts of technological markets (either as scientists or consultants), and entrepreneurs in highly technology-based, internationally-oriented and competitive environments for a variety of industrial sectors(MOT, n.d.)."*

The firm where this thesis was conducted is a multinational organization within the food sector. The novel technology of augmented reality smart glasses is said to play a role in digital transformations of organizational processes, which was also extensively focused upon in this thesis.

Further, they highlight the questions that companies face that can be addressed by the programme (MOT, n.d.). These include:

> *1. What technologies do we need and when?*

This thesis conducted at Cargill studied where and when the technology of augmented reality smart glasses can be used in the organization.

> *2. Do we procure the technology we need with our own research capabilities, in collaboration with outside parties, or by acquiring it or licensing it from others?*

Resources, competencies, and capabilities were identified in this study that could assist organizations in adopting the technology.

> *3. How can we use the abundant technological opportunities to affect our mission, objectives and strategies?*

Through the process of digitalization using smart glasses, organizations like Cargill can achieve sustained competitive advantage. This was also indicated in the thesis. Conclusively, this thesis meets the objectives of the MOT programme.

A-1-1 Connection to other courses

MOT2312: Research Methods: This course was designed to guide students to develop and execute research steps from initial research problem to drawing conclusions. This course introduced an array of qualitative and quantitative research methods and laid the foundation for designing a scientific research project in MOT and evaluating its results. The structure of this research, methods chosen for conducting the research and data collection, and studying the result were all adopted from the course material provided in lectures.

MOT1435: Technology, Strategy, and Entrepreneurship: This course was designed to help students how organizations formulate and implement technology strategy and study the external market environment. The pattern of S-curve followed by innovations that was briefly studied and critiqued in this thesis was introduced in this course. The concept of resource based view was also briefly touched upon in lectures and utilized in this thesis.

MOT2421: Emerging and Breakthrough Technologies: The pattern of development and diffusion followed by smart glasses, and the barriers that may explain why it is in a certain phase were theoretically introduced in this course and used in the thesis. Further, the hype cycle used to assess the future of the technology was practically applied to understand the future of smart glasses. The knowledge imparted through this course proved to be valuable for this thesis.

MOT1524: Leadership and Technology Management: The concept of resource based view, and how talent and employees as human resources can contribute to sustained competitive advantage was explained in lectures and used in this thesis. Also, the importance of leadership management and organizational culture in high-tech organizations was taught in this course.

SEN9720: Logistics and Supply Chain Innovations: This course helped the author learn about the basics of supply chains and how innovations can contribute in enhancing these supply chains. The project that was conducted to create and design a supply chain, and visualize how it can be improved by an innovation was helpful in understanding the supply chain at Cargill.

MOT1003: Integration Moments: In this course, a project on truck platooning was assigned to the author's team. The aim of this course project was to analyze the technology using all the concepts and theories learned in the first year of the MOT programme. The author worked together with students from different disciplines and tried to understand the organizational, commercial, and financial angles to the implementation of the innovation of platooning. The capabilities developed during this course project especially when deriving relationships between different parts of the MOT program and applying MOT knowledge and skills were useful when approaching a technology like augmented reality smart glasses and analyzing it with the theories learned.

A-2 Interview guide

Before any interview, an introduction presentation on the author and the thesis was given. This presentation included the following information:

- *Title Slide:* This included the title of the thesis, the author name and role in the organization
- *Goal of the thesis:* The practical problem of COVID-19 disrupting supply chains, lack of study and research on use of augmented reality smart glasses in food supply chains and food safety and quality in particular, and the organizations' need for a plan for implementation. The opportunity lied in understanding the technology, functionality, and industrial use cases. Additionally, one could document the pros and cons of using AR smart glasses in the food industry for specific use cases, and finally develop a roadmap for implementation.
- *Research questions:* The penultimate slide presented the research questions, which are discussed in 1-5.
- *Thesis Scope:* Finally, the boundaries of this research as shown in the figure below formed the content of the last slide.

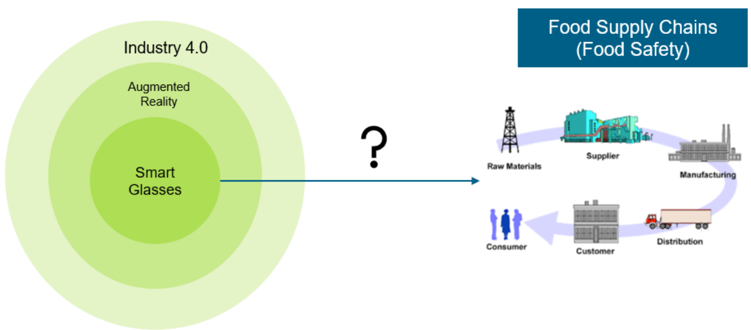

Figure A-1: The focus area of this thesis was within AR smart glasses and food supply chains

Once this background and context was provided, the semi-structured interviews began. For the first research question, there were three sets of stakeholders were: developers and researchers, managers of end-users, and end-users. The questions that were posed and the rationale behind them are as follows.

Developers and Researchers, and Managers of End-Users	
Question	Rationale
Please introduce yourself and your role in the organization	Based on their background and interests, how does their attitude toward the technology differ
Do you think smart glasses have been fully adopted within organizations and is a part of their daily work processes? Or is it still in the testing phases?	Diffusion of technology practically, may not have been captured real time in literature, hints of barriers faced to large scale adoption/diffusion
According to the literature, ARSGs face a lot of barriers to large-scale diffusion. What are the barriers to this technology according to you that are preventing it from fully diffusing into organizations?	Narrate barriers that they feel are significant based on their experience, maybe some of it is not recorded in literature yet
(Provide examples from literature if context is not understood, Insert probing technique if the conversation strays too far)	
What do you think are now the drivers to the technology? What pushes the technology into the market? Why should organizations be buying smart glasses?	Narrate drivers they feel are significant based on their experience, maybe some of it is not recorded in literature yet, latest trends in the technology and field of AR, capture dimensions of value
(Provide examples from literature if context is not understood, Insert probing technique if the conversation strays too far)	
What are the value adding components in smart glasses that are unique to that device? These for example, should not be present in other AR carrying devices like tablets, smartphones, assisted reality, etc.	Arguments that can enhance the value of smart glasses, convincing reasons for businesses and organizations to invest in latest technologies, latest trends in the technology and field of AR, importance of smart glasses for the work force
(Provide examples from literature if context is not understood, Insert probing technique if the conversation strays too far)	
Finally, going back to the challenges and barriers you mentioned (use their examples), do you think these are solvable in the future? Which of them are, if not all?	Future of the technology and where the discipline is headed, technology picking up pace in the next few years to come or is it a trend that fades, should companies actually invest their efforts, time and money in such a technology
Thank you for your time, do you have any questions for me?	If there are any grey areas/limitations that have been missed during the literature review, future recommendations for thesis
Do you know whom can I contact for furthering my research and getting more information?	Snowball sampling, purposive judgement sampling
Thank you once again, have a nice day! I will forward my thesis to you if you are interested! Bye :)	

Table A-1: Questions posed to developers and researchers and managers of end-users on augmented reality smart glasses for RQ1

End-Users	
Question	Rationale
Please introduce yourself and your role in the organization	Based on their background and interests, how does their attitude toward the technology differ
For what purpose did you make use of the smart glasses?	End application it is used for might affect their overall experience and attitude towards the technology
What were the positive aspects when you made use of smart glasses for that application?	Narrate drivers they feel are significant based on their experience, maybe some of it is not recorded in literature yet, latest trends in the technology and field of AR, capture dimensions of value
Did you face any technical difficulties when using the device? If so, what were they?	Narrate barriers that they feel are significant based on their experience, maybe some of it is not recorded in literature yet
(Provide examples from literature if context is not understood, Insert probing technique if the conversation strays too far)	
Did you face any ergonomic challenges when using the device? If so, what were they?	Narrate barriers that they feel are significant based on their experience, maybe some of it is not recorded in literature yet
(Provide examples from literature if context is not understood, Insert probing technique if the conversation strays too far)	
What do you think the device needs to improve upon immediately?	Identify their biggest pain points that might need attention
Do you foresee any applications for the device apart from what application you are familiar with?	Their knowledge and expertise might help in identifying use cases within their discipline
Thank you for your time, do you have any questions for me?	If there are any grey areas/limitations that have been missed during the literature review, future recommendations for thesis
Do you know whom can I contact for furthering my research and getting more information?	Snowball sampling, purposive judgement sampling
Thank you once again, have a nice day! I will forward my thesis to you if you are interested! Bye :)	

Table A-2: Questions posed to end-users on augmented reality smart glasses for RQ1

Proceeding to questions posed to interviewees for research question two, the questions were based on the food safety and quality processes. Initially, the understanding developed from literature was discussed. Additionally, from company documentation, an overview of the edible oils supply chain and what activities take place in the refining and packaging units were presented. The edible oils supply chain is shown in 4-4 and the chemical processes in the refinery and packaging units is shown in **??** in the confidential appendix. This was done to provide context to the interviewee and understand where and what were the intervening food safety and quality processes.

FSQR employees	
Question	Rationale
Please introduce yourself and your role in the organization	Understand their background and interests
Is there a difference between food safety and food quality? If so, what is?	Identify the distinction between the two, if it is different from how it is mentioned in the literature, understand the lingos inside the company and how they classify activities
(Present a diagram of the edible oils supply chain and chemical processes that take place in the refinery and packaging units)	
Where do you think are the FSQR interventions in the above diagram?	Identify a list of FSQR processes within the chosen scope of focus
What are the FSQR processes that take place at these interventions?	Imagine possibilities of digitalizing the FSQR processes
Do you have any additional documentation of the FSQR processes that you can provide?	Deepen understanding of FSQR processes, examine exactly where smart glasses can be used, what sub-processes within the FSQR process can be digitalized
Thank you for your time, do you have any questions for me?	If there are any grey areas/limitations that have been missed during the literature review, future recommendations for thesis
Whom can I contact for furthering my research and getting more information?	Snowball sampling, purposive judgement sampling
Thank you once again, have a nice day! I will forward my thesis to you if you are interested! Bye :)	

Table A-3: Questions posed to FSQR employees for RQ2

For the third research question, the use cases created based on the FSQR processes as shown in 6-3 were presented. The questions posed to the participants were initially on the benefits and risks of each of the use cases, but were quite unstructured. The participants were asked to elaborate on their responses if it was unclear and further questions stemmed from their responses.

For the fourth research question, the tangible and intangible resources required needed to be identified. Stakeholders were questioned on how they approached the technology, the approval processes, and other resources they worked towards organized. Since it was semi-structured, there were sometimes additional questions asked out of curiosity and to enhance the output.

Technology security and risk analysts, service owners, Global IT employees	
Question	Rationale
Please introduce yourself and your role in the organization	Understand their background and interests
When a new technology like smart glass is introduced, on what basis is their usability and adoption within the organization evaluated? What are the different parameters of interest?	To identify if assessment procedures need to be drafted, if there were standard procedures created for the purpose, how do employees share information and knowledge (all these classify as additional resources required)
Do you usually have an exclusive team or set of people within the organization working on assessing the technology?	To understand what resources are required for a device like smart glass to get approved by technology, governance, risk and regulatory departments
How can smart glasses be made more compliant to reach maturity?	To understand on what fronts improvements are required with respect to the device, are there workarounds (resources) that companies have arranged in order to use the device
What are the software approval requests to use on the device that have arrived? How are they evaluated?	Will organizations be open to complementary services and products because the devices' value might be limited using just built-in applications, do additional tangible/intangible resources need to be arranged for this
Does the department that monitors and regulates technology and associated risks undergo changes in this age of Industry 4.0?	Are organizations restructuring themselves and their business units to be more responsive, are the roles of individuals changing, are new human resources being hired (all classify as resources)
Do you think there are organizational changes required to adopt new innovations?	Are organizations restructuring themselves and their business units to be more responsive, are the roles of individuals changing, are new human resources being hired overall, are third party organizations being hired to monitor the safety and security of the smart glass ecosystem (all these classify as resources needed)
Are new smart glasses going to be approved in the future?	Do companies only stick to familiar technologies or are they willing to explore alternatives (do they mention the need for resources)
Provide the definition for tangible and intangible resources from theory	
Do you think any other resources are required? If so, what are they?	Additional resources that the literature might not have identified or something that might have not been previously mentioned that are tangible like technology infrastructure
Thank you for your time, do you have any questions for me?	If there are any grey areas/limitations that have been missed during the literature review, future recommendations for thesis
Whom can I contact for furthering my research and getting more information?	Snowball sampling, purposive judgement sampling
Thank you once again, have a nice day! I will forward my thesis to you if you are interested! Bye :)	

Table A-4: Questions posed to a set of stakeholders for RQ4

A-3 Relevant figures

Middle ground approach

First cycle of coding: Descriptive coding	
Category	
Barriers	
1	Adjustment to darker of brighter than usual environments
2	Audio issues due to noisy environments
3	Battery
4	Battery depends on application
5	Brightness and contrast
6	Computation and performance
7	Connectivity
8	Cooling
9	Cost
10	Display technology
11	Field of view
12	Heavy on the head
13	Inhibited usage in ATEX areas
14	Interaction
15	Lack of complementary products and services
16	Lack of training
17	Mindset changes
18	Overall comfort and wearability
19	Privacy concerns
20	Safety
21	User interface
22	Visual discomfort
Drivers	
23	Contextualized information
24	Cost-effectiveness
25	Depth perception
26	Engagement with employees
27	Flexibility in training and communication
28	Hands-free
29	Immersion experience
30	Information overlay
31	Registration
32	Self-contained
33	Standardized workflow
34	Visual documentation and process tracking

Second cycle of coding: Descriptive + Pattern coding		
Category	Codes	Sub-codes
Barriers		
	Technological	Adjustment to darker of brighter than usual environments
		Audio issues due to noisy environments
		Computation and performance
		Connectivity
		Display technology
		Field of view
		Interactions
		User interface
	Organizational	Cost
		Mindset changes
		Privacy issues
		Safety
	Ergonomic	Heavy on the head
		Overall comfort and wearability
		Visual discomfort
Drivers		
		Contextualized information
		Cost-effectiveness
		Engagement with employees
		Flexibility in training and communication
		Immersion experience and depth perception
		Information overlay
		Standardized workflows
		Visual documentation and process tracking

Figure A-2: Cycles of coding during qualitative data analysis to identify most impact drivers and barriers

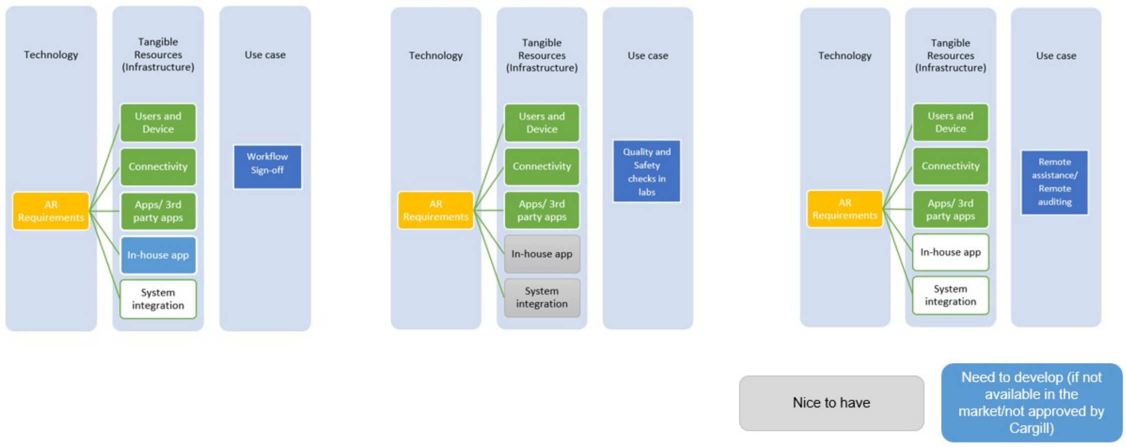

Figure A-3: Tangible resources required per use case - Part 1 (Authors' own interpretation based on literature mentions and interview findings)

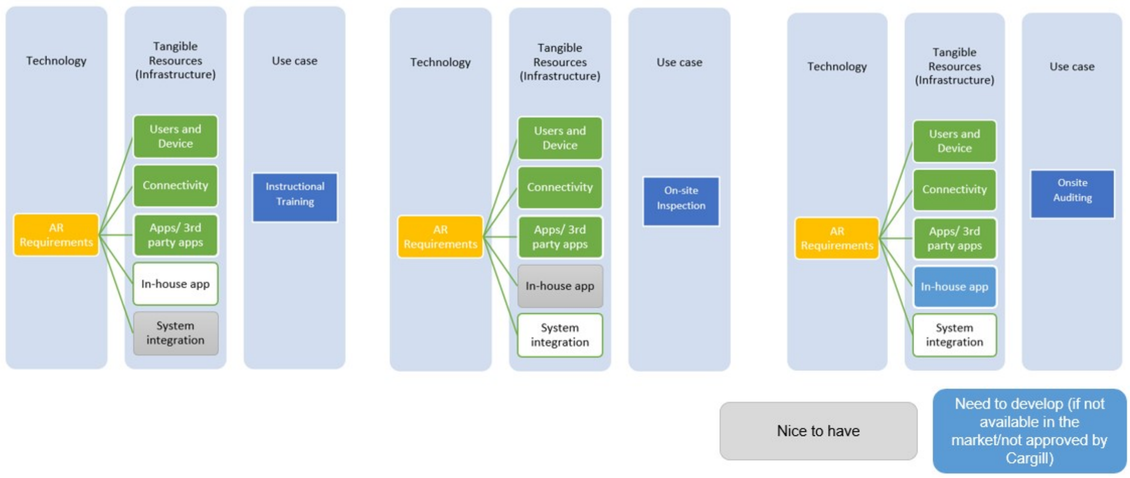

Figure A-4: Tangible resources required per use case - Part 2 (Authors' own interpretation based on literature mentions and interview findings)

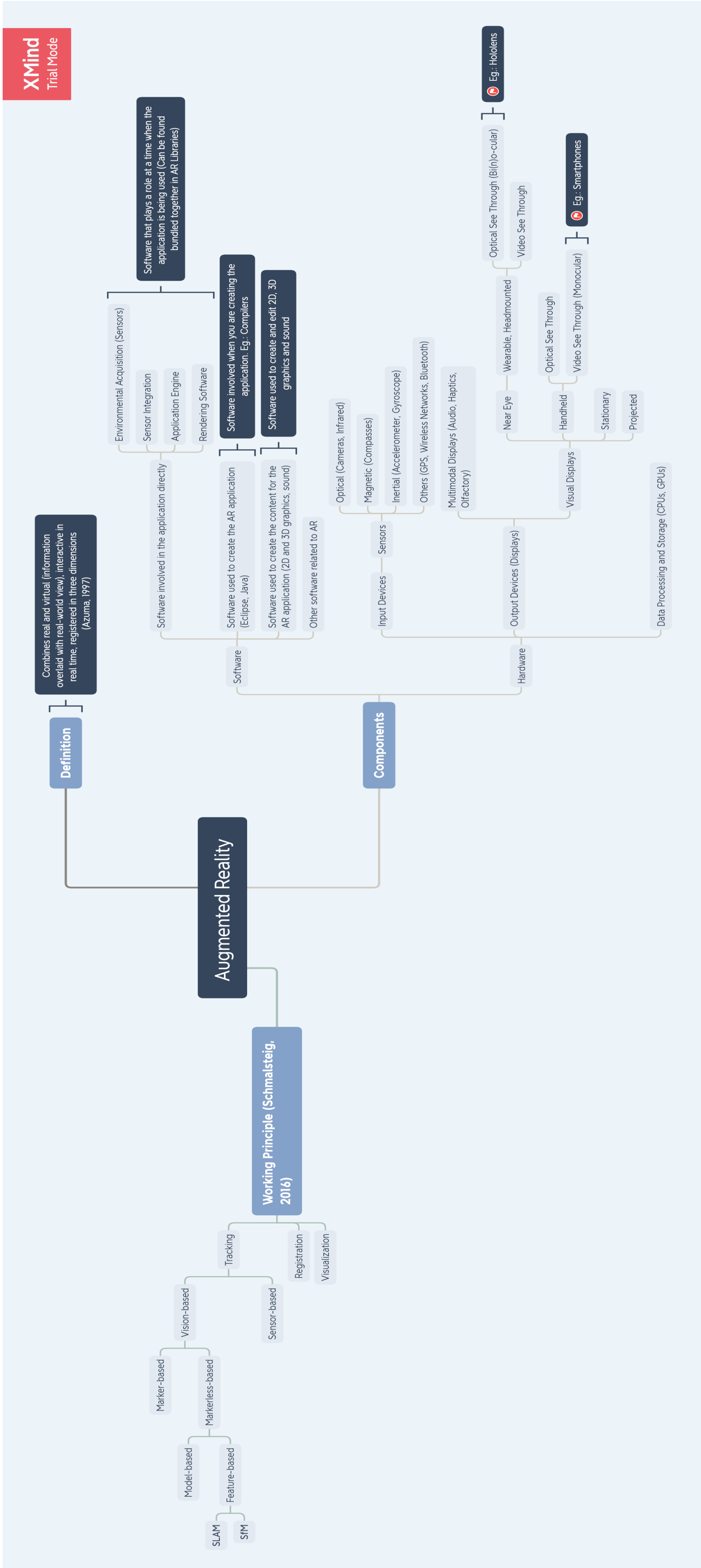

Figure A-5: Augmented Reality Mind Map (Authors' own interpretation)

Glossary

List of Acronyms

2/3-D	2/3 Dimension
3/4/5-G	3/4/5 Generation
ANZFA	Australia New Zealand Food Authority
AR	Augmented Reality
ARSG	Augmented Reality Smart Glasses
ATEX	ATmosphere EXplosibles
BRC	British Retail Consortium
CAD	Computer Aided Design
CCP	Critical Control Point
CCTV	Closed Circuit Television
CoE	Center of Excellence
CoP	Community of Practice
COVID-19	Coronavirus Disease 2019
CPU	Central Processing Unit
DHL	Dalsey Hillblom Lynn
ERP	Enterprise Resource Planning
EU	European Union
FAO-WHO	Food and Agriculture Organization - World Health Organization
FSQR	Food Safety, Quality, and Regulatory

GDP	Gross Domestic Product
GE	General Electric
GIS	Geographic Information System
GPS	Global Positioning System
HACCP	Hazard Analysis
HBR	Harvard Business Review
IoT	Internet of Things
IP	Intellectual Property
IT	Information Technology
OPRP/oPRP	Operational Prerequisite Program
PC	Personal Computer
PLM	Product Lifecycle Management
PRP	Prerequisite Program
QACP	Quality Assurance Control Point
QMS	Quality Management System
QR	Quick Response
RD	Research and Development
RAM	Random Access Memory
RBV	Resource Based View
SAR	Spatial Augmented Reality
SCP	Smart Connected Products
SfM	Structure from Motion
SLAM	Simultaneous Localization And Mapping
TIM	Technology and Information Management
TQM	Total Quality Management
UI	User Interface
VR	Virtual Reality
WiFi	Wireless Fidelity