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Automation of Stores

A case study about using unmanned vehicles at IKEA

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Abstract

Background and Problem Discussion: Industry 4.0 changes business climates and the value creation for companies, rendering some processes obsolete when new requirements are being placed on operational efficiency and flexibility. The transformation towards using Industry 4.0 technologies has already begun, but companies face challenges when wanting to use them. IKEA wants to transform stores by using unmanned vehicles, an Industry 4.0 technology. However, it creates implications as there is no clear guideline of what companies should consider when wanting to use unmanned vehicles. This is especially evident in stores that are part warehouse, such as in IKEA's case.

Purpose and Research Question: The purpose of this study was to get an overview of how unmanned vehicles would affect IKEA's organization. The research question was: *What are the factors that IKEA should consider to use unmanned vehicles in stores?*

Literature Review: The literature review found current studies on Automation Projects, IT, and Impact on Humans in relation to Industry 4.0 and unmanned vehicles. In some cases, studies specifically addressed unmanned vehicles, but in other cases, broader articles covering Industry 4.0 were used due to the lack of studies on the former.

Methodology: Ontological and epistemological beliefs influenced the decisions made in terms of methodology and methods. An abductive approach and qualitative research strategy were used together with a single case study design. In addition, 10 Semi-structured Interviews were held with employees at IKEA. These were analyzed with a thematic analysis. In addition, a narrative literature review was done. To summarize, it was an explorative study.

Empirical Findings: Three themes were found after a thematic analysis was done. The first, *Automation Objectives*, included projects, costs, and scalability. The second, *IT*, included Systems and Data. The third, *Impact on Humans* consisted of Impact on Employees as well as Ergonomics and Safety.

Analysis and Conclusion: After comparing the literature with the empirical findings, 13 factors to consider if using unmanned vehicles in IKEA's stores were found. They were divided into three main groups: *Automation Objectives, IT, Impact on Humans.* In terms of managerial implications, IKEA is recommended to take those factors into account, but should remember that they do not guarantee success by themselves and could create new implications if not investigated properly. Research implications include additional research on what to consider if using unmanned vehicles or a similar technology related to Industry 4.0.

Keywords: Automated Guided Vehicles, Autonomous Mobile Robots, Digitalization, Industry 4.0, Unmanned Vehicles

Abbreviations

AGV: Automated Guided Vehicle

AMR: Autonomous Mobile Robot

CPS: Cyber-Physical Systems

IoT: Internet of Things

WMS: Warehouse Management System

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Ida Gustafsson
Gothenburg, June 2, 2021

Björn Olmarker
Gothenburg, June 2, 2021

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Introduction

1.1 Background

Digitalization is one of the most significant elements that affect businesses and their operations in many industries (Matt, Hess and Benlian, 2015). In addition, the global competition and customer requirements can be met by using new technology (Rojko, 2017). To improve operational effectiveness, an important step for companies is to forecast changing business conditions that might impact the business in the future (Chase, Shankar and Jacobs, 2018). Moreover, anticipating new technologies and adapting to changing customer needs is crucial for improved performance (Finger, Flynn and Paiva, 2014). To this end, Industry 4.0 is being anticipated and adopted by companies (Rojko, 2017).

Industry 4.0 is the communication between machines and the utilization of automation technologies (Hermann, Pentek and Otto, 2016; Xu, Xu and Li, 2018). The main components of Industry 4.0 include Cyber-Physical Systems (CPS), Internet of Things (IoT), Big Data, Robotics, Cloud Computing and Augmented Reality (Kagermann, Wahlster and Helbig, 2013; Radivojević and Milosavljević, 2019). These technologies change current business climates and the value creation for companies, rendering some processes obsolete when new requirements are being placed on efficiency and flexibility (Hofmann and Rüsch, 2017; Xu et al., 2018).

The logistics sector is affected by Industry 4.0 (Hofmann and Rüsch, 2017). It leads to new opportunities of tracing goods flows in real time and reduced handling damages, due to automation of tasks and analysis of data (Hofmann and Rüsch, 2017). Both small and large companies to this end question using human resources to move material, when it can instead be automated and thereby optimize productivity and reduce bottlenecks (Mobile Industrial Robots, n.d). More specifically, McKinsey & Company (2017) discussed that there is a huge potential for warehouses in the field of logistics to automate tasks, leading to substantial automation breakthroughs in the sector. Moreover, online shopping is a contributing factor to the digitalization of warehouses, leading to the need of a quick transformation by retailers to integrate their online and offline channels and to optimize their warehouses to improve lead time (Bayram and Cesaret, 2020). Automation in warehouses eliminates errors, increases efficiency, reduces operating costs, assures availability of goods as well as increases precision and speed of information flows (Bałys, Buła, Dziedzic and Uznańska, 2020).

To reap the benefits of Industry 4.0 technologies and automation, modern warehouses have already been implemented (Bałys et al., 2020). However, the transformation towards using Industry 4.0 technologies will not happen overnight, even though it has already begun (Drath and Horch, 2014).

1.1.1 Concepts in focus

As previously discussed in section 1.1, Industry 4.0 technologies commonly refer to CPS, IoT, Big Data, Robotics, Cloud Computing and Augmented Reality (Kagermann et al., 2013; Radivojević and Milosavljević, 2019). Therefore, in this study, the term Industry 4.0 technologies is used for those. In addition, automation technologies are part of Industry 4.0 (Baker and Halim, 2007). Therefore, in this study, warehouse automation is used to describe technologies related to automation in the context of Industry 4.0. Warehouse automation is thus handling equipment that produces movements and storage without operators or drivers, hence excluding technology where operators are necessary (Baker and Halim, 2007).

Two central technologies for automation in warehouses in the context of Industry 4.0 are Automated Guided Vehicles (AGV) and Autonomous Mobile Robots (AMR), which are machines, or physical robots, that can help automate transportation and picking tasks (Fragapane, de Koster, Sgarbossa and Strandhagen, 2021; Oyekanlu, Smith, Thomas, Mulroy, Hitesh, Ramsey, Kuhn, Mcghinnis, Buonavita, Looper, Ng, Ng'Oma, Liu, Mcbride, Shultz, Cerasi and Sun, 2020). AGVs have traditionally been used for repetitive transportation tasks in warehouses, following a guiding infrastructure for navigation (Oyekanlu et al., 2020). They can detect obstacles, but cannot navigate around them, leading to many stops (Mobile Industrial Robots, n.d). AMRs on the other hand can navigate autonomously which has resulted in them being more effective in flexible scenarios (Michel, 2020; Oyekanlu et al., 2020). Hence, they can autonomously move around obstacles, such as humans and pallets, and plan an efficient route to reach the target (Mobile Industrial Robots, n.d).

Over time, AGVs have however become more flexible and can navigate more autonomously due to advancements in technology (Michel, 2020). This has resulted in AGVs and AMRs not being so different, and in many cases, they are used interchangeably in automation tasks in warehouses (Michel, 2020; Oyekanlu et al., 2020). Hellmann, Marino, Megahed, Suggs, Borowski and Negahban (2019) use the terms AGV and AIV, an abbreviation for automated intelligent vehicles. Krkoška, Gregor and Matuszek (2017), Liu-Henke, Jacobitz, Göllner, Zhang, Scherler and Yarom (2020) and Rey, Corzetto, Cobano, Merino and Caballero (2019) instead define AGVs as autonomous. As there is no consensus of the difference between these two technologies in the literature, AGVs and AMRs will be assessed together and not separately in this study and will be called unmanned vehicles.

To summarize, unmanned vehicles is used in this study when such detailed and specific information is available. If not, a categorization for Industry 4.0 technologies or automation technologies has been made in relation to the distinguishing criteria discussed above.

1.2 Case Company

After being founded in 1943 by Ingvar Kamprad as a mail order company, IKEA has been on an accelerating growth journey and is today one of the most well known furniture brands across the world (IKEA, n.d*a*). IKEA has developed into a franchise business with Inter IKEA being the franchiser and 12 different companies being franchisees, operating in 54 markets. Inter IKEA and the franchisees work together with fulfilling their common vision to '*create a better everyday life for the many people*'. In their business idea, the vision comes to life, which is to '*offer a wide range of well-designed, functional, home furniture products at prices so low that as many people as possible will be able to afford them*' (IKEA, n.d*b*). Ingka Group is the largest franchisee, and consist of IKEA Retail, Ingka Centres and Ingka Investments. Ingka Retail is the core of Ingka Groups' business, and represents 90% of IKEA's total sales (Ingka, n.d.). This study will focus on Ingka Group stores.

The last decade, IKEA has encountered a continuous increase in their online sales, which has been further accelerated as a result of the global pandemic Covid-19 (IKEA, 2021). In the financial year 2020, IKEA's online sales grew by 45 percent and the online order share of total sales grew from 10 to 16 percent (IKEA, 2021). Online orders can be fulfilled in several different ways, where customers can choose home-delivery, delivery to a parcel service point or to be collected at their local IKEA store. This is in contrast to sales in physical stores, which are fulfilled in what IKEA calls a 'Cash and Carry'-concept, where customers traditionally have been picking up and carrying products home themselves[1]. In response to customers' changing shopping behaviour, and the implications for logistics in fulfilling these orders, IKEA is considering different ways to integrate the fulfillment of online orders with physical sales[1].

To work towards their vision of '*reaching more of the many people*' in a cost efficient way, where an increasing share of sales are done online, IKEA has developed a store fulfillment concept. To transform stores, IKEA is planning on repurposing areas of the stores in six different steps. These steps are required for IKEA to transform their stores which are currently optimized for the "Cash and Carry"-concept. This study is focusing on exploring the conditions for the fifth step in this transformation, *Automation Solution*, which is the last step before a total rebuild and repurpose of IKEA's stores[1]. In that step, IKEA consider using unmanned vehicles to automate processes[1]. The step is highlighted in fig. 1.1.

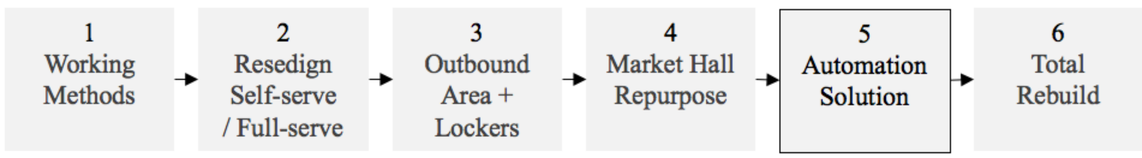

Figure 1.1: IKEA's Store Fulfillment Enhancement

[1]Customer Fulfillment Specialist at IKEA Retail Experience, Personal Communication 11 of February 2021

1.3 Problem Discussion

Industry 4.0 is the first revolution predicted in advance, which provides opportunities for companies to shape their future (Hermann et al., 2016). That is, companies can use Industry 4.0 technologies to increase operational effectiveness (Hermann et al., 2016). However, Culot, Fattori, Podrecca and Sartor (2019) and Hermann et al. (2016) identified that companies face challenges when trying to identify and use Industry 4.0 technologies. In their report, McCreary and Petrick (2018) also found a challenge in the sense that Industry 4.0 technologies change faster than companies make decisions or can change their skills. Companies change too slowly to reach the anticipated transformation (McCreary and Petrick, 2018). This leads to challenges in terms of how companies can make sense of unmanned vehicles. No thorough analysis of what to consider if companies want to use unmanned vehicles is found in the current literature.

The concern of how companies can introduce Industry 4.0 technologies in the context of logistics operations in warehouses is prevailing. That is, many considerations have to be made in regards to how much transformation and automation of the existing processes are necessary to meet customers' requirements of short lead time when ordering online (Dekhne, Hastings, Murnane and Neuhaus, 2019). This is prevalent for IKEA, that is facing the same change of customer shopping behavior, necessitating a transformation of their fulfillment process in the upcoming future. Optimal implementation of warehouse automation is far from done and there exist many areas for further analysis and development (Patricio and Mendes, 2020). Since IKEA wants to transform stores to fulfillment concepts, where one step is to unmanned vehicles, it creates implications as there is no clear definition of how companies should think in terms of Industry 4.0, or terms of warehouse automation. Moreover, as IKEA's stores are part store and part warehouse, they need to consider their stores' specific characteristics when introducing unmanned vehicles.

Previous studies describe the function of unmanned vehicles (Schulze, Behling and Buhrs, 2008) as well as how to change processes (Van Looy, 2021) and transform digitally (Matt et al., 2015). Although there are success stories on organizations automating warehouses, such as Amazon (Laber, Thamma and Kirby, 2020), there is a gap in the literature of how to use unmanned vehicles in stores, where there are both customers and employees. Therefore, this study aims at closing this gap, which will essentially contribute to help IKEA with what to consider to use unmanned vehicles in their stores. Ultimately, helping IKEA transforming to fulfillment stores, and other companies facing the same challenge.

1.4 Purpose and Research Question

As previously discussed, Industry 4.0 technologies affect companies and many want to use unmanned vehicles to reap its benefits. Companies face challenges when wanting to use unmanned vehicles, and more specifically IKEA faces challenges in terms of using them in their stores. Thereby, this study starts from both a practical problem but also due to a lack of current literature in the field. Based on this, the purpose of this study is to get an overview of how unmanned vehicles would affect IKEA's organization. More specifically, IKEA's Ingka stores. By fulfilling this purpose, new research on the field is created, which will further help companies and IKEA understand how to make sense of unmanned vehicles. Hence, the research question aims at investigating this, and is as follows:

Research Question: *What are the factors that IKEA should consider to use unmanned vehicles in stores?*

1.5 Disposition

The following chapters of this study include a literature review, methodology, empirical findings, analysis, and conclusion. The figure below, fig. 1.2, allows the reader to visualize the disposition of this study for an easier understanding of the following chapters.

Figure 1.2: Disposition of Chapters

2

Literature Review

2.1 Industry 4.0

There is no clear definition of Industry 4.0 in the literature (Hermann et al., 2016; Hofmann and Rüsch, 2017; Xu et al., 2018). Moreover, several different words are synonymous with Industry 4.0, such as Industrial Internet, Smart Industry, Advanced Manufacturing, Integrated Industry and Smart Manufacturing (Hermann et al., 2016). Xu et al. (2018) wrote that Industry 4.0 is the fourth industrial revolution, following the previous three industrial revolutions: steam power, electricity, and the information age. Hermann et al. (2016) and Xu et al. (2018) argue that Industry 4.0 is not a future trend but a revolution happening right now. However, Schroeder (2016) described Industry 4.0 as an evolution. Hermann et al. (2016) conducted an extensive analysis of keywords associated with Industry 4.0 and grouped them in different clusters, primarily generating the five most prevalent themes: interconnection, collaboration, standards, security, and data analytics. Moreover, they found that human-machine collaboration, data and information security, and decentralized decisions are more discussed in industrial publications, where the first two are the biggest challenge to successfully use Industry 4.0 (Hermann et al., 2016).

Industry 4.0 was originally introduced in 2011 as a vision for strengthening the German competitiveness in the manufacturing industry (Drath and Horch, 2014; Hermann et al., 2016; Horst and Santiago, 2018; Xu et al., 2018). Thereafter, Industry 4.0 was publicly announced by the German government as a strategic vision in 2013 (Xu et al., 2018), but officially adopted as a concept in academia in 2015 at the world economic forum annual meeting (Devezas, Leitão and Sarygulov, 2017). There has been a proposed plan of actions on how Germany could implement Industry 4.0 (Zhou, Liu and Zhou, 2015; Kagermann et al., 2013). This plan of actions consisted of eight objectives to be able to achieve Industry 4.0 (Kagermann et al., 2013; Zhou et al., 2015) and was widely considered to be the initial definition of Industry 4.0 (Horst and Santiago, 2018). Horst and Santiago (2018) argued that what Germany's strategy does not by itself work in other countries or situations. However, Liao, Deschamps, Loures and Ramos (2017) found, in an extensive literature review, that more than 40% of academic reports cited this initial plan of action, indicating its importance to science. In addition, Kagermann et al. (2013) highlighted that the eight objectives are research recommendations since they are assessed to be key priority areas to reach Industry 4.0. The areas are summarized in table 2.1.

Standardization of systems and building a reference architecture
Management of complex systems
Establishment of comprehensive and reliable industrial broadband infrastructure
Safety and security
Organization and design of work
Staff training and professional development
Establishing a regulatory framework
Improving efficiency of resource use

Table 2.1: Priority Areas for Action Proposed by Kagermann et al. (2013)

One priority area concerns the *standardization of systems and building a reference architecture* (Kagermann et al., 2013). Technologies need to be standardized between different systems and companies (Kagermann et al., 2013). These standardizations have to be done through the perspectives of software applications in manufacturing, business planning, intralogistics, and product lifecycle management (Kagermann et al., 2013). Kagermann et al. (2013) believes this reference architecture should be developed incrementally instead to integrate different perspectives and to later be unified in an international standard. Another area is the *management of complex systems* (Kagermann et al., 2013). Increasing product customization, increasingly dynamic delivery requirements, and integration of different technical disciplines are creating new challenges (Kagermann et al., 2013). Ivanov, Dolgui and Sokolov (2019) wrote that Industry 4.0 technologies can help address manufacturing flexibility, market responsiveness, and reduce lead times. The *establishment of comprehensive and reliable industrial broadband infrastructure* is also a priority area (Kagermann et al., 2013). For CPS for Industry 4.0 to work, there needs to be a broadband infrastructure that is reliable and capable enough of hosting this technology (Kagermann et al., 2013).

Safety and security is moreover a priority, as Industry 4.0 technologies should not be dangerous for humans or the environment (Kagermann et al., 2013). In addition, data and equipment should also be protected. Industry 4.0 technologies are networked and interconnected with real time data analysis and exchange. This puts new implications in safety in regard to third parties. Safety affects people and the environment and security affect data and services (Kagermann et al., 2013). *Organization and design of work* is another area and regards the impact of Industry 4.0 on jobs, and the responsibilities of different stakeholders (Kagermann et al., 2013). Jobs might change drastically, and it is important to include them in the change (Kagermann et al., 2013). As jobs might be transformed due to the automation of manual tasks, new roles are created (Kagermann et al., 2013). Therefore, staff training and professional development is another important area. This, as it is important to continuously train employees for this change (Kagermann et al., 2013).

Establishing a regulatory framework is another area and concern that laws might need to be changed or revised to work with the changing business context of Industry 4.0 (Kagermann et al., 2013). This is primarily a challenge for protecting corporate data, assessing new liabilities, handling of personal data, and possible trade restrictions (Kagermann et al., 2013). Lastly, *improving the efficiency of resource use* is one area that highlights the importance of reducing environmental impact and using existing resources more efficiently. This includes physical, human, and financial resources (Kagermann et al., 2013).

Liao et al. (2017) found that the most common articles that highlight the eight plans addressed standardization reference architecture as well as resource productivity and efficiency. Only one article addressed the regulatory framework. Liao et al. (2017) further argued that there are other important areas to research concerning Industry 4.0 that were not explicitly mentioned in the Industry 4.0 report by Kagermann et al. (2013), namely real time data analysis, data integration, and big data analytics. Moreover, Schroeder (2016) argued that the early stage of Industry 4.0 enables companies to adopt it and apply their ideas. Therefore, the following sections are influenced by the areas found by Kagermann et al. (2013) and the additional important areas found by Liao et al. (2017), and their relation to unmanned vehicles. This, since it is important, according to the mentioned authors, that companies apply Industry 4.0 technologies to their specific context.

2.1.1 Automation Projects

In addition to the eight priority areas mentioned by Kagermann et al. (2013), those authors also highlighted that Industry 4.0 is a long-term project that involves a gradual process. Moreover, it is an evolutionary process that progresses differently depending on individual companies. In the literature, incorporating unmanned vehicles in different businesses has also been studied (Bechtsis, Tsolakis, Vlachos and Iakovou, 2017). Therefore, this section will investigate literature describing areas associated with important areas in projects concerning unmanned vehicles. More specifically, this section addresses Management, Costs and Standardization.

2.1.1.1 Management

Understanding the business requirement use automate technologies, analyzing the automation options and defining the scope of automation is important in automation projects, according to Baker and Halim (2007). Similarly, Hirman, Benesova, Steiner and Tupa (2019) argued that defining the company vision and strategy for implementing Industry 4.0 is important. Moreover, Maroušek and Novotnỳ (2016) discussed that projects related to Industry 4.0 must have a project goal in line with the corporate strategy to be successful. Unrealistic or undefined goals are described as the main reasons for failing automation projects (Varila, Seppänen and Heinonen, 2005). Thus, authors agree that understanding the reason to automate and to have clear objectives is important when running automation projects (Baker and Halim, 2007; Hirman et al., 2019; Maroušek and Novotný, 2016; Varila et al., 2005). The reasons for companies to use automation technology are different according to the existing literature. Baker and Halim (2007) investigated the reasons for automation technologies in warehouses. They found that reasons were to accommodate growth in terms of capacity, reduce operating cost, and reduce the staff (Baker and Halim, 2007). This is to some extent in line with the findings by Varila et al. (2005), who found increased cost efficiency and better controllability over operations and material flows as the main reasons and effects of automation. The case company that Varila et al. (2005) analysed found it impossible to handle a growing number of orders manually, and using automation was deemed as the most cost-efficient way to achieve growth. Their assumption was moreover that automation would reduce employees needed and thereby perform operations at lower costs (Varila et al., 2005).

Including employees in automation projects, or projects related to Industry 4.0 technology, was found important in several studies for a successful outcome (Baker and Halim, 2007; Klumpp, Hesenius, Meyer, Ruiner and Gruhn, 2019; Neumann, Winkelhaus, Grosse and Glock, 2021). Tortorella, Miorando, Caiado, Nascimento and Portioli Staudacher (2021) concluded that the relationship between Industry 4.0 technologies and operational performance was positively affected by employees' involvement. Managers who reinforce employees' involvement during the project have higher operational performance when adopting Industry 4.0 technologies than the ones who fail to care about the employees' involvement (Tortorella et al., 2021). Müller, Kiel and Voigt (2018) also found a similar effect in the sense that employees' trust plays an important role in the adoption of new technology related to Industry 4.0. In addition, Sanders, Kaplan, Koch, Schwartz and Hancock (2019) saw that employees are more likely to choose to use unmanned vehicles when they trust that the technology will work. Therefore, employees are critical success factors, and their acceptance plays an important role in the diffusion of new technology related to Industry 4.0 (Müller et al., 2018). Thus, authors agree that taking employees into account in automation projects is important.

Overall, using automation technologies run as major projects within companies and those projects are complex (Baker and Halim, 2007). Sarvari, Ustundag, Cevikcan, Kaya and Cebi (2018) argued for the importance of scheduling and defining milestones and project statuses to in the end start using Industry 4.0 technologies. The scheduling moreover should define concrete actions (Sarvari et al., 2018). Baker and Halim (2007) also explained that it is important to plan automation projects, criticize them, and refine them several times. Moreover, using computer simulations to test and identify bottlenecks of the automation solution was deemed as important by Baker and Halim (2007). Simulation and tests should be done before introducing Industry 4.0 technologies, as it reflects different scenarios that can improve the robustness of the Industry 4.0 technologies (Salkin, Oner, Ustundag and Cevikcan, 2018). Simulation can thereby be a supportive tool (Salkin et al., 2018). Rodič (2017) discussed using simulations to digitally represent the technology that is going to be used in Industry 4.0, before introducing it. In addition, suppliers were, in some cases, involved from the start and the whole project developed together with them (Baker and Halim, 2007). Suppliers as well system integrators could be important in complex projects in the sense that they could bring value to the project and develop the automation solution together with the company (Baker and Halim, 2007). Akdil, Ustundag and Cevikcan (2018) described the role of suppliers and discussed that for companies to be ready to use Industry 4.0 technologies, partnerships with suppliers are important and could preferably be a part of the planning. Sarvari et al. (2018) also emphasized that companies should consider what to gain when collaborating with suppliers.

2.1.1.2 Costs

Dehnavi-Arani, Sadegheih, Mehrjerdi and Honarvar (2020) and Hwang, Moon and Gen (2002) explained how unmanned vehicles decrease material handling costs. However, the installation cost of the technology is significant and if the technology does not work, it can result in losses in productivity and profits (Hwang et al., 2002). Varila et al. (2005) argued that problems related to automation in warehouses have been cost related, which could be a result of unrealistic expectations. Moreover, Varila et al. (2005) found that costs can relate to that automation requires standard procedures. That is, activities must be redefined and changed to use automation technologies (Varila et al., 2005). In addition, it was found to be related to increased indirect costs, such as electricity, maintenance, and time by management and the IT department to solve automation technology issues (Varila et al., 2005). Varila et al. (2005) moreover saw that if the objective with automation technologies is to only cut costs in part of a process, it only results in moving bottlenecks somewhere else instead of eliminating them. Thus, they suggest that when deciding to automate for example the material handling activities, the whole process must be optimized and not just separate parts.

Using unmanned vehicles will change the current way of performing tasks, which ultimately reduces labor costs (Schulze and Wullner, 2006; Vivaldini, Rocha, Martarelli, Becker and Moreira, 2016). Baker and Halim (2007) however discussed implications of reducing costs or reducing the staffing levels as main objectives for automation. In those cases, they found that automation projects had major disruptions on companies' ongoing operations (Baker and Halim, 2007). Baker and Halim (2007) moreoever discussed the importance of having key performing indicators (KPIs) to monitor the automation project. In addition, Aguiar, Oliveira, Tan, Kazantsev and Setti (2019) explained that identifying and using KPIs is important when using unmanned vehicles. Similarly, Hrušecká, Lopes and Juřičková (2019) discussed that companies should not have many KPIs, but instead use ones focused on key elements important to the specific department or business. Having too many could instead lead to confusion (Hrušecká et al., 2019).

2.1.1.3 Standardization

Schulze and Wullner (2006) describe that material flow processes in warehouses are characterized by high volume. It is an area where unmanned vehicles normally work, as they have a high loading capacity (Schulze and Wullner, 2006). In addition, unmanned vehicles are characterized by scalability, in the sense that increasing the number of unmanned vehicles can be done (Fragapane et al., 2021). Erol, Sahin, Baykasoglu and Kaplanoglu (2012) discussed how unmanned vehicles are an efficient way for handling materials due to better space utilization and safety. Dehnavi-Arani et al. (2020) additionally highlighted that unmanned vehicles can increase space flexibility.

The unmanned vehicles usually handle standardized pallets and are therefore equipped with standard loading devices (Schulze and Wullner, 2006). Dombrowski and Wagner (2014) argued that automation results in positive scale effects from standard sequences of high volume processes. Custodio and Machado (2020) however identified problems with standardized tasks when reviewing the literature, in the sense that there are problems for automated equipment to handle products of different shapes, sizes, and weights. Unmanned vehicles usually perform repeatable processes that are characterized by small variations (Custodio and Machado, 2020). Echelmeyer, Kirchheim and Wellbrock (2008) also highlighted this and discussed that, normally, unmanned vehicles are involved in repetitive activities with standardized operations, leading to a challenge to handle different sizes and compositions of products. Salkin et al. (2018) suggested to standardize processes and avoid variations to start using Industry 4.0 technologies. Thus, areas where automation technologies are normally used, according to the authors, involves standardized processes with no variation.

2.1.2 IT

CPS is one of the revolutionary changes in the fourth industrial revolution, according to Xu et al. (2018). In addition, one of the eight important priority areas proposed by Kagermann et al. (2013) to achieve Industry 4.0 included management of complex systems, where integrating technological disciplines was mentioned. Another area included security, where data should be protected from third parties (Kagermann et al., 2013). Kagermann et al. (2013) additionally described that one of the eight priority areas for Industry 4.0 concerns resource efficiency, where companies have to increase productivity through better utilization of, among others, physical resources. Liao et al. (2017) moreover discussed the importance of real time data analysis, data integration and big data analytics. Thus, as these areas was mentioned as important in Industry 4.0, and since software, CPS and data is used together with unmanned vehicles (Aguiar et al., 2019; Zhang, Zhu and Lv, 2017), this will be discussed further in this section. More specifically, this section addresses Cyber-Physical Systems / Internet of Things, Big Data Analytics, Cloud Computing and Security.

2.1.2.1 Cyber-Physical Systems / Internet of Things

CPS is an integrated system of communication, computing and control for bringing the physical and virtual worlds together in many fields such as manufacturing, transportation and logistics (Mostafa, Hamdy and Alawady, 2019). It is a mediator to connect people, objects and physical processes in a warehouse operation (Lee, Lv, Ng, Ho and Choy, 2018). IoT is a concept where physical objects can communicate with each other through various means of technology (Mostafa et al., 2019; Sung and Lu, 2018; Tran-Dang, Krommenacker, Charpentier and Kim, 2020; Trappey, Trappey, Hareesh Govindarajan, Chuang and Sun, 2017; Yuan and Zhao, 2012). This increased connectivity between objects creates the opportunity for them to do various tasks such as to increase interaction between machines and humans, or machines to machines through identification, linking physical and digital objects, location services, monitoring, tracking and control (Mostafa et al., 2019; Sung and Lu, 2018; Yuan and Zhao, 2012).

There are several authors that argue that the difference between these two technologies is not that big. Zhu, Zhou, Yen and Bastani (2015) wrote that CPS and IoT are very similar, but that CPS regards the full control of a system, whereas IoT rather regards the control of individual objects. There are many authors in academia that group these two technologies together for simplicity. Shih, Chou, Reijers and Kuo (2016) discussed that they are grouping CPS and IoT together in their report, although there are some differences in the system architecture between them. Moreover, Pisching, Junqueira, Dos Santos Filho and Miyagi (2016) argued that Industry 4.0 is still in its infancy and that standardized definitions are still being developed and argued that CPS is more prevalent than IoT in literature regarding Industry 4.0. Costa, Santos, Schaefer, Baierle and Nara (2019) investigated the usage of Industry 4.0 keywords and found that CPS and IoT are closely interrelated in academia, with some difference being that CPS is more commonly used in the context of sensors, simulation and transmission systems. At the same time, IoT was more commonly used in the context of digitization, data analysis and big data (Costa et al., 2019). Costa et al. (2019) also argued that since the technologies are still being developed it is difficult to distinguish how closely related CPS and IoT will become in the future. Following other authors (Costa et al., 2019; Pisching et al., 2016; Shih et al., 2016; Zhu et al., 2015), CPS and IoT will be grouped together in this report for the sake of clarity as CPS/IoT.

CPS/IoT can bring a virtual and physical world together to construct a networked world, where smart objects communicate and interact with each other to increase productivity, resource efficiency, and accuracy (Liu, Cao, Yang and Jiang, 2018). Aguiar et al. (2019), Costa et al. (2019), Liu et al. (2018), Shih et al. (2016), Tran-Dang et al. (2020) and Zhang et al. (2017) discussed that unmanned vehicles often are connected to CPS/IoT. Liu et al. (2018) and Zhang et al. (2017) described that unmanned vehicles use many sensors to navigate, avoid collisions, and communicate with other systems and that this information needs to be properly managed for unmanned vehicles to be efficient. Aguiar et al. (2019) further argued that connecting unmanned vehicles with CPS/IoT allows for better management of operations since it increases productivity and uses resources more efficiently.

CPS/IoT network is beneficial when working with a warehouse management system (WMS), where real time information sharing enables correct decision support to address increasing order variety and complexity in the context of Industry 4.0 (Lee et al., 2018). Lee et al. (2018) further described that unmanned vehicles can help increase the performance of picking activities, as a WMS can use analysis and propose suitable picking patterns and coordination of tasks for them. Liu et al. (2018), Mao, Xing and Zhang (2018) and Mostafa et al. (2019) wrote that CPS/IoT is beneficial in warehouses, where data is gathered and sent to the WMS. The WMS can then in turn validate quantities, the authenticity of articles in real time and make decisions of what the proper actions in the warehouse to take (Liu et al., 2018; Mao et al., 2018; Mostafa et al., 2019). This standardizes tasks, reducing or even removing human intervention which increases efficiency, cuts cost and reduces lead time (Gorse, Johnston and Pritchard, 2020; Mostafa et al., 2019; Trappey et al., 2017). Cogo, Zunic, Besirevic, Delalic and Hodzic (2020) and Tejesh and Neeraja (2018) further argued that a WMS can localize products within the system through using CPS/IoT. Lee et al. (2018) additionally described that CPS/IoT facilitates responsiveness and flexibility in the WMS, which makes dealing with modern order and demand patterns easier.

Lee et al. (2018), Mao et al. (2018) and Tran-Dang et al. (2020) discussed that using CPS/IoT in a warehouse can be difficult if management of data flows in the warehouse is incorrect, inefficient or not in time. Liu et al. (2018) wrote that there is a lot of work to be done to digitize the information in a warehouse to make it ready for Industry 4.0 and to be connected to a CPS/IoT. Moreover, if the management of information is done correctly, Lee et al. (2018) and Mostafa et al. (2019) argued that CPS/IoT would increase the amount of generated data and that it could be shared in real time, making data analysis more efficient to support decision-making processes. It is important to remember that with new processes, employee's tasks should be easier and not become more of an administrative hassle (Mostafa et al., 2019).

Several authors argue that integration with legacy systems can be complex for CPS/IoT (Choi, Kang, Jun, Lee and Han, 2017; Guo and Wong, 2017; Givehchi, Landsdorf, Simoens and Colombo, 2017; Hoske, 2016; Mostafa et al., 2019; Trappey et al., 2017). Thus, the main challenge for CPS/IoT is the collaboration with legacy IT-systems of companies, or systems that are separate and can not be connected to them (Trappey et al., 2017). Givehchi et al. (2017) wrote that the variety of different systems in an organization can create issues in integration with new technology due to local adjustments in line with the organization's needs. The integration of CPS/IoT with legacy systems can severely affect the efficiency and cost if not addressed correctly due to legacy systems being created towards other purposes or in other contexts than they are performed in today (Guo and Wong, 2017). Hoske (2016) further argued that legacy systems often were not created for communication with other systems, and instead often purposively isolated for safety reasons. Interface solutions can make complex integrations of legacy systems and CPS/IoT easier and more convenient (Choi et al., 2017) .

2.1.2.2 Big Data Analytics

Big data is an essential component of Industry 4.0 due to all the data that is generated through CPS/IoT in the connectivity and interoperability between humans and systems (Santos, Oliveira E Sá, Andrade, Vale Lima, Costa, Costa, Martinho and Galvão, 2017). Xu and Duan (2019) described that while CPS/IoT is required for Industry 4.0, big data is needed to manage and use this data efficiently. In this way, Ivanov et al. (2019), Lee et al. (2018) and Li, Tan and Chaudhry (2019) discussed that big data and CPS/IoT are very closely connected in the context of Industry 4.0. Efficient management and processing of data is a success factor for using unmanned vehicles (Aguiar et al., 2019). Lee et al. (2018), Sanders (2016), Xu and Duan (2019) and Yin and Kaynak (2015) argued that using big data is potentially very meaningful for operational optimization in companies, and Ivanov et al. (2019), Li et al. (2019), Sanders (2016) and Xu and Duan (2019) explicitly mentioned big data to increase resource efficiency in Industry 4.0 systems. In addition, Xu and Duan (2019) argued that the quality of Industry 4.0 processes would increase with big data. Thus, big data creates many opportunities for companies to become more flexible and adaptive, creating new possibilities to compete (Mcafee and Brynjolfsson, 2012).

Mcafee and Brynjolfsson (2012) distinguished big data from traditional data as it consists of three new dimensions. The first one concerns how the amount of generated data is increasing exponentially and is referred to as *Volume* (Coda, Salles, Junqueira, Filho, Silva and Miyagi, 2018; Ivanov et al., 2019; Mcafee and Brynjolfsson, 2012; Wang, 2018; Xu and Duan, 2019; Yin and Kaynak, 2015). Waller and Fawcett (2013) discussed that more details in data is generated, giving depth to it and increasing its size. Xu and Duan (2019) wrote that increasing affordability and utilization of sensors makes CPS/IoT more common, resulting in huge amounts of data in logistics operations using it. The second one, *Velocity* of data means that it is gathered quicker than before, making it possible to manage it in real time (Coda et al., 2018; Ivanov et al., 2019; Mcafee and Brynjolfsson, 2012; Xu and Duan, 2019; Yin and Kaynak, 2015). With big data, it is possible for companies in the context of Industry 4.0 to process data and take decisions in real time (Santos et al., 2017). It also means more frequently collection of data, where, as an example, it could be collected every minute instead of every day (Waller and Fawcett, 2013). The third one, the *Variety* of data, is created in an increasing number of formats and on different platforms such as sensors and new signal networks (Coda et al., 2018; Ivanov et al., 2019; Mcafee and Brynjolfsson, 2012; Wang, 2018; Xu and Duan, 2019; Yin and Kaynak, 2015). The variety of data for logistics inventories often increases with online shopping (Waller and Fawcett, 2013). Xu and Duan (2019) further described that increasing variety of data is important for understanding complex problems, since the variety gives different perspectives on it.

Coda et al. (2018), Gil and Song (2016), Ivanov et al. (2019) and Yin and Kaynak (2015) argued that there are two additional dimensions to big data - *Veracity* and *Value*. *Veracity* refers to the credibility of the data itself, and *Value* constitutes the potential value of the data itself (Coda et al., 2018; Gil and Song, 2016; Yin and Kaynak, 2015; Ivanov et al., 2019). Xu and Duan (2019) referred to veracity as the accuracy of the data and value as the gain and impact from it.

Data in itself is not valuable but needs to be analysed to become meaningful (Ivanov et al., 2019; Wang, 2018). Ivanov et al. (2019) and Nguyen, Gosine and Warrian (2020) further argued that data analysts to this sense analyse big data to support decision making in companies, and Xu and Duan (2019) wrote that proper analysis of big data can improve forecasts of customer behavior. Mcafee and Brynjolfsson (2012), Sanders (2016) and Tan, Zhan, Ji, Ye and Chang (2015) discussed that whereas data traditionally used to be structured, now a larger share is becoming unstructured, making analysis of it more complex. Nguyen et al. (2020) further argued that lack of standardization in Industry 4.0 has created increasing amounts of unstructured data. The rapidly increasing volume of big data makes it even more important to analyse it in real time (Tan et al., 2015). Waller and Fawcett (2013) further described that the volume of big data has grown to the point that it has to be reduced and structured in real time to be able to draw meaningful conclusions from it. Furthermore, Nguyen et al. (2020) wrote that it is not uncommon that data in organizations is not accessible centrally but instead exists in different locations, making analysis more difficult since the data additionally have to become integrated. However, the changing dimension of data makes structuring and analysing it more important (Tan et al., 2015).

2.1.2.3 Cloud Computing

Cloud is an online infrastructure that supports Industry 4.0 through servers and cloud computing technologies (Choi et al., 2017; Costa et al., 2019; Gil and Song, 2016; Li et al., 2019; Nguyen et al., 2020; Tran-Dang et al., 2020; Xu et al., 2018). This means that a company does not have to own their own physical computers on a specific site, but that it is instead provided through the internet (Choi et al., 2017). Nguyen et al. (2020) further described that cloud computing is when companies are using services through the cloud, such as analysis, storage or management of data. Moreover, Costa et al. (2019) and Mostafa et al. (2019) wrote that it is a key technology for Industry 4.0, and Tran-Dang et al. (2020) argued that it reduces the workload on CPS/IoT since the computational power and capacity for managing data does not have to exist locally on these devices but instead are more efficiently managed centrally. Other benefits are not needing to invest in hardware, which reduces costs, and using cloud greatly increases the capacity of managing and storing data (Costa et al., 2019; Gil and Song, 2016; Mostafa et al., 2019; Nguyen et al., 2020; Velasquez, Estevez and Pesado, 2018; Xu et al., 2018).

When Industry 4.0 technologies are connected to cloud computing, it helps decision making in companies (Li et al., 2019). Gil and Song (2016) argued that it is almost a requirement to efficiently manage big data. Cloud computing increases flexibility in companies, making it easier to address variations in customer demand due to more efficient utilization of resources (Costa et al., 2019). Nguyen et al. (2020) described that using clouds increases the scalability of automation technologies since it can storage large sets of data. Tran-Dang et al. (2020) however argued that using cloud can be negative in the sense that using central computational power increases latency in systems, which can affect the management of real time data, and also that there is a risk of more computational errors.

Li et al. (2019), Nguyen et al. (2020) and Xu and Duan (2019) wrote that cloud computing helps enable data availability through the central accessibility, meaning that data does not have to be stored physically at the location of where it is managed. Nguyen et al. (2020) however argued that this central accessibility through using cloud computation increases risks in companies in the sense that they do not have physical control of the data anymore.

2.1.2.4 Security

Kagermann et al. (2013) wrote that data security was another priority area to achieve Industry 4.0, as protection of confidentiality, integrity and availability of Industry 4.0 technologies is important. Confidentiality concerns restricting access to data to specific users (Kagermann et al., 2013). Integrity concerns the accuracy of data and correct operation of services, while availability means measuring a system's ability to perform a function (Kagermann et al., 2013). Several authors (Benias and Markopoulos, 2017; Culot et al., 2019; Ervural and Ervural, 2018; Kagermann et al., 2013) described that since Industry 4.0 includes exchange of data, interconnected technologies, and integrated information systems, it can lead to cyber criminals trying to exploit the data in their interest. Moreover, Zhou et al. (2015) highlighted big data analysis and processing as a challenge in Industry 4.0, and that enterprise protection of data has to be improved.

Benias and Markopoulos (2017), Culot et al. (2019), Ervural and Ervural (2018) and Sarder and Haschak (2019) explained how CPS/IoT increases the risk of cyber-attacks, and Culot et al. (2019) moreover discussed how it increases the number of entry points for organizations to defend themselves from intruders. Large companies are in particular exposed to hostile cyber attacks that can result in, among others, financial implications, system crashes, and data corruption (Ervural and Ervural, 2018). Moreover, it can disrupt business operations and cause implications on the organization's reputation (Culot et al., 2019).

Sarder and Haschak (2019) addressed cyber security in the context of unmanned vehicles. They described how vulnerable the interconnected system is for a cyber attack, which could lead to cyber criminals taking control of individual devices, a part of a system, or the whole system. Ultimately, it could result in damages, including data loss, equipment damage, property loss, or injury to people (Sarder and Haschak, 2019). Therefore, they emphasize building a resilient cyber security system (Sarder and Haschak, 2019). Benias and Markopoulos (2017), Culot et al. (2019) as well as Ervural and Ervural (2018) also highlighted the importance of a cyber security system, as it protects digital business information from abuse, unauthorized access, and thefts. Many organizations therefore prioritize strengthening their cyber security when they implement Industry 4.0 technologies (Ervural and Ervural, 2018). Several authors, (Kagermann et al., 2013; Liagkou and Stylios, 2019; Ozkan-Ozen, 2018) further argued that security awareness is a key role for Industry 4.0, and that it concerns employees on all levels in companies. Organizations need a cyber security strategy to ensure that everyone has an awareness of threats and competence on how to act in response to it (Kagermann et al., 2013; Ozkan-Ozen, 2018).

2.1.3 Impact on Humans

In Kagermann et al. (2013) priority areas to achieve Industry 4.0, improving the efficiency of resources was one area. This includes using human resources more efficiently. Furthermore, employees were mentioned in two other areas, indicating the important role of employees. More specifically, the two other areas were organization and design of work as well as staff training and professional development. Jobs might change and new roles could be created as an effect of Industry 4.0. Manual tasks become automated, and training is then important for the employees to cope with such change (Kagermann et al., 2013). In addition, safety was also mentioned by Kagermann et al. (2013), and this included that Industry 4.0 technologies should not be dangerous for humans. Besides, several authors highlighted humans as important to consider in regard to unmanned vehicles (Ejsmont, 2021; Kadir, Broberg and Da Conceicao, 2019; Schmidtke, Behrendt, Thater and Meixner, 2018). Based on this, the impact on humans is further elaborated in this section. More specifically, this section addresses Impact on Employees as well as Ergonomics and Safety.

2.1.3.1 Impact on Employees

Ejsmont (2021) discussed that human capital is one the main resources for companies, and if used properly it can allow the company to reach their goals. With Industry 4.0 technologies companies' processes will change, which in turn also changes the competencies and skills required by employees (Ejsmont, 2021; Kadir et al., 2019; McCreary and Petrick, 2018). Ejsmont (2021) argued that the biggest challenge of Industry 4.0 is not the technologies, but the people. Kipper, Iepsen, Dal Forno, Frozza, Furstenau, Agnes and Cossul (2021) emphasize that companies must also be able to attract new talents that are capable of handling the complexity of Industry 4.0 technologies.

It is not exactly clear how Industry 4.0 technologies impacts employees (Ejsmont, 2021). On one hand, it creates possibilities for improving the working environment and leads to the need for specific skills and competencies, but at the same time, it could mean that employees are replaced by automation technologies (Ejsmont, 2021). Employees are more likely to be replaced by automation technology if their tasks relate to the use of physical force, such as repetitive activities (Cimini, Lagorio, Pirola and Pinto, 2019). Thus, repetitive tasks that are not value-adding activities can be automated and assigned to automation technology rather than employees (Cimini et al., 2019; Zacharaki, Kostavelis, Gasteratos and Dokas, 2020). Kadir et al. (2019) also argued that companies will automate easy, repetitive, and manual tasks, while Bonekamp and Sure (2015) explained that companies will automate standardized non-complex tasks. Results from the authors show a common agreement that simple, repetitive and dangerous tasks are the ones that might become automated (Bonekamp and Sure, 2015; Cimini et al., 2019; Kadir et al., 2019; Zacharaki et al., 2020). McCreary and Petrick (2018) and Schmidtke et al. (2018) also discussed that there is a fear of losing jobs, and this fear is an obstacle to implement Industry 4.0 technologies. Hence, it could lead to opportunities but also a decreased employment and an increase in the complexity of human tasks (Ejsmont, 2021). Dombrowski and Wagner (2014) clarified that they do not believe that Industry 4.0 technologies aims at substituting people, but to create a collaborative environment between humans and the technology.

If employees' repetitive and simpler tasks are replaced by automation technologies, they can focus on value-adding tasks (Cimini et al., 2019). Enriching the tasks of employees leads to new competencies required (Cimini et al., 2019) and creates a demand for labor in non-automated tasks (Acemoglu and Restrepo, 2019). Authors agree that various job positions will disappear while some will be created (Benešová and Tupa, 2017; Cimini et al., 2019). Acemoglu and Restrepo (2019) explained that automation technologies are not meant to displace human labor, but to reinstate labor in the sense that new tasks are created. Kadir et al. (2019) agreed and explained that automation technologies have limited flexibility and humans still have to perform complex tasks that require problem-solving skills. Dombrowski and Wagner (2014) also highlighted that employees are needed for complex tasks. The new value-created and non-automated tasks can benefit other departments of the company as employees can instead, for example, support the customer service of the company (Cimini et al., 2019). Moreover, based on these findings in the literature there is an agreement that using automation technologies to complements employees' capabilities allows for higher efficiency and productivity (Acemoglu and Restrepo, 2019; Cimini et al., 2019; Kipper et al., 2021).

When performing more value-adding tasks, employees need to understand abstract information, solve complex problems, have IT competence (Kadir et al., 2019) as well as supervise and monitor the unmanned vehicles' actions (Scholtz, 2003). Kipper et al. (2021) thoroughly analysed what skills and knowledge are needed, and for example concluded that knowledge in automation, data analysis as well as skills in problem solving are needed. Besides, both Bag, Gupta and Luo (2020) and Schmidtke et al. (2018) discussed that employees must interact with the automation technology and monitor it. In addition, authors agreed that these changing competence requirements mean that companies must invest in training and skill development (Baker and Halim, 2007; Bonekamp and Sure, 2015; Hofmann and Rüsch, 2017; Kadir et al., 2019; Kipper et al., 2021; McCreary and Petrick, 2018; Winkler and Zinsmeister, 2019). McCreary and Petrick (2018) argued that some companies are afraid of investing in training employees since they are afraid that the employees would be more desirable by other companies. Benešová and Tupa (2017), however, emphasized the importance of retraining the existing employee rather than hiring new ones, since they know the current processes within the company. Kadir et al. (2019) suggested that companies should identify the skills needed with the new technology, before investing in new automation technologies. Rüßmann, Lorenz, Gerbert, Waldner, Justus, Engel and Harnisch (2015) also emphasized to conduct strategic workforce planning. This is a method for anticipating and understanding the technology and evaluate what skills are needed if using it (Kadir et al., 2019).

2.1.3.2 Ergonomics and Safety

In teams that consist of both employees and unmanned vehicles, the unmanned vehicles will support the physical limitations of the employees by helping with heavy lifts and perform other physical or dangerous tasks (Cimini et al., 2019; Kadir et al., 2019). When humans and unmanned vehicles collaborate, they will enhance each other's strengths (Kadir et al., 2019; Scholtz, 2003; Zacharaki et al., 2020). Ergonomics is an important factor for employees in warehouses, and if not considered it could lead to numerous health problems for employees (Cimini et al., 2019; Loos, Merino and Rodriguez, 2016). Ergonomics in the workplace could be improved when using Industry 4.0 technologies, as heavy tasks are automated (Kadir et al., 2019).

In the literature, authors agreed that collaboration and integration between humans of and unmanned vehicles should be safe (Cimini et al., 2019; Custodio and Machado, 2020; Kirks, Jost, Uhlott and Jakobs, 2018; Krkoška et al., 2017; Löcklin, Ruppert, Jakab, Libert, Jazdi and Weyrich, 2020; Rey et al., 2019; Shackleford, Cheok, Hong, Saidi and Shneier, 2016; Zuin, Hanson, Battini and Persona, 2020), so that injuries are reduced (Zacharaki et al., 2020). Cimini et al. (2019) argued that automation can increase employees' safety since dangerous tasks are among the first to be automated. However, they mentioned that the interaction between humans and unmanned vehicles should be limited if safety could not be assured (Cimini et al., 2019). Jost, Kirks, Gupta, Lünsch and Stenzel (2018) described that due to safety issues in warehouses, unmanned vehicles are in many cases separated from humans.

Jost et al. (2018), Löcklin et al. (2020) and Rey et al. (2019) try to find a safe solution where humans and unmanned vehicles are close together in cramped spaces by making the unmanned vehicles avoid collisions. It is however a risk, as human movements are unpredictable, which increases the risk for collision (Zuin et al., 2020). Zuin et al. (2020) problematize that workers rely on the unmanned vehicles to stop when detecting the workers. Thus, dangerous interactions often happen due to employees not respecting safety rules sufficiently, which in turn also affects the productivity of the unmanned vehicles as they are forced to slow down or stop (Zuin et al., 2020). In addition, another perspective on safety was discussed by Krkoška et al. (2017). Using unmanned vehicles in public areas is increasing, where there are people unaware of the unmanned vehicles that do not know how to act in such environments (Krkoška et al., 2017). Krkoška et al. (2017) found that an increasing number of people in the vicinity of unmanned vehicles create delays for them to reach their destination as they are obstructed and have to stop, impacting the productivity and the utilization of the unmanned vehicles. Krkoška et al. (2017) thereby concluded that the effect of people is a factor that must be considered when using unmanned vehicles in public areas. This insight might affect the movements of the unmanned vehicles, as they can instead pass where there are no people or move during times when they are at least expected to collide with the people. What could be concluded from the findings by Krkoška et al. (2017) and Zuin et al. (2020) is that a safe environment for humans together with unmanned vehicles is possible, but that it might impact the productivity.

As previously discussed, for a safe and collaborative environment, mutual understanding is important in the sense that humans must understand what an unmanned vehicle intends to do, and an unmanned vehicle must understand the humans (Löcklin et al., 2020). This means that the unmanned vehicles must adapt to and estimate humans' intentions to ensure safety and efficiency (Custodio and Machado, 2020). Humans can use their senses and knowledge about unmanned vehicles, but unmanned vehicles need technology to estimate the movements of humans (Löcklin et al., 2020). Zacharaki et al. (2020) argued that there is no standardized method to achieve safety and it can also differ depending on the purpose of usage. However, Zacharaki et al. (2020) discussed that unmanned vehicles should be able to perceive humans and be aware of their presence. In addition, safety should be inherited in the unmanned vehicles' cognitive abilities, meaning that the unmanned vehicles should observe humans and thereby decide on their actions. Both Löcklin et al. (2020) and Rey et al. (2019) suggest using real time localization, which is a combination of hard- and software used to provide real time positions of assets, or in this case humans.

3

Methodology

3.1 The Research Paradigm

Scientists must understand reality, what can be known about it, and how to get that knowledge to conduct a study (Rehman and Alharthi, 2016). Therefore, this was considered before starting this study, to get a proper understanding of the reality that was studied. This study was influenced by what is referred to as the Research Paradigm, which according to Bell, Bryman and Harley (2018) is *"a cluster of beliefs and dictates which for scientists in a particular discipline influence what should be studied, how research should be done, and how results should be interpreted"* (p. 34). Brand (2009) wrote that a paradigm is used to describe the framework for the research. Ultimately, it is about how to understand the world and how to study it (Rehman and Alharthi, 2016). Rehman and Alharthi (2016) argued that the paradigm consists of assumptions about ontology, epistemology, methodology, and methods, which is in line with both Bell et al. (2018) and Brand (2009). The research paradigm is visualized below in fig. 3.1.

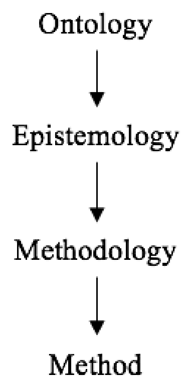

Figure 3.1: The Research Paradigm

Ontology is the researcher's understanding of what reality is and what can be known about it (Bell et al., 2018; Brand, 2009; Rehman and Alharthi, 2016). Understanding ontology enables the researcher to do a study that captures the reality of the world the researcher wishes to understand. Epistemology is instead the understanding of how to gain knowledge about reality (Bell et al., 2018; Rehman and Alharthi, 2016), or how it is possible to know things (Brand, 2009). These two are divided, or influenced, by two philosophical positions. Positivism, sometimes named objectivism (Bell et al., 2018) is the belief that the object under study should be understood as existing objectively and is independent of the observer's role (Bell et al., 2018; Brand, 2009; Rehman and Alharthi, 2016). Rehman and Alharthi (2016) describe it as trying to understand the world as context-free. One could gain knowledge of it by observing, measuring or studying it in a static form (Bell et al., 2018). In contrast, constructionism, sometimes labelled as interpretivism by Brand (2009) and Rehman and Alharthi (2016), distinguishes from the objective view of positivism. Instead, this position believes that the object under study is made by social interactions that constantly change and are made real by meanings the observer attaches to it (Bell et al., 2018). Rehman and Alharthi (2016) describe it as the truth and reality are created, and not discovered. Thus, this position is subjective and is affected by researchers' view of the world, concepts, and backgrounds (Rehman and Alharthi, 2016).

What can be concluded from the discussion above is that the ontology position chosen affects the epistemological position (Bell et al., 2018; Brand, 2009; Rehman and Alharthi, 2016). When studying the factors that IKEA should consider to use unmanned vehicles in their stores, it was important to understand the conditions of the company, as that was the reality studied. The assumption the authors made about IKEA's reality was that it continuously changed and was affected by both employees and customers. Besides, the authors of this study early understood that they were going to interpret their findings themselves and would be influenced by their own beliefs, and were in that sense subjective. Therefore, the authors concluded that they were influenced by a constructionist, or interpretivism, ontology. Since reality was viewed as existing subjectively, it needed to be interpreted rather than measured, as discussed by Bell et al. (2018), Brand (2009) and Rehman and Alharthi (2016). This led to the decision of the epistemology position constructionism, or interpretivism.

As previously stated, ontology affects epistemology (Bell et al., 2018). In turn, the epistemological assumptions determine the methodological assumptions, which is the theory of how research should be done (Bell et al., 2018; Rehman and Alharthi, 2016). Bell et al. (2018), Brand (2009), and Rehman and Alharthi (2016) distinguish methodology from method. To clarify, a methodology is a strategy, plan, or process design that refers to how to conduct research, while a method is about practice, such as means of collecting and analysing data (Bell et al., 2018; Rehman and Alharthi, 2016). Methodology is the application of ontological and epistemological beliefs in the research, and regards the research design and links the method chosen to the objective of the research (Brand, 2009). A method is a part of the methodology and refers to the techniques or procedure of the research (Brand, 2009). Bell et al. (2018) discuss that researchers do not always differentiate between these two terms, which is a mistake the authors of this study aimed to avoid by discussing the different definitions. To summarize, the chosen method reflects the methodological assumptions, which follow from epistemology and ontology (Bell et al., 2018).

3.2 Research Strategy

The relationship between theory and research influences the choice of research strategy (Bell et al., 2018), which is why the authors of this study started to discuss that relationship before deciding on a strategy. The relationship concerns whether the research starts from theory or from empirical data, where the former is a deductive approach and the latter is an inductive approach (Bell et al., 2018; Patel and Davidson, 2011). A deductive approach starts from theory and aims to test a hypothesis, and is usually influenced by positivism or objectivism in the sense that knowledge can be measured (Rehman and Alharthi, 2016). Together the theory and hypothesis derive the process of gathering data (Bell et al., 2018). In contrast, an inductive approach starts from the empirical findings and thereafter considers theory related to it (Bell et al., 2018), and is usually influenced by constructionism or interpretivism beliefs (Rehman and Alharthi, 2016). Thus, whether the research starts from theory or empirical data in combination with the philosophical assumptions determines whether an inductive or deductive approach is taken (Bell et al., 2018).

Bell et al. (2018) argue that if choosing constructionist or interpretivism, an inductive approach is suitable. However, the authors of this study argued that the decision of what approach to use was not that straightforward. Since the purpose of this study was to get an overview of how unmanned vehicles would affect IKEA's organization, it was not appropriate to start from theory or the empirical findings as it was an unexplored area of research, as mentioned in the *Introduction* in chapter 1. Moreover, as the research question was formed based on both a practical problem and a lack of literature, the authors needed to gain knowledge of the topic simultaneously from both theory and empirical findings to be able to answer the research question and fulfill the purpose. Chamberlain (2006) discussed that rejecting a positivism belief means rejecting both induction and deduction as those are, according to Chamberlain (2006), based on positivism. Van Hoek, Aronsson, Kovács and Spens (2005) and Patel and Davidson (2011) discuss a third approach, an abductive approach, that originated from the fact that advances in science neither follow pure deduction or induction. Instead, an abductive approach collects data and theory simultaneously and combines an inductive and deductive approach (Bell et al., 2018; Van Hoek et al., 2005). Dubois and Gadde (2002) referred to this process as Systematic Combining, but also explained it as an integrated research process. It is based on constructionism or interpretivism (Bell et al., 2018). Different authors agreed that an abductive approach is suitable when researchers cannot start from theory nor empirical findings (Bell et al., 2018; Chamberlain, 2006; Dubois and Gadde, 2002; Van Hoek et al., 2005). Therefore, an abductive approach was used in this study, as it was in line with both the philosophical assumptions and the explorative and practical research question, where insights were gained during the process to be able to answer it.

After deciding on the relationship between theory and strategy, the authors discussed what research strategy to use, namely a qualitative or quantitative one. Bell et al. (2018) and Patel and Davidson (2011) explained that the distinction between qualitative and quantitative goes deeper than the fact quantitative strategy use measurements while qualitative strategy does not. There is also a difference in terms of ontological and epistemological beliefs (Bell et al., 2018). A quantitative strategy view reality as existing objectively, while a qualitative strategy rejects an objective view, and instead emphasizes that individuals interpret their social world and that the reality is constantly shifting (Bell et al., 2018). Patel and Davidson (2011) further described that a qualitative strategy is commonly used for verbal gathering and interpretation of data. Followed by the philosophical assumptions and the relationship between theory and research in this study, a qualitative research strategy was decided, as both Bell et al. (2018) and Patel and Davidson (2011) argued that it is favorable when choosing an abductive approach. Moreover, it was decided since the research question needed depth of knowledge from employees at IKEA rather than numeric and statistical data to be answered.

Despite their different ontological and epistemological concerns, there is a discussion regarding the real distinction between qualitative and quantitative strategies (Bell et al., 2018). That is, qualitative strategy is mostly focused on generating theories rather than testing them, but in some cases, the strategy has been used to test theories rather than generating them, and qualitative data can in many cases also be quantifiable (Bell et al., 2018). Hence, the authors of this study were careful of distinguishing the two different strategies too much, which leads to the discussion of a mixed-method research design. To answer the research questions, hard data, such as numbers, was initially deemed as a useful possibility to understand factors to consider to use unmanned vehicles. At the beginning of the research process, the study was not restricted to a purely qualitative research strategy. However, as the research progressed in its abductive approach, it was decided not to use any hard data, but instead to use a qualitative research strategy. One reason for this was also philosophical assumptions and the difficulties in accessing and collecting quantifiable data to answer the research question and fulfill the purpose.

Although advantages with a qualitative research strategy and its connection with the philosophical assumptions and research question have been discussed, criticizing it is important to understand its limitations. Bell et al. (2018) expresses a possibility of a qualitative strategy being too subjective, difficult to replicate, difficult to generalize, and a lacks transparency. The authors of this study were aware of this and took actions to reduce the limitations, such as motivating all of the decisions. This is further argued in terms of Credibility, Transferability, Dependability, Confirmability and Authenticity in section 3.5, *Research Quality*.

3.3 Research Design

A research design is a framework for collecting and analysing data to answer the research question, and depends on the purpose, causality, generalizability, time, and research setting, as discussed by (Bell et al., 2018). This study aimed to answer a research question in a specific context, that of using unmanned vehicles in IKEA's stores. Thus, it was complex and required the authors to understand that context to be able to collect and analyse data. Therefore, a case study design was chosen, as it focuses on the specific situation in an entity and highlights the uniqueness of the case (Bell et al., 2018). Besides, Baxter and Jack (2008) explained that it helps to explore the phenomena and to see it from different perspectives. They describe one type of case study design as exploratory, where there is no clear outcome (Baxter and Jack, 2008). To answer the research question, different perspectives were needed to get a nuanced picture of factors to consider for IKEA, and exploring the phenomenon was crucial. Thus, this was another argument for choosing a case study design. Moreover, the research design followed the previous decision made in terms of research strategy, since Bell et al. (2018) emphasized that case study design favors qualitative strategies. Another reason for choosing this design was the philosophical assumptions. Baxter and Jack (2008) discuss how a case study design is built on constructionism or interpretivism and argued that the advantage of the design is the close collaboration between the researcher and respondents, where the respondents can explain their perspectives (Baxter and Jack, 2008).

Bell et al. (2018) explained that case study design is often done in an inductive approach, while Dubois and Gadde (2002) discuss how to do it using abductive reasoning. Hence, with support from Dubois and Gadde (2002), the authors decided that it was feasible to combine a case study design with an abductive approach. However, it is important to note that research designs are not mutually exclusive, meaning that it is possible to combine different ones (Bell et al., 2018). A case study design is in many cases used together with a comparative research design, but such combination requires using multiple case studies as the objective is to compare them (Bell et al., 2018). However, the research question of this study did not require comparing different cases to be answered. Thereby this study focused on a single case study design only and excluded the possibility to make comparisons. There is however criticism towards case studies, as there may be a lack of making generalizable conclusions (Bell et al., 2018; Dubois and Gadde, 2002; Patel and Davidson, 2011). Van Hoek et al. (2005) discuss that this limitation might already start when choosing an abductive approach. This study did not aim at making generalizable conclusions but rather to take advantage of the possibility to explore and get an in-depth understanding of an unexplored topic. The authors were thus aware of this limitation but argue that the findings will still be useful, as discussed further in chapter 6, *Conclusion*.

3.4 Research Method

3.4.1 Primary Data

An initial observation was made by visiting an IKEA store to get an understanding of the company. This observation provided an understanding of the context where unmanned vehicles could be used and helped to give a body to the research topic. Ultimately, it simplified answering the research question. However, after the visit, another phase of the primary data collection began.

The authors of this study early decided on a case study research design, derived from a qualitative strategy, an abductive approach, and philosophical assumptions, and thereby they early agreed on how to gain knowledge of reality. That is, they needed depth of knowledge about IKEA to understand what factors to consider if using unmanned vehicles and decided to conduct interviews. Interviewing is a flexible method in qualitative studies to gather data from respondents, and it can be divided into different types, namely Semi-conducted interviews and Unstructured interviews (Bell et al., 2018). However, Semi-structured interviews were conducted to get responses related to the research purpose and research question, while at the same time allow for follow-up questions, and for the respondents to speak freely. In Semi-structured interviews, an interview guide is used as a base for the interviews (Bell et al., 2018; Patel and Davidson, 2011). Therefore, the authors of this study conducted an interview guide, which also was necessary for comparing and analysing the interviews. Although the interview guide was used as a basis, the order of the questions varied and new questions were be added when needed, based on insights gained from the respondents, as also discussed by Bell et al. (2018) and Patel and Davidson (2011). The semi-structured interviews were appropriate in relation to the abductive approach chosen, since some questions from the interview guide were removed as the authors realized they were unnecessary to answer the research question. The advantage with an interview guide is to be able to rely on questions if interviews show to be inefficient, or if the respondents initially do not want to share their thoughts (Bell et al., 2018). However, respondents cannot speak completely freely, as in unstructured interviews (Bell et al., 2018; Patel and Davidson, 2011), but the authors wanted the interviews to have a balance of free discussions, and standardized questions and thus chose Semi-structured interviews.

The interview guide, found in appendix A, required thorough questions so that the interviews could reach their full potential. Before starting the interviews, the purpose of the study was explained to the respondents. That is, the authors discussed that the study aimed at investigating what factors to consider for IKEA to use AGVs or AMRs in stores. However, the authors explained that the term unmanned vehicles will be used in the report, due to the lack of clear definition and distinction between the two terms. Therefore, some respondents answered the questions using the term *Automation Technologies*, as they did not either know the difference or definition of the terms. After the purpose of the study was explained, the interviews started with introducing questions about the respondent's role and responsibility in the company. Thereafter the interview was divided into different main topics with related questions: *Experience, Project Process, Automation in Stores* and *Software*. Inspired by the different types of questions discussed by Bell et al. (2018), open questions were used to facilitate an environment where the respondents had time to reflect and argue. In some cases, silence was used as a method for making the respondent reflect more, but follow-up questions were used if the respondents did not reflect on the answer. Additionally, probing questions, which is to follow up what has been said through direct questions, was used when the respondent mentioned information relevant to answer the research question. Bell et al. (2018) suggest using a final question to get perspectives of the topic that the interviewer might miss. The last question of the interview guide was therefore *'Is there something you think we should have asked you about that we haven't?'*. This enabled an exhaustive interview that did not exclude any relevant information to the research question. Finally, the type of questions varied during the Semi-structured interviews, as suggested by Bell et al. (2018), which facilitated an open climate during the interviews, and enough answers relevant to the research question.

All interviews were held online through Microsoft Teams with camera and audio, due to the Covid-19 restrictions. Advantages of synchronous online interviews are the ability to do late time adjustments and to be at different geographical places (Bell et al., 2018). Online interviews enabled the authors to gain insights from respondents based outside of Sweden. Some disadvantages, however, are technical issues with internet connection and not being able to observe respondents' behaviour in person (Bell et al., 2018), although cameras were used to reduce that problem. The limitations of online interviews were mitigated by being technically prepared for every interview and by knowing the limitations of online interviewing. The respondents were informed about the purpose of the interview and were given a preliminary interview guide before agreeing to an interview, to make the process as transparent as possible. The respondents were recorded with consent to simplify the process of transcribing. The interviews were directly transcribed since it is an advantage to have it fresh in mind, as discussed by Bell et al. (2018). Also, as many details as possible were included in the transcription which allowed getting a full understanding of the interviews. However, the disadvantage is the large amount of data to handle (Bell et al., 2018). Moreover, three interviews were conducted in Swedish and then translated to English by the authors of this study, which might have had implications as a result. However, this was mitigated as the authors tried to be as accurate as possible when translating, and those respondents were able to make changes if they believed the translation was misleading. Finally, all respondents were able to read the empirical findings, and made changes in cases where they felt misinterpreted. Ethical considerations discussed by Bell et al. (2018) regarding harm to participants, lack of consent, invasion of privacy, and deception were thereby avoided during the primary data collection. It was avoided by being transparent about the process, asking for consent, giving respondents the ability to read the empirical findings, and making them anonymous in the study. That is, they are called by numbers instead of names, which will be shown in the next section 3.4.1.1, *Sampling*.

3.4.1.1 Sampling

The purpose of qualitative sampling is to compile information from people likely to provide insights useful to the research question (Marshall, 1996). Thus, in qualitative studies, improved understanding of an issue is more important than generalizing the conclusions (Marshall, 1996). To randomly pick a sample, which is an approach used in quantitative studies, with the objective that it will represent the whole population is not possible in complex qualitative studies (Marshall, 1996). Instead, an appropriate sample is one that enables the research question to be answered, and for detailed studies, it might be enough with a small one (Marshall, 1996). Bell et al. (2018) define such an approach as purposive sampling, where sampling is done with reference to the goal of the research and to the research question. More specifically, it means to gather data in a non-probable way (Bell et al., 2018). There are different types of purposive samplings, such as theoretical and generic, but which one to use depends on the research question, research design, and style of data analysis (Bell et al., 2018; Marshall, 1996).

In generic purposive sampling, the sampling is purposive to the research question (Bell et al., 2018). That is, respondents are selected based on their ability to answer the research question (Bell et al., 2018). It is commonly used in business research when wanting to gain insight into a range of different roles in an organization (Bell et al., 2018). Thus, since the research question in this study needed different perspectives to be answered, and since a case study design and thematic analysis were used, the authors agreed on a generic purposive sampling. That is, respondents from IKEA with different experiences from automation projects were needed to answer the research question. Moreover, as this study focused on the franchisee Ingka Group, respondents from both Ingka Group and Inter IKEA were interviewed. Bell et al. (2018) discuss how generic purposive sampling can be done sequentially or in a fixed manner, where individuals are decided beforehand. Bell et al. (2018) moreover discussed that it can also be a mix between those two, which was done in this study as well. That is, some initial respondents were decided, but additional respondents were interviewed and were not decided beforehand. More specifically, some initial respondents suggested other respondents, which the authors of this study decided to interview as they also had a relevant role within IKEA and experience of automation. This is a process called snowballing according to Bell et al. (2018). Using more than one sampling approach is common, where purposive sampling often is done in combination with snowball sampling (Bell et al., 2018). Therefore, both generic purposive sampling and snowball sampling were used to answer the research question.

The sample size was not decided beforehand, as previously discussed, as a mix of sequential and a fixed sampling was done in combination with snowballing. Instead, the sampling continued until no new findings were generated from the interviews, a concept called data saturation (Bell et al., 2018; Marshall, 1996). However, theoretical saturation is sometimes used, but it is more related to grounded theory (Bell et al., 2018), which was not used in this study. Thereby, data saturation was used instead. Bell et al. (2018) discussed how sample sizes should not be too small to make it difficult to reach data saturation, but not too large to analyse and answer the research question. Thereby, 10 respondents were interviewed before data saturation was met. From that point, the respondents discussed similar topics and the authors decided that no further interviews were needed. One issue with data saturation is that authors need to make sure to not generalize inappropriately from the data (Bell et al., 2018), but the authors of this study mitigated this by continuously reading and analysing the data and gave the respondents the possibility to read the transcriptions. Moreover, Bell et al. (2018) found that some researchers are critical to saturation, as researchers do not explain how it was achieved. This was mitigated by being transparent with the description of data saturation in this section. Finally, the respondents are described in table 3.1. The duration of the interviews was rounded up to the closest period of five minutes.

Number	Date	Role	Language	Duration
1	10/3 2021	Head of Logistics	Swedish	60 min
2	11/3 2021	Logistics Project Manager	English	90 min
3	17/3 2021	Product Specialist in Automation	English	60 min
4	19/3 2021	Operations Manager	English	60 min
5	23/3 2021	Store with Fulfillment Capability Initiative Leader	English	60 min
6	26/3 2021	Project Implementation Manager	English	60 min
7	30/3 2021	Innovation Leader	English	60 min
8	30/3 2021	Global Business Development Leader	Swedish	60 min
9	31/3 2021	Service Provider Development Leader	English	60 min
10	1/4 2021	Customer Fulfillment Specialist	Swedish	90 min

Table 3.1: Respondents in Primary Data Collection

3.4.2 Secondary Data

The secondary data collection depends on the epistemological position, which in turn is affected by ontology (Bell et al., 2018). Positivists want to synthesize knowledge, but constructionism or interpretivism rather accumulates knowledge (Bell et al., 2018). Therefore, constructionism or interpretivism can find a systematic literature review challenging, as it aims at generating understanding of a topic (Bell et al., 2018). Moreover, when subject boundaries are fluid and can change, a systematic review can be difficult (Bell et al., 2018). This is common for research in business since it borrows theory from other disciplines (Bell et al., 2018), and this limitation affected the literature review of this study. For example, there was no clear definition of AGVs or AMR, as previously discussed in *Concepts in Focus* in section 1.1.1. In addition Bell et al. (2018) argue that a systematic literature review is problematic if not adopting a deductive approach, as the theory in that sense is the basis of the study. Therefore, studies based on constructionist or interpretivism with a qualitative research strategy are more suited to a narrative review as it is less focused and wider in scope than a systematic literature review (Bell et al., 2018). Moreover, a narrative review is also less specific about the criteria for exclusion or inclusion of studies (Bell et al., 2018), which benefited the exploitative research question of this study. Enferm (2007) argue that narrative literature review better suits broad research question, which the question of this study is in terms of a broad spectrum of factors to consider. Thus, it was decided that a narrative review was done in this study, to collect secondary data about unmanned vehicles aimed at answering the research question and fulfill the purpose.

Bell et al. (2018) discuss how there is no longer that big difference between systematic and narrative reviews since some processes in systematic reviews are used in narrative reviews as well. This means that researchers doing narrative reviews can describe some details in their data collection, such as inclusion and exclusion criteria (Bell et al., 2018). Jahan, Naveed, Zeshan and Tahir (2016) however argued that narrative reviews do not require reporting keywords, databases, inclusion, and exclusion criteria. This makes the review biased as literature is selected by the authors themselves (Jahan et al., 2016). The authors of this study concluded that they want to avoid being biased, and thereby chose to describe details about their narrative literature review, as discussed by Bell et al. (2018).

Literature was searched for in scientific databases. More specifically, Google Scholar, GU Super Search, IEEE Xplore, Science Direct, and Web of Science were used. Initial general keywords were used to find articles that proved useful for the topic to get an understanding of it. Those keywords are presented below in fig. 3.2.

General
- Industry 4.0
- Intralogistics automation
- Smart warehouse
- Store automation
- Warehouse automation

Figure 3.2: General Keywords Used

After reading initial articles, the authors of this study gained more knowledge about how keywords were connected and used in the context of unmanned vehicles, which made them search for other, more specific keywords. In addition, as they gathered primary data simultaneously with the abductive approach, keywords were added along the process when new concepts and themes were discovered from the empirical findings. The authors realized they needed literature within different fields to analyse it with the empirical findings. Hence, keywords to find literature in the field of *Projects*, *IT*, and *Humans* in relation to unmanned vehicles were used. These are presented below in fig. 3.3. Keywords were searched for together with the phrases *'AGV'* and *'AMR'*. If no relevant literature was found, the keywords were used together with the phrases *'Industry 4.0'* or *'Automation'*. In other cases, keywords were used together with the phrase *'4.0'*, which for example gave relevant articles that discussed Logistics 4.0. It was an experimental process of finding proper literature with relevant keywords, which Bell et al. (2018) explained as common. Bell et al. (2018) moreover discussed how researchers come across alternative terms, which the authors of this study also did. Different synonyms of the keywords and different combinations, such as *'employees + AGV'* or *'cyber security + big data'*, were used. Bell et al. (2018) also discuss how using different synonyms can help researchers find relevant articles.

Automation Projects
- Costs automation
- KPIs automation
- Projects
- Project management
- Standardization

IT
- Big data
- Cloud automation
- Cyber-physical Systems
- Cyber security
- Internet of things
- Legacy systems integration
- Real time data analysis
- Warehouse management system

Impact on Humans
- Automation employees
- Changing tasks automation
- Ergonomics automation
- Human-robot collaboration
- New skills automation
- Safety

Figure 3.3: Specific Keywords Used

Since this study investigated unmanned vehicles, recent articles were needed, as older articles commonly describe obsolete technology. The authors first tried to include articles written after 2015 and tried to exclude articles written before 2015. However, it was difficult, and instead, older articles were used when there was a lack of newer ones. It resulted in instead including articles written after 2000 and excluding articles written before 2000. Articles covering the topic of *Impact on Humans* were older ones, as the authors of this study concluded that human impact should not differ too much, but articles covering *IT* were newer. In addition, the authors tried to include peer-reviewed articles, and exclude non-peer-reviewed ones. However, as the topic of this study was a specific technology in Industry 4.0, some non-peer-reviewed articles were needed since there is not yet a wide range of studies on the topic. Moreover, robots not connected to transportation tasks or picking tasks in different environments were excluded. The final inclusion and exclusion criteria are visualized below in fig. 3.4.

Inclusion	Exclusion
- Peer-reviewed and non-peer-reviewed articles - AGVs, AMRs, Automation, Industry 4.0 - Mix of qualitative and quantitative articles - Written after 2000 - Written in English	- Technical articles - Other robots apart from AGVs and AMRs - Automation and robots not connected to transportation and picking - Written before 2000 - Not written in English

Figure 3.4: Inclusion and Exclusion Criteria

3.4.3 Data Analysis

A thematic analysis was done to analyse the primary data gathered during the interviews with employees at IKEA. Thematic analysis is a process for identifying and organizing patterns, called themes, in the data (Braun and Clarke, 2012). Those themes are thereafter used to answer the research question (Bell et al., 2018; Braun and Clarke, 2012). In addition, it provides a theoretical understanding that can contribute to the literature related to the research focus. It is important to balance new themes that emerge through the analysis to remain to the topic under study (Bell et al., 2018).

Since a thematic analysis can be used together with both inductive and inductive approaches (Braun and Clarke, 2012), the authors of this report thereby decided use it together with the abductive approach since it is a mix of inductive and deductive. Thereby, they could analyse their data by finding themes, as suggested by Braun and Clarke (2012) and in that sense answer the research question. However, Bell et al. (2018) discuss that thematic analysis lacks specified procedures and different authors define a theme differently. For some, a theme is the same as a code, while for others it is built up by a group of codes (Bell et al., 2018). However, Bell et al. (2018) concluded that a theme is a category identified in the data that relates to the research question and is built on codes identified in the transcripts of the interviews. Hence, that definition was used in this study as well.

Braun and Clarke (2012) described how to make a thematic analysis. That is, to start by familiarizing with the data, generate initial codes, search for themes, review themes, define and name themes, and lastly to produce the report that includes the themes. The thematic analysis in this study was influenced by those steps. That is, the authors started a first phase with coding while still collecting data, and read each transcripts five times while simultaneously making notes about topics that could be used to answer the research question. Starting as soon as possible and reading transcripts several times was also recommended by Bell et al. (2018). Thereafter, those topics were generated into codes. To exemplify, the authors found that respondents spoke about the vision of using unmanned vehicles. Thus, *Vision* became a code in the thematic analysis. This code was found by repetitions in the transcripts, which Bell et al. (2018) argue is the most common criteria for establishing a pattern in the data. However, followed by recommendations from Bell et al. (2018), codes were only created if the repetition of topics were related to the research question. As the thematic analysis progressed, new codes were added and some were modified to better represent the data. That is, initially, first-level codes were found, but thereafter were compared and regrouped into second-level codes, a process also discussed by Bell et al. (2018). Moreover, Bell et al. (2018) discuss the important of reviewing the codes in relation to the transcripts, which the authors of this study did several times before all codes were decided and found. Finally, this phase ended when the data that could answer the research question was fully coded.

In the next phase, the authors started looking for themes. Braun and Clarke (2012) discuss that this phase is an active process where themes are generated rather than discovered. It is a process where the codes are reviewed to identify similarities between them (Braun and Clarke, 2012). Therefore, the authors discussed how the codes could be built into different themes and thereafter found three themes. The authors put data that did not fit into any theme in a specific undefined theme, not used in the study, as discussed by Braun and Clarke (2012). In the next phase, when reviewing the themes again, some data in the undefined theme could be used. Moreover, in that phase, the authors discussed the different themes again and made some changes. Thereafter, the authors named the themes and lastly described them in this report in chapter 4, *Empirical Findings*. An example of the thematic analysis is presented below in fig. 3.5, where the derivation of the theme *Automation Objectives* is visualized together with the first-level codes and second-level codes. The final themes are found in appendix B.

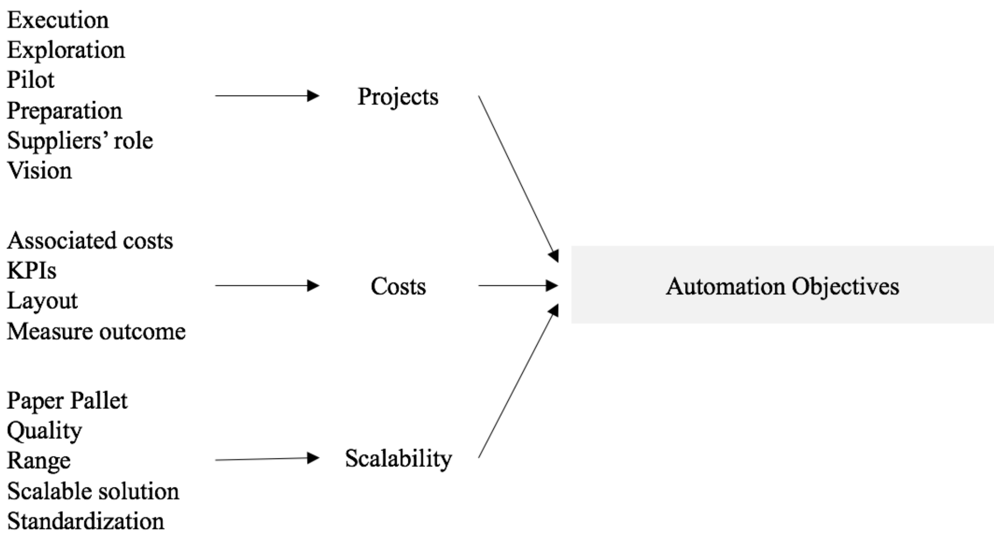

Figure 3.5: Example of the Thematic Analysis

The main advantage of thematic analysis is to make sense of a lot of data (Bell et al., 2018), which this study generated through the Semi-structured interviews. However, by reducing the data through the coding process, there is a risk of losing context (Bell et al., 2018). This was mitigated by revising the data several times to assure that no data related to the research question was removed. Braun and Clarke (2012) similarly discussed how providing data with no analysis and interpretation is another mistake. It is important to give examples of enough data to give evidence to the themes (Braun and Clarke, 2012). This was mitigated by the authors of this study by providing a thorough analysis in chapter 5 with different quotes from the respondents. In addition, Bell et al. (2018) discussed how a thematic analysis can be subjective, since authors are trying to find codes and themes to answer the research question, but might not be able to separate their own bias from personal experiences (Bell et al., 2018). This was mitigated by providing the full data analysis to the respondents so they could comment on it and change it if they did not agree. Moreover, this was discussed when describing the philosophical assumptions, and the authors have made it clear by being meticulous in their methodology.

3.5 Research Quality

Reliability, replicability, and validity are important criteria when evaluating business and management research according to Bell et al. (2018). However, their usage in qualitative research has been questioned as they are mainly related to quantitative research (Bell et al., 2018; Hammersley, 2007). Those criteria, for example, investigate the adequacy of measures and casual relationships (Bell et al., 2018) and are based on other philosophical theories than the ones used in qualitative research (Jenner, Flick, von Kardoff and Steinke, 2004). Thus, those measurements are not in line with the objectives of qualitative research (Bell et al., 2018). Bell et al. (2018) especially question how the quality of case studies can be measured with such criteria but argue that it depends on what the authors of the study deem appropriate. Nevertheless, Bell et al. (2018) found that some researchers doing case studies consider the traditional criteria appropriate, while others do not. Similarly, Hammersley (2007) discuss that some researchers adopt the traditional quantitative criteria to their qualitative work, while others reformulate them. However, some researchers even reject using quality criteria (Hammersley, 2007). This difference could be due to that quality criteria depend on the philosophical assumptions taken in a study, and those can differ between qualitative studies as well (Hammersley, 2007).

Bell et al. (2018) explain that two researchers, Lincoln and Guba, proposed another criterion to evaluate the quality of qualitative research to pursue a reliable study, namely trustworthiness. Trustworthiness consists of credibility, transferability, dependability, and confirmability, which correspond to the criteria used in quantitative research (Bell et al., 2018). Anney (2014), Jenner et al. (2004) and Shenton (2004) also discussed such criteria, originally introduced by Lincoln and Guba, when they explained how qualitative research could be assessed. Lastly, Bell et al. (2018) discussed another criterion by Lincoln and Guba, namely authenticity. The authors of this study considered the criticism of reliability, replicability, and validity, and concluded to use quality criteria that better measure their qualitative study. Thus, it was decided to use trustworthiness.

3.5.1 Credibility

Credibility concerns if the findings of a study represent logical information drawn from the data, and if the analysis of the respondents' viewpoint was correct (Anney, 2014). Shenton (2004) describe it as how the findings correspond to reality. As suggested by Shenton (2004) to achieve credibility, the authors of this study early familiarized themselves with the organization before collecting data, by visiting one of IKEA's stores. Moreover, the respondents were informed that they would be anonymous in this study which resulted in a safe and open environment where they could express themselves, as also suggested by Shenton (2004). In addition, respondents were also allowed to read the empirical findings and notified the authors in cases where they might have been misinterpreted. That way, the authors ensured that the findings correctly corresponded to reality and the respondents' viewpoint. The authors were also given feedback from their supervisor at the university, their supervisor at IKEA as well as course colleagues, which are other ways of improving the credibility, according to Shenton (2004).

3.5.2 Transferability

Transferability is to what extent the result of the research can be transferred to other settings, thus it is similar to generalizability (Anney, 2014). Shenton (2004) found that some authors believe small qualitative studies are impossible to apply to other situations, while other authors found it possible. However, researchers should present enough information about their study so that readers can apply it to their situations (Shenton, 2004). As suggested by Shenton (2004), this study includes information about the number of respondents involved, data collection methods, length of the interviews as well as during what period the data was collected, to increase the transferability. It is however important to mention that the research question is specifically aimed at understanding what factors IKEA should consider to use unmanned vehicles in their stores. More specifically, it was focused on the Ingka Group, which could have implications on transferring the findings to other franchisees within IKEA. However, the authors of this study argue that factors concerning *Automation Objectives* and *Impact on Humans* should apply to other stores, but *IT* might be somewhat different depending on the WMS. However, if other companies with stores want to know what to consider, they can still apply the findings from this study to their situation. To that end, other companies can adjust them to their specific conditions.

3.5.3 Dependability

Bell et al. (2018) explain dependability as to what extent the phases of the study have been described, including for example problem formulation, sampling method, and data analysis decisions. Shenton (2004) similarly highlights that the research process should be described in detail, including research design, data collection, and reflection of the project. Bell et al. (2018), Golafshani (2003) and Shenton (2004) agreed on the importance to make such a description to facilitate the process to be replicated by other researchers.

The authors of this study thoroughly described and argued for every decision made in terms of their methodology and methods to increase the dependability. Although, as they were influenced by their own assumptions and as the reality they studied constantly changed, as discussed in the Research Paradigm, the authors could ensure that other researchers would come to the same conclusion. However, other researchers could come close to similar results by applying the same methodology and methods by simply reading the research process of this study. Although, that also depends on the development of the technology and Industry 4.0, as it is under constant improvement.

3.5.4 Confirmability

Confirmability concerns that the study and interpretations of the findings are not affected by the researchers' imagination (Anney, 2014) or personal values (Shenton, 2004). However, both Bell et al. (2018) and Shenton (2004) discuss the inability to conduct complete objective research, and Shenton (2004) argued that it difficult even if a quantitative research strategy is adopted. To increase the confirmability of a study, Shenton (2004) argued that it is important that the researchers admit their potential biases by describing why certain decisions were made and why their methods were chosen. In addition, describing the weakness of the decisions taken is important (Shenton, 2004). To this end, the authors of this study started by discussing how they viewed reality and how to gain knowledge of it. Thereafter, they made decisions regarding their method and carefully discussed the weakness of their decisions. Thereby, they admitted their potential biases and could increase the confirmability of the study.

3.5.5 Authenticity

Authenticity is an extension of the trustworthiness criteria and it questions how interpretations of people have made (Johnson and Rasulova, 2017). Hence, authenticity involves conducting a study that reflects the experiences perceived by the participants and includes a representation of their differences (Whittemore, Chase and Mandle, 2001). It is vital to be true to the subject that is investigated (Whittemore et al., 2001), and Bell et al. (2018) explain that the researcher is responsible to represent different perspectives. Johnson and Rasulova (2017) further argued that interpreting the respondents' diversity, and position is important. When the researchers of this study interpreted the respondents' answers, they tried to understand what the respondent really meant. In doing so, they took the respondents role and position at IKEA into consideration as well as their experience. The respondents were chosen based on their experience of automation project, but their experiences varied. Thereby, the authors tried to take the respondents different perspectives into account. To exemplify, if a respondent had experience of working with IT in an automation project, that respondent's answer was specifically highlighted in the IT section of this study. Thereby, the authenticity was considered in this study, which further increases the quality of this study.

3.6 Summary of Choices

In the previous sections of this chapter, the Research Paradigm, methodology and methods have been discussed and criticised. The quality of this study was moreover discussed. The different choices in terms of philosophy, methodology and methods are visualized and summarized below in fig. 3.6.

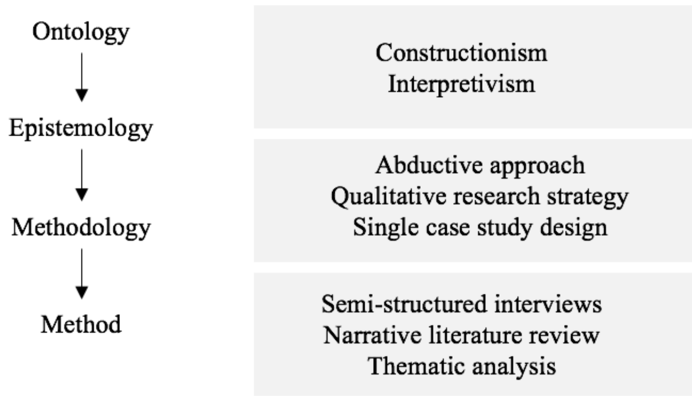

Figure 3.6: Summary of the Research Paradigm and Choices

4

Empirical Findings

4.1 Automation Objectives

4.1.1 Projects

All of the respondents described that the main reasons to use automation technologies are to improve capacity, improve the safety and ergonomics of the employees, support IKEA's sustainability goals and to reduce operational costs. Respondent 10 described that IKEA has a long-term vision to reach 3 billion people around the world. There is always a criteria of reducing operational costs for automation technologies (respondent 9). Five of the respondents emphasized that automation technologies in most cases support IKEA's sustainability agenda, reducing the environmental footprint when performing the same tasks. Additionally, another reason for using automation technologies was to reduce the number of damaged articles associated with manual handling (respondent 3,5 and 10).

"Some solutions are super sustainable, or good in improving the safety for workers, but if it is not securing efficiency and cost improvements in short- or long term, it become less interesting" - Respondent 9

Seven of the respondents emphasized the importance of understanding the need for automation technologies and the problem they should solve, as there is sometimes a desire for it even though it might not be needed. A lot of managers ask for automation, but in those cases it is important to first reflect about the purpose with automating the process (respondent 1). Moreover, it is important to understand the end-to-end concept for automation technologies to determine what processes are needed and towards what ends (respondent 1, 5, 7 and 10). Respondent 5 and 10 emphasized that for unmanned vehicles to really work, IKEA needs to build a new solution backwards. Everything should not always be automated, as discussed by respondent 8, and it is therefore important to find a right level of it. However, understanding the purpose of it can sometimes be challenging for IKEA and to understand what the given automation is geared towards (respondent 3).

"There is far too much overconfidence in that automation will be the solution to all the problems in the world in the future" - Respondent 10

All of the respondents discussed suppliers' role when exploring new automation technologies. There is a culture of cooperation with IKEA's suppliers, where they approach IKEA with new ideas or proposals about automation technologies (respondent 6 and 9). Respondent 9 described that suppliers have specific technical knowledge that IKEA lacks. However, it is important to be realistic and challenge the merits of those proposals (respondent 7).

Seven of the respondents discussed how time planning of automation projects is difficult. Respondent 9 said that this is a recurring issue at IKEA, and respondent 1 gave an example where they implemented a recent automation project too early. This resulted in them having to revert back to the old process and resume the testing before implementing again. Three respondents also explained that it is important to know when to stop an automation project if it is not successful.

It is important to test automation technologies before implementing them, according to six of the respondents. Respondent 3 and 10 thought it would be better to test automation technologies early on, before investing too much if they would not be successful. Respondent 7 argued that it can be very difficult to test automation technologies in a real environment since it could interfere with the current operational processes. Respondent 7 and 9 therefore suggested using computer simulation to a bigger degree, when possible.

"Test, test, test, pilot and even when you believe you are getting close, still give some time to help the real time testing and real time use. We need to be very pessimistic about timelines before going live" - Respondent 9

There are difficulties in measuring the outcome of automation technologies, according to seven of the respondents. In general IKEA has a lot of work left to be better at following up outcomes on automation technologies that they have implemented (respondent 8). Respondent 10 described that it can be complex to determine the precise outcomes of automation technologies. Some KPIs are easier to measure than others, and for example it is easier to measure productivity than safety or sustainability (respondent 9). Respondents 2 and 6 said that often KPIs are situational and that normally used KPIs might not be suitable for automation technologies. There can sometimes be unrealized outcomes from automation technologies that were not calculated beforehand (respondent 8 and 10). Respondent 10 gave an example that in one automation project the sickness ratio dramatically dropped.

"A confirmation that an automation technology is good is that it is actually being used and that it is relevant for the recipient" - Respondent 8

4.1.2 Costs

A major reason for using automation technologies in stores was to reduce costs, according to seven of the respondents. It is needed in the long-term to lower operational costs (respondent 10). More specifically, respondent 5 said that with the trend of increasing online sales, IKEA needs to use their fixed costs more efficiently. Moreover, 4 respondents described that automation technologies are often considered to offset increased costs of labour. The level of automation discussed often varies a lot between countries, mainly due to the differences in labour costs (respondent 10). Automation technologies are mainly considered in countries with expensive salaries for employees and where there is a large order volume (respondent 7).

Seven of the respondents also explained that the return on investment is important, and additionally a requirement for automation technologies to be considered. Usually IKEA makes an initial business case in a prestudy, analyzing a current process and its associated costs (respondent 7). In addition to measuring the return on investment, it is important to compare the benefits with the existing costs and investigate if it weighs up the other (respondent 8). Both respondent 8 and 9 agreed that it is however not always easy to measure such assessments.

Another topic discussed by four of the respondents was that the space in stores should be efficiently utilized. Respondent 5 argued that space is the most important asset in the store, both the square meter and the cubic meter. Since space is a high cost for IKEA, they want to condense it to make better use of it (respondent 7). Respondent 5 said that IKEA also wants to avoid investing in new sites and make better use of their current stores. Moreover, IKEA will never accept unutilized space in their stores, and automation is therefore mainly used to optimize the space and density (respondent 5).

"We need to use the space in a super-efficient way" - Respondent 3

4.1.3 Scalability

Scalability of automation technologies is an important requirement to use them, according to eight of the respondents. Respondent 5 distinguished growing a specific automation technology bigger from replicating a previously proven one with low effort to other stores, and argued that IKEA needs both of these types of scalability to utilize automation technologies. There can be a pressure to implement automation technologies in different stores worldwide, further making scalability an important criteria (respondent 2). Moreover, IKEA has a vision of reaching more customers, and that sales are increasing rapidly, which means that automation technologies have to take future sales into account (respondent 7). This is further argued by respondent 4 who described that future sales are uncertain, and that they could be mitigated by the flexibility of automation technologies. If an automation technology is not scalable, chances are that the capacity is not enough a few years in the future (respondent 1). Issues with the scalability of automation technologies was discussed by seven of the respondents, in regard to individual factors of stores. That is, a specific automation technology could work in one store but not in another one (respondent 5, 7, 9 and 10).

"A manager asked me when we could have a specific automation technology implemented in all stores worldwide. The manager wondered if we needed three years or maybe four years. And I was thinking that we have 400 stores and could probably do ten projects per year" - Respondent 2

Economies of scales are created when standardizing, which can then be used to apply automation (respondent 8). Four respondents discussed the importance of standardization. More specifically, standardizing should be the first thing to do before using automation technologies, since it is a challenge when things differ from each other (respondent 8). When standardizing, regardless of if it is physical objects or data, economies of scale are created which can then be used to apply automation (respondent 8).

Moreover, IKEA's pallets were thoroughly discussed in regard to standardization. IKEA has different pallets (respondent 6), although paper pallets are the most commonly used ones (respondent 8). IKEA is one of very few companies in the world to have paper pallets (respondent 6), and they use it since it minimizes the space needed in transportation (respondent 7). The paper pallets differ from each other in terms of size and it would be easier to use unmanned vehicles if all pallets were in a standard size (respondent 4). The lack of standardized pallets is a challenge since IKEA therefore needs automation technology customized for their business (respondent 4), since unmanned vehicles typically are designed for wooden pallets. Therefore, it was challenging to find vendors that are geared towards paper pallets (respondent 3, 5 and 8). Respondent 8 further argued that this was challenging due to the forks being too thick and the required precision when handling paper pallets. Moreover, respondent 10 said that they did not complete an unmanned vehicle project due to the challenge with paper pallets and the special forks needed on those unmanned vehicles to make it work. It would be more cost efficient if IKEA would use automation technologies that could manage all their different kinds of pallets, which would save money, improve quality and safety (respondent 6).

"Automation versus paper pallet is generally a challenge" - Respondent 10

In addition to the different paper pallets, IKEA has many articles with different dimensions ranging from small to large objects (respondent 2 and 5). Respondent 5 described that it makes automation difficult. Respondent 3 argued that the bulky articles are IKEA's main challenges in automation as automation technologies available on the market can not handle it. In contrast, respondent 7 described that smaller, lighter articles one fell down when unmanned vehicles moved which ultimately stopped the system due to different sensors. Therefore it is important to use unmanned vehicles that can handle the small articles as well (respondent 7). Another issue concerned articles in multipacks, meaning that some boxes include multiples of the same article. Besides, some articles are split into different boxes as they consist of different items (respondent 7). This makes it challenging for the automation technology to identify, handle and put together such boxes (respondent 7). Respondent 3, 4, 5 and 7 agreed that IKEA must use automation technologies that can cover their range. This is the biggest challenge, according to respondent 3, and a fundamental requirement for IKEA according to respondent 5.

"We have 4-5,000 articles that are shaped differently. That makes it complex to use unmanned vehicles" - Respondent 2

4.2 IT

4.2.1 Systems

IKEA currently has 400 to 500 different IT-systems throughout their organization (respondent 1). A small adjustment in one system might impact the functionality of another one, which creates a problem when introducing new systems or new features (respondent 1). Respondent 8 moreover explained that it is quite common in older and larger companies to have many legacy systems, and that it often becomes a challenge when using new IT-systems. This, since all these systems communicate with each other and that automation technologies in one way or the other then have to be integrated to these legacy systems (respondent 8). Respondent 2 said that IT is supposed to be a tool to make life easier, but currently the stores' legacy systems are a hindrance to move IKEA's business forward.

"I can say that IKEA and IT traditionally have not been the best of friends" - Respondent 1

The integration between legacy systems and new technology is challenging, and even impacts the viability of several automation technologies (respondent 2). Respondent 2 and 5 further argued that it is important not to underestimate the existing legacy systems and how it might not fit for the purpose of an automation technology. More investments have to be done in IT-systems, since several automation projects could not be finished due to the challenges of using them (respondent 8). Respondent 6 gave an example where one automation technology was not even integrated with the existing legacy systems, but instead worked as a stand-alone system. Respondent 10 described that historically IKEA have had to make many adjustments to integrate their legacy systems with automation technologies.

"The integration between old and new IT-systems might be the biggest bottleneck IKEA has for automation technologies" - Respondent 8

Eight of the respondents specifically talked about IKEA's current WMS in the context of legacy systems in stores. It has been developed since the beginning of the 1990s and that it is built upon old standards, written in various outdated codes, that are not being educated anymore (respondent 2). Respondent 2 further said that the current WMS is a perfect match and optimized for the Cash & Carry business need for IKEA, but that it has several challenges when customers are shopping more online. Respondent 5 gave an example where IKEA learned that the WMS' picking system crashes if it surpasses a limit of 10,000 active orders. In light of the Covid-19 pandemic, several stores have realized this when an increasing number of customers shop online (respondent 1 and 2).

IKEA has added different interconnected functions and modules to the WMS instead of replacing the WMS, making it more fragile and complex for future updates (respondent 2). Respondent 10 explained that in some cases, it can take up to two years to make a change in the system. IKEA is currently running a project to transform this WMS to a modern one, preferably on a modern cloud based platform (respondent 2). Respondent 4 argued that this has to happen, since adding additional modules and interfaces to make new automation technologies work is always a risk and creates unnecessary complexity. Respondents 2 and 9 however said that this is a challenge, since there is no existing standard package that can replace the current system without massive adjustments. Another challenge is that most major WMS are focused on warehouses, whereas IKEA's stores are a hybrid of a warehouse and store (respondent 2 and 5). Moreover, one challenge with automation technologies is that the suppliers often base them on existing, well known WMS (respondent 4). This means that the automation technologies are already optimized for those WMS, and for a company-specific WMS such as in IKEA's case, major adjustments would have to be made to make it work (respondent 4).

It is important to remember that IKEA's existing WMS is very capable, and that it is only a matter of how much time and money IKEA should spend to update it instead of putting a state of the art new system in place (respondent 3). Respondent 2 described that it is difficult to decide when to integrate new technology to the legacy WMS or when to integrate it with a new system.

"I am not a fan of throwing away 30 years of experience just because the current WMS is missing some features" - Respondent 3

In one recent project, IKEA built an interface between the current WMS and automation technologies in general, as discussed by five of the respondents. Respondent 1 said that even if every warehouse is different and there are different suppliers of automation technologies, the interface is built for everyone. The idea of the interface was to utilize the strengths of the legacy system without having to make any major changes in them (respondent 3). Respondent 5 described that this was done to apply automation technologies easier through an integration gateway instead of building new systems each time. Moreover, respondent 1 and 3 described that the interface is running in the cloud.

4.2.2 Data

Data management is important, including real time data and big data, as discussed by seven of the respondents. It is a long-term vision for IKEA to use big data to make customer predictions (respondent 5). However, six of the respondents described that a lot of information in stores is not digitized. In many cases, it is not possible to see a precise sales location of an article in the IT-systems and this is a major issue for automation technology, since exact physical position of articles is needed (respondent 1). Respondent 9 further explained that it is not uncommon for employees to walk around and physically search for articles with their own eyes. Thus, in order to process data, it has to first be digitized (respondent 9).

Eight of the respondents additionally discussed the role of data and automation technologies in stores due to changing customer shopping behaviour. When stores are changing from a cash and carry-concept, it means that customers to a lesser degree pick orders by themselves (respondent 2). This means that employees at IKEA have to pick orders, and respondent 3 described that it is becoming an increasing problem for them since the picking service is ramping up quickly. Moreover, customers expect it to be just as easy to order online as purchasing in stores (respondent 10). Respondent 3 and 5 described that the picking process is more efficient when batching several orders together and planning how to sequence and perform the picking in advance. This is especially true when an order has to be picked from different parts of the store (respondent 3). However, the lack of real time information exchange of data in stores leads to the same kind of picks being done separately instead of together in a batch (respondent 2 and 3).

"Today employees in IKEA-warehouses run around with a trolley collecting goods, with a

colleague walking behind them and doing the exactly same thing for another customer" - Respondent 2

The picking service for customers in stores and for online orders are optimized in different metrics, with the former being optimized for lead time and the latter for efficiency (respondent 3). Respondent 1 and 5 argued that this is a major difference from traditional stores since they can not prepare orders to the same extent and that IKEA has a long journey ahead in finding this balance. Furthermore, customers usually have very short expectations on lead time of the picking service process in stores (respondent 3). As an example, respondent 3, 5 and 10 described that longer waiting time impacts the customer experience. Respondent 3 and 5 argued that batching is difficult for the picking service for customers in the store as the lead time is short. Instead, there are many online orders with a future shipping- or collect date, where IKEA can batch orders together (respondent 3)

Stock level reliability is very challenging in stores, especially when the same stock is used for both online and physical customers (respondent 5). This is due to stock levels not becoming updated when a customer picks up an article, but instead when the customer has completed a purchase. This leads to a discrepancy when an online customer believes the article still is in stock, when in fact the stock balance could be zero (respondent 5). Respondent 5 argued that by understanding customers' shopping behaviour, the stock in stores could be optimized with the help of algorithms. Furthermore, respondent 1 and 5 argued that locating the same articles at multiple locations to mitigate this dilemma creates inefficient use of space and is a challenge to use automation technologies in stores. Additionally, respondent 10 explained that every time a quantity is changed in the stock balance, there is a risk of problems happening. IKEA is discussing a real time dashboard to address this issue, increasing the accuracy of stock levels in real time and showing possible constraints (respondent 9).

Another challenge IKEA has with management of data in general regards the location and availability of data (respondent 7). The data is not accessible centrally but rather exists in the different stores, or sites, which limits the depth of data readily available. This is due to each store being responsible for the data in their systems (respondent 7) and also different IT-systems are used between stores which further makes it difficult to retrieve data (respondent 9). Moreover, there is a lack of historical data since it is deleted after six weeks (respondent 7).

4.3 Impact on Humans

4.3.1 Impact on Employees

All of respondents highlighted the importance of considering employees when using automation and made it clear that it should be beneficial for them. Respondent 4 argued that the future must be to create a better life for employees, and respondent 9 explained that automation technologies should give them an improved work environment.

"I believe what we gain from it will ultimately be good for employees" - Respondent 10

Including employees is important in early investigations and when introducing automation since they appreciate being a part of the creation of something new from the beginning, as discussed by seven of the respondents. Ultimately it leads to more enthusiasm and commitment from the employees (respondent 2). Moreover, respondent 2 said that implementing something in a store without listening to the employees, in a top-down approach, has a risk of not being used by the employees. Instead, employees would try to recreate their old way of working (respondent 2).

"Ingvar Kamprad told me to listen to the employees since they better know how things work out in reality than 10 people sitting behind a desk in the global organization will ever know" - Respondent 2

Employees can initially be afraid of automation technologies, in the sense that they believe that they might be replaced by them, as discussed by five of the respondents. Respondent 10 explained that there is a built-in resistance to it from the start. In addition, respondent 8 and 9 mentioned that some employees do not support and that automation sometimes has negative connotations among the employees.

"People are sometimes scared of automation because for them it means that fewer people are needed" - Respondent 9

The first thing to do in automation is to remove the fear and threat of it (respondent 5). To more quickly adapt to changes and be flexible, IKEA needs a mind shift, which does not happen overnight (respondent 3). Respondent 7 believed that resistance exists in the beginning if employees do not understand the purpose of automation. Respondent 8 described that the people already working with automation see it differently and are not afraid of it. In that sense, there is a positive response by employees that understand that tasks that are automated are tasks the employees do not like to do. Respondent 7 agreed, and mentioned that many employees are motivated to use automation if it will help them with their daily work. The commitment from employees usually comes when automation is implemented and they start working with it (respondent 9). At that point, they become proud, energetic, and satisfied with their work since they are involved in something new and interesting (respondent 9).

As the tasks that would be automated are simpler and not qualitative ones, the respondents agreed that employees will instead work with more value-creating tasks (respondent 3, 4, 8 and 10). It is not about replacing the employees and cutting costs, but rather about finding new ways of working (respondent 10). Moreover, respondent 10 discussed that although IKEA will automate different processes, employees will always be needed. However, employees should do things that really require their knowledge (respondent 2 and 8).

"Automation is a collective term for working smarter and having the right tools that help make things easier for employees. To enable people to work more efficient and value-creating" - Respondent 8

Focusing on value-creating tasks could mean interacting with customers rather than performing repetitive tasks in a goods flow process (respondent 10). Interacting with customers is difficult to automate as unmanned vehicles can not handle customer contact (respondent 8). Therefore it is important to create better conditions for the employees to work with that in the stores (respondent 8). Employees are flexible when dealing with problems which as well is difficult to automate, which is one reason why IKEA still has tasks performed by employees (respondent 8). However, respondent 8 said that there are things that automation technologies do better than people, such as calculating and analyzing, but without people, you would not be able to make the right decisions based on the analysis presented. So ultimately it is about upgrading employees' tasks and enabling them to work with value-creating tasks (respondent 8).

Respondent 5 and 8 agreed that new roles are created with new automation technologies. IKEA needs employees to understand the technology related to automation, maintain it and make it more efficient (responded 5). Furthermore, respondent 5 discussed that IKEA needs employees doing data analysis and predictions on purchases, for both customers online and customers in the store. That knowledge does not exist in the stores now (respondent 5). Although IKEA might need some competence outside the company, respondent 5 believed that a lot of the competence needed can be found within IKEA by simply retraining the current employees.

The majority of employees you can retrain. Because it's not a revolution, it's an evolution" - Respondent 5

Automation technologies must support the employees in the sense that they should work in symbiosis (respondent 2). There will always be an interaction between employees and the different types of automation technologies (respondent 10). Respondent 4 argued that automation technologies have to serve employees and not substitute them.

"It is not automation versus employees. It is automation together with employees, and growing together and helping" - Respondent 5

When speaking of collaboration and automation, there are certain things to be questioned, and this regards whether it requires other ways of working or different types of layout in the store (respondent 10). Employees and automation technologies are in some cases going to work in the same environment (respondent 7). However, respondent 8 believed that interaction with automation technologies is not that simple. Respondent 3 thought that IKEA needs technology, such as advanced analysis, to make the unmanned vehicles work dynamically in the same areas as employees. At the same time, respondent 3 explained using unmanned vehicles to follow employees when picking goods in the store does not require the technology to be super intelligent. It just needs to be able to follow employees and not hit any bystanders, since there are customers in the stores (respondent 3).

4.3.2 Ergonomics and Safety

Six of the respondent said that one reason for using automation technologies is to improve the ergonomics for the workers.

"When thinking of automation I connect it immediately to ergonomics" - Respondent 2

Automating tasks will reduce the injuries of the workers, as discussed by two respondents. Employees today need to stock pallets several meters above the floor, which hurts their neck (respondent 4) and they must lift heavy furniture boxes weighing 30-40 kilograms (respondent 2). One respondent explained that automation will ensure that the workers do not have to pick from a high level, which creates a better working environment.

A safe environment in the stores is a high priority for IKEA, as discussed by eight of the respondents. Respondent 4 said if an automation technology in a store is not safe, IKEA will not use it.

"Safety is number one. Number two is also safety" - Respondent 9

Safety in regard to automation concerns both employees and customers, as described by two respondents. IKEA does not want automation technologies hurting people (respondent 7). Moreover, nine respondents discussed different solutions on how to increase safety in the store when using automation. Five agreed to separate the people and the unmanned vehicles. Respondent 4 recommended segregating the floors to reduce safety risks, and believed it to be a requirement for IKEA to use automation technologies. Similarly, Respondent 1 discussed a solution where unmanned vehicles and employees were divided into different zones in an ongoing project. Respondent 8 explained that IKEA must block an aisle if using unmanned vehicles so that the customers are restricted to that area. However in that case the customers lose the opportunity to pick goods from those aisles which will not be appreciated by them. Respondent 7 did not think that IKEA is ready to use unmanned vehicles where the customers are, since accidents can happen.

Another solution proposed by five respondents to ensure safety using unmanned vehicles in stores was to use it when stores are closed for customers. Logistics operations in an IKEA store need to be completed before the store opens for the customers, to avoid a bad shopping experience (respondent 3 and 6). Using unmanned vehicles could therefore help the employees with the logistics operations as the unmanned vehicles would have already moved goods to right locations before the employees start their day (respondent 3).

Automation technologies can be very safe in stores, but in that case also very slow (respondent 10). This is a challenge of whether the automation technology is fast enough to pay off. Respondent 10 discussed that it can pay off in the sense that it will improve the ergonomics for the employees, but might be ineffective in the long run due to the high safety requirement. Respondent 2 also raised concerns about the trade-off between being efficient and at the same time adapting to the coworkers, their needs, and the customers' needs. Customers can sometimes be a hindrance in stores (respondent 2).

5

Analysis

5.1 Automation Objectives

5.1.1 Projects

Understanding the business requirement to use automation technologies, analyzing the automation options, and defining the scope of automation is a crucial first step in automation projects, according to Baker and Halim (2007). A majority of the respondents also highlighted how important it is to understand the need for automation and the problems it should solve. The majority of the respondents moreover argued using automation technologies can sometimes be desired, even though it might not be needed. One respondent said that in those cases it is important to first reflect on the purpose of automating the process, and in that sense build a new solution backward, as explained by two respondents. Varila et al. (2005) explained how unrealistic or undefined goals are the main reasons for failing automation projects. It is therefore important for IKEA to be clear and have a purpose with using automation technologies, as they otherwise risk failing. One respondent explained how understanding the purpose can be challenging, which is something for IKEA to consider. Moreover, Hirman et al. (2019) and Maroušek and Novotnỳ (2016) explained that it was important to have a company vision and strategy for implementing Industry 4.0 technologies, and to have a goal in line with the corporate strategy to be successful. All of the respondents discussed how using unmanned vehicles supports IKEA's sustainability goals, and one respondent explained that they have a vision to reach 3 billion people around the world. This shows that IKEA has thought about the strategic use of unmanned vehicles, and they are in line with the findings from the literature. Thereby, IKEA understands that it is important with a purpose and they have objectives in line with their corporate strategy, which gives them the opportunities to have a successful automation project.

Automation projects are major and complex in companies according to Baker and Halim (2007). That could also be the case for IKEA, as a majority of the respondents highlighted that time planning of automation projects is difficult and a recurring issue. Both Baker and Halim (2007) and Sarvari et al. (2018) discussed the importance of planning an automation project. Defining milestones and defining concrete actions is important (Sarvari et al., 2018), but also to criticize a plan and refine it (Baker and Halim, 2007). One respondent said that IKEA once implemented an automation project too early, resulting in them having to revert and start testing before implementing it again. IKEA has a plan on how to transform to fulfillment centers, where one step is using automation technologies, as explained in '*Case Company*' in section 1.2. Hence, IKEA has a plan but could take action to improve and set feasible objectives so that they follow their time plans. That way, the mistake of implementing something too early could be avoided.

All of the respondents discussed suppliers' roles when exploring new automation technologies. Often, the suppliers approach IKEA with new ideas or proposals about automation technologies, and they have information that IKEA lacks. Baker and Halim (2007) described how suppliers are often involved from start in automation projects, and that projects developed together with the suppliers. According to Baker and Halim (2007), suppliers bring value to automation projects. For companies to be ready to use Industry 4.0 technologies, partnerships with suppliers are important and could preferably be a part of the planning (Akdil et al., 2018). Sarvari et al. (2018) also emphasized that companies should consider what to gain when collaborating with suppliers. Thus, IKEA's involvement of suppliers should help them reach their goal and succeed with their automation projects. However, one respondent argued that be realistic and challenge the merits of suppliers' proposals, which was not found in the literature.

The importance of testing automation technologies was mentioned by a majority of the respondents. Two respondents emphasized that it was important to test early to avoid substantial investments if the automation technology would not be successful. However, one respondent highlighted that is can be difficult. That is, testing it in real environments could interfere with current processes. Baker and Halim (2007) also discussed that it is important to test, and suggested using computer simulation. Simulation and tests should be done before introducing Industry 4.0 technologies, as it reflects different scenarios that can improve the robustness of the Industry 4.0 technologies process (Salkin et al., 2018). Rodič (2017) also emphasised using simulations. If IKEA also uses simulations, they can test the unmanned vehicles without interfering with current processes. However, since only two respondents discussed simulations, IKEA should start considering it as it will help with using unmanned vehicles. Moreover, as several respondents explained that it is important to know when to stop an automation project if it is not successful, using computer simulations could help to mitigate that problem.

A majority of the respondents described that there are difficulties in measuring the outcome of automation technologies. One respondent explained that some KPIs are easier to measure than others, and gave an example that it is easier to measure productivity than safety or sustainability. Two of the respondents described how there can be unrealized outcomes from automation solutions that were not calculated beforehand. In addition, often KPIs are situational and some might not be suitable for automation technologies, according to two respondents. Hrušecká et al. (2019) highlighted that it is not efficient to have many KPIs. Instead, the KPIs should focus on the key elements important to the particular department or part of a business, since too many can lead to confusion (Hrušecká et al., 2019). Some respondents believed that KPIs should be situational. However, the fact that IKEA considers KPIs is important since Aguiar et al. (2019), Baker and Halim (2007) and Hrušecká et al. (2019) highlighted using it to monitor automation projects. One respondent explained how it can be complex to determine the precise outcomes of automation solutions, and in that situation, IKEA could again follow the recommendations by Hrušecká et al. (2019) in the sense that they should have situational KPIs and not too many.

When analyzing above, two factors could be found concerning projects. The first one, *Defining a strategic purpose* means to have a clear purpose of using with unmanned vehicles. It should be in line with the corporate vision. The second one *Coordination of project* includes to test unmanned vehicles before using them in real stores. This could be done though computer simulations to avoid interfering with current processes. Moreover, including suppliers and managing time could improve the successful outcome of using unmanned vehicles. The factors are summarized in table 5.1.

Defining a strategic purpose
Coordination of project

Table 5.1: Factors - Projects

5.1.2 Costs

All of the respondents highlighted that a major reason for using automation technologies in stores was to reduce costs. A majority of the respondents also explained that the return on investment is an important requirement for automation technologies to be considered. Additionally, several respondents discussed that reducing the number of damaged articles associated with manual handling was an objective of using automation technologies. Dehnavi-Arani et al. (2020), Hwang et al. (2002) and Varila et al. (2005) discussed how automation technologies can lower material handling costs, and Varila et al. (2005) also mentioned that it can lead to better control over operations and material flows. Moreover, if IKEA collects data through CPS/IoT and thereafter sends the data to the WMS, it could reduce costs as human intervention in that process is not needed, as discussed by Gorse et al. (2020), Mostafa et al. (2019), and Trappey et al. (2017). Additionally, if IKEA uses the cloud to increase the capacity of managing and storing data it leads to not having to invest as much in hardware, which further reduces costs (Costa et al., 2019; Gil and Song, 2016; Mostafa et al., 2019; Nguyen et al., 2020; Velasquez et al., 2018; Xu et al., 2018). Thereby, the benefits of using CPS, IoT, and Cloud can help IKEA reducing costs when using unmanned vehicles.

Hwang et al. (2002) however highlighted that the installation cost of automation technologies is significant and if it does not work, it can result in productivity and profits losses. Moreover, if not correctly integrating CPS/IoT with legacy systems, it can affect efficiency and costs (Guo and Wong, 2017). Thus, if IKEA does not make a correct integration of systems needed to use unmanned vehicles, it could increase their costs. This was raised by several respondents, indicating that they are aware of how it could affect the economical feasibility of automation technologies. Moreover, Varila et al. (2005) argued that problems related to automation projects in warehouses have been cost related, which could be a result of unrealistic expectations. Based on this, IKEA should set clear expectations to not overestimate how much costs can be reduced and underestimate investments needed. In addition, as increased indirect costs, such as electricity and maintenance, were found to impact automation projects' costs (Varila et al., 2005), IKEA should consider indirect costs as well. Few respondents highlighted that IKEA currently takes that consideration into account. Varila et al. (2005) moreover found that if the objective with automation technologies was to cut costs in part of a process, it only results in moving bottlenecks instead of eliminating them. Thus, Varila et al. (2005) therefore argued that a process must be optimized with automation technology and not just separate parts. This could also be done if IKEA uses CPS/IoT to connect people, objects and physical processes (Lee et al., 2018), analyze data (Xu and Duan, 2019) and use a cloud (Gil and Song, 2016) to make sure that unmanned vehicles can be used in whole processes, and not just in one specific part.

Based on the answers from several of the respondents, it was clear that the space in the stores should be optimized, and one respondent argued that automation technology can facilitate that. Erol et al. (2012) argued that unmanned vehicles can better utilize space, while Dehnavi-Arani et al. (2020) said that they can increase space flexibility. Hence, respondents and authors in the literature both concluded that unmanned vehicles can be used for that purpose. Moreover, as CPS/IoT can collect data that can provide insights and support for decision-making processes (Lee et al., 2018), and the data can be used to increase resource efficiency (Ivanov et al., 2019; Li et al., 2019; Sanders, 2016; Xu and Duan, 2019), it could also help unmanned vehicles to optimize the space. Moreover, that will enable IKEA to use their resources more efficiently and to lower their costs.

Several of the respondents explained that automation technologies are often considered when the cost of labour increases. From the literature review, authors also found that using unmanned vehicles would decrease labor costs as the execution of tasks are changed (Schulze and Wullner, 2006; Vivaldini et al., 2016). As previously mentioned, if IKEA uses CPS/IoT in combination with WMS, the WMS can make decisions, which reduces or removes the need for human intervention, ultimately leading to reduced costs (Gorse et al., 2020; Mostafa et al., 2019; Trappey et al., 2017). However, Baker and Halim (2007) found that reducing costs by decreasing the staff was one reason for using automation technologies, but that such objective in automation projects disrupted companies' ongoing operations. One respondent said automation technologies are mainly considered in countries with expensive salaries, and that the level of automation, therefore, varies between countries. Hence, IKEA should be aware that if they have an objective of reducing employees to lower costs in some countries, it could affect their operations. None of the respondents at IKEA did discuss how reducing the cost of labor would affect their ongoing operations, which thereby is something they should consider.

Based on the analysis, the factor to have *Realistic expectations of costs* was found. This includes to be aware of system integration costs, labor costs, indirect costs that could occur as well as how much IKEA could decrease these by using unmanned vehicles. To exemplify, if space is optimized or if tasks are changed, then costs might decrease. In addition, calculating the return on investment could be important to get a better understanding of the costs. The factor is summarized in table 5.2.

Realistic expectations of costs

Table 5.2: Factor - Costs

5.1.3 Scalability

A majority of the respondents described that the scalability of automation technologies is an important requirement and all respondents said that they want to use it to improve capacity. One respondent described that if automation technology is not scalable, IKEA's capacity to fulfill orders might not be enough in the future. Baker and Halim (2007) found that companies usually use automation technologies to improve capacity, indicating that if IKEA starts using unmanned vehicles, they could be able to achieve a higher capacity if they can scale up. In addition, unmanned vehicles are associated with scalability, in the sense that they scale well when increasing the fleet size according to Fragapane et al. (2021). In addition, IKEA could use cloud computing, as it increases the scalability of automation technologies by storing and managing large sets of data (Nguyen et al., 2020). Aguiar et al. (2019) described how data processing is a success factor for using unmanned vehicles. Hence, to get a large set of data to in the end be able to scale up, IKEA should first start with digitizing information to make it ready for CPS/IoT (Liu et al., 2018) and the cloud (Gil and Song, 2016). This is further developed in section 5.2, *IT*.

Dombrowski and Wagner (2014) argued that automation results in positive scale effects from standard sequences of high volume processes. Since IKEA has a vision of reaching more customers and thereby increasing sales, they should be able to scale up the unmanned vehicles as they have high volume processes. However, a majority of the respondents discussed how individual factors of different stores can be an issue when scaling up. Several respondents described how a specific automation technology could work in one store but not in another one. Thereby, IKEA should consider standardizing processes to simplify scaling up. Moreover, Salkin et al. (2018) described how standardized processes are needed in Industry 4.0, and similarly, several respondents argued for the importance of standardization. However, it could be difficult for IKEA as half of the respondents discussed the peculiarities of IKEA's paper pallets, and how the sizes differ from each other. One respondent expressed how it would be easier to use unmanned vehicles if all pallets were in a standard size. Schulze and Wullner (2006) discussed how unmanned vehicles usually handle standardized pallets and are therefore equipped with standard loading devices. This could be important for IKEA to consider, and one respondent was also concerned about this as IKEA's lack of standardized pallets leads to the need for automation technology customized for their business, as unmanned vehicles typically are designed for wooden pallet standards. Varila et al. (2005) found that standardizing processes can lead to extra costs, but it is a necessity to use automation technologies. If applying this to the paper pallets at IKEA, they could consider the implications of using different sizes to enable automation technologies. In addition, several respondents agreed that it is challenging to find vendors geared towards paper pallets. One respondent explained how a project with unmanned vehicles was not completed due to the challenge with paper pallets and the special forks needed on those unmanned vehicles to make it work. Another respondent argued that it would be more cost efficient if IKEA would use automation technologies that could manage all their different kinds of pallets.

In addition to the different paper pallets, two of the respondents described that IKEA has many articles in different dimensions, which also can make it difficult to use automation technologies. One respondent said that the bulky articles are the biggest challenge when using automation technologies, while another respondent argued that the smaller articles are a challenge. In addition, one respondent said that different packages of the articles make it challenging to use automation technologies. Custodio and Machado (2020) also identified this issue, in the sense that there are problems for automated technologies to handle products of different shapes, sizes, and weights. Unmanned vehicles usually perform repeatable processes that are characterized by small variations (Custodio and Machado, 2020). Moreover, Echelmeyer et al. (2008) discussed that normally unmanned vehicles are involved in repetitive activities with standardized operations, leading to a challenge to handle different sizes and compositions of products. This could create a challenge to use unmanned vehicles at IKEA's stores. This was also acknowledged by several respondents as they believed standardization is necessary before using automation technologies. Returning to the discussion by Salkin et al. (2018) and Varila et al. (2005), where they suggest standardizing processes, IKEA could consider this factor in regards to their range. One respondent expressed that it is a challenge when things differ, and if standardizing economies of scales are created which can be used to apply automation. Similarly, Dombrowski and Wagner (2014) argued that automation results in positive scale effects from standard sequences. Hence, by standardizing it can help IKEA reach their goal of scaling up unmanned vehicles. However, some respondents instead emphasized the importance of using unmanned vehicles that can handle IKEA's range of articles, and according to one respondent that is a fundamental requirement for IKEA. There is an agreement between authors in the literature and some respondents that standardization of pallets and range is important if using unmanned vehicles, while some respondents instead argued that the unmanned vehicles should be able to handle IKEA's range. Hence, overall a discussion about standardization is an important factor for IKEA to consider if scaling up and using unmanned vehicles in their stores.

Since scalability is an important criteria for IKEA, they should consider that *Standardization enables scalability*, as seen in table 5.3. By standardizing processes, pallets and the product range IKEA can increase the scalability of unmanned vehicles. It could be expensive to standardize, which IKEA also should consider. In addition IKEA should consider that efficiently managing and analyzing data generated by CPS/IoT could support scaling up unmanned vehicles.

Standardization enables scalability

Table 5.3: Factor - Scalability

5.2 IT

5.2.1 Systems

Several of the respondents discussed the implications of legacy IT-systems at IKEA in the context of automation technologies. One respondent described that IKEA has hundreds of different IT-systems and that their interconnections are complex, where making changes in one system might have an outcome in another one. Another respondent further argued that this is a problem in using new automation technologies since they have to be connected to the existing systems at IKEA. Givehchi et al. (2017) described that a big variety of different systems in a company might create difficulties in the integration of new automation technologies. This could be an issue for IKEA to use unmanned vehicles, since integrating them with existing systems might be challenging. Aguiar et al. (2019), Costa et al. (2019), Liu-Henke et al. (2020), Shih et al. (2016), Tran-Dang et al. (2020) and Zhang et al. (2017) wrote that unmanned vehicles often are connected to CPS/IoT. Aguiar et al. (2019) described that such a connection increases the productivity of unmanned vehicles and increases the utilization of resources. This indicates that there are benefits for IKEA to connect unmanned vehicles with CPS/IoT. However, since CPS/IoT relies on connectivity and interoperability between humans and systems, as described by Santos et al. (2017), the integration with the wide range of IKEA's legacy systems might be complicated.

Legacy systems at IKEA might not fit with the purpose of a new automation technology, as described by two respondents. This issue was also found in the literature, since Guo and Wong (2017) described that legacy systems might have been created towards another end than a new automation technology. Guo and Wong (2017) further argued that if this is not addressed it might even threaten the viability of an automation technology, which is one challenge that one of the respondents also explicitly mentioned. Therefore IKEA should investigate the implications of integrating unmanned vehicles with the existing legacy systems to ensure viability. Two respondents further described that there have been cases where automation projects could not be finished due to challenges in integration with the existing legacy systems. Another respondent described that there was a recent project where the automation technology was not even integrated with existing systems, instead working separately by itself. Even though many authors (Choi et al., 2017; Givehchi et al., 2017; Guo and Wong, 2017; Hoske, 2016; Mostafa et al., 2019; Trappey et al., 2017) agree that integration with legacy systems can be a challenge for CPS/IoT to be successful, Trappey et al. (2017) argued that it is the biggest challenge. Similarly, one of the respondents argued that the integration between old and new IT-systems might be the biggest bottleneck for IKEA to implement automation technologies. Hence, for IKEA to successfully use unmanned vehicles, they should address the challenge of integrating unmanned vehicles with legacy systems, especially when using CPS/IoT.

Lee et al. (2018) described that CPS/IoT is beneficial when connected to the WMS at companies, and Liu et al. (2018), Mao et al. (2018) and Mostafa et al. (2019) described that CPS/IoT gathers data that should then be sent to the WMS to be managed. It might therefore be a problem for IKEA to leverage the synergy between CPS/IoT and the WMS since a majority of the respondents specifically talked about the challenges of IKEA's WMS in the context of challenges in legacy systems. One of the respondents said that the current WMS at IKEA is perfectly tailored to the Cash & Carry-process but that it is not well suited for online orders. This is an issue for IKEA, since as described in '*Case Company*' in section 1.2 an increasing share of their total sales are done online, and online customers expect their orders to be fulfilled in different ways. Lee et al. (2018) argued that connecting CPS/IoT with WMS supports the responsiveness and flexibility for companies to address increasing order variety and order complexity. To this end, the WMS could then efficiently coordinate tasks and validate data in real time which would decrease lead time (Gorse et al., 2020; Liu et al., 2018; Mao et al., 2018; Mostafa et al., 2019; Trappey et al., 2017). Therefore, If IKEA successfully connects CPS/IoT with their WMS, they could become more flexible in response to the increasing complexity of fulfilling customers' online shopping behaviour. Another respondent described that they recently learned that there is a limit of 10,000 active orders in the current WMS. This is a barrier for IKEA in their order fulfillment transformation as, described in '*Case Company*' in section 1.2, they want to reach more of the many people and expect increasing online sales.

Half of the respondents described that IKEA is currently investigating transforming their WMS to a modern cloud based platform. Some of these respondents described that IKEA traditionally has made many adjustments to make automation technologies work with the current WMS, but that these adjustments have made the WMS more complex. Tran-Dang et al. (2020) described that using a cloud system reduces the workload on CPS/IoT since the data storage and computational power is centralized in the network. Li et al. (2019) argued that cloud computing helps decision making in companies when connected to Industry 4.0 technologies. Costa et al. (2019) further argued that cloud computing increases responsiveness in companies, which makes it easier for them to address variations in customer demand. This is interesting in the context of IKEA's order fulfillment transformation where a WMS leveraging cloud computing could help address the increasing number of online sales and also to facilitate more efficient utilization of CPS/IoT. Two of the respondents, however, argued that there is no existing standard package that could replace the current WMS without massive adjustments to make it work. Another challenge described by two respondents is that most of the WMS on the market is optimized for warehouses, but IKEA's stores are a hybrid of a warehouse and store. This is something IKEA needs to consider before using unmanned vehicles, since if they replace their current WMS with a new one, a lot of adjustments might be necessary for it to work in IKEA's specific business context. Another respondent emphasized that the existing WMS is still very capable and that there is 30 years of experience in working with it in the organization. Thereby, IKEA should investigate how much effort is needed to build this competence anew in the organization if switching to a new WMS, and the implications it might have on their current processes.

Half of the respondents described that another way to address the issue with legacy systems is through using interface solutions. They described that a cloud based interface was created in a recent project, where this interface connected unmanned vehicles with legacy systems. One respondent described that the purpose was to utilize the strengths of the legacy systems without having to make too many adjustments, and another respondent described that this interface was not created for a specific type of unmanned vehicles but rather automation technologies in general. This is in line with Choi et al. (2017) who described that interface solutions can be a convenient way to integrate legacy systems and CPS/IoT. Tran-Dang et al. (2020) however raised the issue that using cloud can increase latency and errors in systems which can affect the management of real time data. This is an issue since Lee et al. (2018), Mao et al. (2018) and Tran-Dang et al. (2020) described that CPS/IoT is relying on efficient management of data. Thereby, for IKEA to use cloud computing, or CPS/IoT in connection with cloud computing specifically, they should investigate how it might be impacted by latencies and how to mitigate it.

Three factors for IKEA to consider were found in the analysis, as seen in table 5.4. The first one, *Managing Integration with Legacy Systems*, refers to mitigating the challenges of integrating unmanned vehicles with legacy systems. The second one, *Enabling Data through CPS/IoT*, means to connect WMS and unmanned vehicles to CPS/IoT to utilize coordination of tasks and analysis in real time. The third one *Centralizing Storage and Computation in Cloud*, is important since it centralizes storage and management of data, increasing the accessibility while reducing the need for local IT-infrastructure.

Managing integration with legacy systems
Enabling data through CPS/IoT
Centralizing storage and computation in cloud

Table 5.4: Factors - Systems

5.2.2 Data

A majority of the respondents described that management of data is important for IKEA. However, they described that there is a lot of information in IKEA's stores that is still not digitized. One respondent described that it is not possible to see the physical locations of many articles in the IT-systems. Another respondent described that the lack of digitized data means that employees are physically searching for articles in the store. Liu et al. (2018) described that it is usually a lot of work to digitize information but that the benefits of connecting the physical and virtual world in a CPS/IoT often are increased productivity, resource efficiency and data accuracy. Therefore IKEA should investigate digitizing information in their stores to locate products more easily. One of the respondents further described that the lack of localization of products is a major challenge for automation technologies, since they need to know precise physical positions in the system. This is a challenge for IKEA to use unmanned vehicles, but Cogo et al. (2020) and Tejesh and Neeraja (2018) described that a WMS can localize products through the data that is generated from CPS/IoT. To this end, the location requirement for unmanned vehicles could be mitigated by IKEA through using CPS/IoT with a WMS.

Several authors in the literature (Ivanov et al., 2019; Lee et al., 2018; Li et al., 2019; Mostafa et al., 2019; Xu and Duan, 2019) described that using CPS/IoT generates a large volume of data which necessitates efficient data management. Furthermore, Coda et al. (2018), Ivanov et al. (2019), Mcafee and Brynjolfsson (2012), Wang (2018) and Yin and Kaynak (2015) wrote that the variety of data is increasing due to data being gathered from many new platforms and in new formats and Waller and Fawcett (2013) argued that this is especially true for logistic inventories for online shopping. Mcafee and Brynjolfsson (2012), Sanders (2016) and Tan et al. (2015) further described that this variety of unstructured data makes analysis more challenging but Xu and Duan (2019) argued that the variety gives different perspectives to understand complex problems. If IKEA would use CPS/IoT in connection with unmanned vehicles, it increases the volume and variety of data, which could make it more complex to analyse. This could be a challenge for IKEA as Aguiar et al. (2019) argued that efficient management and processing of data is a success factor for using unmanned vehicles. One of the respondents believed that algorithms to analyse data could help and understand customer order patterns and optimize stock allocation in stores. This is in line with Lee et al. (2018), Mostafa et al. (2019) and Xu and Duan (2019) who wrote that analysis of big data can improve forecasts of consumer orders. Two respondents additionally described that management of data is a challenge at IKEA since it is not accessible centrally. This was described to be due to stores being responsible for their own data and that different stores use different IT-systems. One respondent described that this limits the depth of data that is available centrally, and that historical data is deleted after six weeks. Nguyen et al. (2020) argued that it is common for data in companies to be decentralized, and that it makes analysis more difficult. Moreover, Li et al. (2019), Nguyen et al. (2020) and Xu and Duan (2019) described that cloud computing helps companies manage data since storage and computations are centralized, removing the need for local storage of data. Therefore, if IKEA would centralize their data through using cloud, as discussed in the previous section 5.2.1, it could make central analysis between different stores more efficient and meaningful. Furthermore, it would reduce the need for local IT-infrastructure, which would benefit unmanned vehicles through less risk of data constraints in CPS/IoT.

A majority of the respondents additionally discussed the role of data and automation technologies in stores in the context of IKEA's order fulfillment transformation. Several of them described that the changing customer shopping behaviour requires new ways to fulfill orders, leading to an increase of the picking service for customers. This means that employees at IKEA to a higher degree have to pick orders for customers in the store and creates new challenges for operational effectiveness, in how to coordinate picking tasks. This is exemplified by one of the respondents who said that there can be two different employees picking the same article for two different kinds of customers. Two of the respondents argued that this inefficiency is due to a lack of real time data exchange. Several authors (Coda et al., 2018; Ivanov et al., 2019; Mcafee and Brynjolfsson, 2012; Santos et al., 2017; Wang, 2018; Yin and Kaynak, 2015) described that data is generated at a quicker pace than before, which enables using it in real time. Tan et al. (2015) Waller and Fawcett (2013) further argued that the rapidly increasing volume of big data makes it important to reduce and analyse it in real time. Liu et al. (2018), Mao et al. (2018) and Mostafa et al. (2019) described that using CPS/IoT with real time data can support a WMS in efficient decision making and coordination of tasks. This could further enhance the performance of picking activities through using unmanned vehicles (Lee et al., 2018). Therefore, IKEA could use use real time data in combination with CPS/IoT and WMS to mitigate employees performing unnecessary tasks. Two of the respondents additionally described that stock balances for articles are not updated in real time, which can create confusion for customers, as they could believe an article is in stock when it is not. One of the respondents described that this might be addressed through a real time dashboard, which IKEA currently is investigating. To this end, both the respondents and the authors in academia agree that real time data is important for operational efficiency.

Another challenge with the picking service at IKEA is that they pick orders for both customers in stores and for online orders. One respondent described that this process is optimized for lead time for customers in stores, and optimized for efficiency for online orders. Two respondents argued that finding a balance between these two metrics is a challenge for IKEA. Several of the respondents described that it is more efficient to group picking tasks together in a batch instead of doing them separately. Furthermore, they described that batching is difficult for the picking service for customers in stores as they have short expectations on lead time. One respondent described that batching picking tasks together is more common for online orders, as the lead time is not as critical. Several authors described that Industry 4.0 technologies can be used to address the increasing variety and complexity of order patterns since they increase flexibility, responsiveness, reduce lead times through efficient utilization of resources (Costa et al., 2019; Ivanov et al., 2019; Lee et al., 2018). Mcafee and Brynjolfsson (2012) further described that being more flexible and adaptive can lead to more possibilities to compete. Therefore IKEA should consider using unmanned vehicles in combination with CPS/IoT and Cloud as a way to manage the increasing complexity of fulfilling orders in their order fulfillment transformation.

Based on the analysis above, one factor for IKEA to consider was found. The data generated through CPS/IoT could be used with big data analysis to optimize *Coordinating Picking Tasks with Real Time Data*. Unmanned vehicles could then be allocated picking tasks through a WMS to better fulfill orders for online orders and customers in stores. The factor is summarized in table 5.5.

Coordinating picking tasks with real time data

Table 5.5: Factor - Data

5.2.3 Security

With the increased exchange of data and interconnectedness in Industry 4.0, several authors (Benias and Markopoulos, 2017; Culot et al., 2019; Ervural and Ervural, 2018; Kagermann et al., 2013) argued that cyber security to a higher degree can be threatened. This is in contrast to the respondents who did not discuss the risk of data nor processes being breached when using unmanned vehicles. Using automation technologies increases the risk of cyber security breaches, such as in the case of CPS/IoT (Benias and Markopoulos, 2017; Culot et al., 2019; Ervural and Ervural, 2018; Sarder and Haschak, 2019), big data analysis (Zhou et al., 2015), cloud computation (Nguyen et al., 2020) and unmanned vehicles (Sarder and Haschak, 2019). Hoske (2016) argued that legacy systems at companies often were purposively isolated from communication with other systems to increase safety. This is exemplified by Nguyen et al. (2020) who described that increasing accessibility through centralization of data increases cyber risks since companies do not have local physical control of the data. This increased risk of cyber attacks is something IKEA should consider if using unmanned vehicles, especially since Ervural and Ervural (2018) stated that large companies are particularly subjected to them.

Cyber attacks can disrupt operational effectiveness and affect companies' reputation (Culot et al., 2019). In the case of unmanned vehicles, Sarder and Haschak (2019) described that there is a risk of individual devices or the system being compromised, where the company could lose control over the entities. If IKEA would use unmanned vehicles and lose control over them, the implications could be monumental as there are many customers and employees in the stores. Furthermore, it could lead to material damage, equipment damage and data loss, as described by Sarder and Haschak (2019). Several authors (Benias and Markopoulos, 2017; Culot et al., 2019; Ervural and Ervural, 2018; Sarder and Haschak, 2019; Kagermann et al., 2013) therefore emphasized the importance of having a cyber security system to ward off these attacks. Kagermann et al. (2013) and Ozkan-Ozen (2018) further argued that companies need a cyber security strategy to raise awareness and address the competencies needed to address these threats. Several authors (Kagermann et al., 2013; Liagkou and Stylios, 2019; Ozkan-Ozen, 2018) described that security awareness is a key role in Industry 4.0, and that all employees in organizations must know how to act upon it. Authors in academia stated that cyber security is a concern for all employees, and it is therefore especially important for IKEA when considering automation technologies to facilitate the use of unmanned vehicles. To this end, it could be beneficial for IKEA, on all levels in the organization, to acknowledge the increasing risk of cyber attacks to a higher degree when considering using unmanned vehicles.

Based on the analysis above, *Cyber Security Risks* was found as a factor for IKEA to consider when using unmanned vehicles, as seen in table 5.6. This means that IKEA should raise awareness in the organization about increasing cyber security risks and how to manage it when using unmanned vehicles and its associated automation technologies.

Cyber security risks

Table 5.6: Factor - Security

5.3 Impact on Humans

5.3.1 Impact on Employees

There was a common agreement between a majority of the respondents that including and listening to employees is important when using automation technologies in stores. One respondent believed that employees appreciate to be part of something new, and another respondent believed that inclusion leads to more enthusiasm and commitment. This was also discussed by authors in the literature, and based on their findings, including employees is important to make an automation project successful (Baker and Halim, 2007; Klumpp et al., 2019; Neumann et al., 2021).

One respondent discussed that it might lead to employees not embracing automation technologies if not listening to them. This could be connected to the findings by Tortorella et al. (2021) who argued that inclusion of employees has a positive effect on operational performance. A department where a manager reinforces employees' involvement has higher operational performance than the ones who fail to care about it (Tortorella et al., 2021). Thereby, if IKEA does not include the employees it might lead to a risk in the sense that they would not use the technology, which would affect IKEA's operational performance. Moreover, one respondent highlighted that employees should trust that the automation works technically, which Sanders et al. (2019) and Müller et al. (2018) also saw was important if employees would use automation technology.

Half of the respondents discussed that it might be difficult to include employees, since they can be afraid of unmanned vehicles. Those respondents said that employees can be frightened of being replaced by the unmanned vehicles, and that they might have resistance to it. McCreary and Petrick (2018) and Schmidtke et al. (2018) further discussed that there is a fear of losing jobs due to automation technologies in Industry 4.0, and that this fear is an obstacle to implementing new technologies. Ejsmont (2021) argued that the biggest challenge in Industry 4.0 is not the technology, but the people. Ejsmont (2021) also discussed that it can lead to that employees are replaced by new technology and machines. To this purpose, both IKEA, Ejsmont (2021) and Schmidtke et al. (2018) acknowledge the challenge of resistance among employees against automation.

Several of the respondents believed that IKEA needs to remove the fear of automation technologies and that fear is often based on that employees do not understand the purpose of it. When the employees understand that the tasks that are automated are often not desirable tasks, and that the automation can help them with their work, they become motivated and committed. Dombrowski and Wagner (2014) do not believe that Industry 4.0 will substitute people, but to create a collaborative environment between humans and technology. Based on the empirical and literature findings, there is a shared view of what tasks will be automated. Respondents agree that repetitive and simpler tasks will be automated, while Bonekamp and Sure (2015), Cimini et al. (2019), Kadir et al. (2019) and Zacharaki et al. (2020) also concluded that repetitive, manual, and simple tasks will be automated. Moreover, when transforming a WMS, as discussed by Mostafa et al. (2019) it is important that it makes employees' tasks easier and not more of an administrative hassle. One respondent emphasized that although IKEA will automate different processes, employees will always be needed. Several respondents said that employees should perform tasks that require their knowledge and that the employees are more flexible when dealing with problems. Based on this, the respondents agreed that employees should work with more value-creating tasks. Kadir et al. (2019) explained that automation have limited flexibility and humans must still perform the complex tasks that require problem-solving skills. One respondent gave an example of a more value-creating task, to interact with customers since that interaction is difficult to automate. Cimini et al. (2019) similarly argued that the new value created and not automated tasks can benefit other departments of the company as employees can instead, for example, integrate with customers. Both findings from the respondents and the authors in the literature highlighted the importance of interaction with customers.

One respondent discussed that automation is about upgrading employees' tasks and enabling them to work with value-creating tasks. Two respondents argued that new roles will be created, since employees need to understand the technology related to automation, maintain it, and make it more efficient. Furthermore, IKEA needs employees performing tasks related to data analysis and predictions on purchases. Authors in the literature review also discussed new skills that employees need. As an example, Xu and Duan (2019) described that through analysing big data, companies can improve forecasts of customer behaviour. Ivanov et al. (2019), Nguyen et al. (2020) and Wang (2018) also discussed how data analysis becomes more important and can create value. Furthermore, Kadir et al. (2019) discussed that employees need to understand abstract information, solve complex problems and have IT competence. Bag et al. (2020), Schmidtke et al. (2018) and Scholtz (2003) argued that employees need to supervise and monitor unmanned vehicles. Kipper et al. (2021) discussed that knowledge in automation, data analysis as well as skills in problem solving are important. Both respondents from IKEA and authors from the literature highlighted importance of data analysis, solving problems and ability to maintain unmanned vehicles. Hence the respondents and findings from the literature review highlighted similar skills needed when using automation technologies, or unmanned vehicles.

Authors agreed that changing roles implies that companies must invest in training and skill development (Baker and Halim, 2007; Bonekamp and Sure, 2015; Hofmann and Rüsch, 2017; Kadir et al., 2019; Kipper et al., 2021; McCreary and Petrick, 2018; Winkler and Zinsmeister, 2019). One respondent also argued that IKEA needs to have new competencies from outside the company, but that a lot of the competence needed can be found within IKEA by simply retraining the current employees. Similarly, Benešová and Tupa (2017) highlighted the importance of retraining existing employees rather than hiring new ones, since they know the current processes within the company. Something that was not discussed by the respondents, but discussed by Kadir et al. (2019) is that companies need to identify the new skills needed before investing in new automation technologies. Rüßmann et al. (2015) also emphasized to conduct strategic workforce planning. Hence, IKEA might need to consider planning their workforce.

Based on the analysis two factors were decided by the authors to be important for IKEA to consider for using unmanned vehicles in stores, as seen in table 5.7. The first one is *Managing resistance of employees*. This means that IKEA should include employees in automation projects since it leads to more enthusiasm and commitment. It also means that IKEA should help the employees understand and trust the automation technology. This would help address the fear that some employees have.

The second one is *Matching the requirements of changing roles with skills among the employees*. This means to anticipate what skills are needed, upgrade the tasks and train the current employees. The current employees know the processes at IKEA, but in cases where they lack specific skills and cannot retrain the current workforce, they might need to hire new employees.

Managing resistance of employees
Matching the requirements of changing roles with skills among the employees

Table 5.7: Factors - Impact on Employees

5.3.2 Ergonomics and Safety

One reason for using automation technologies, as discussed by all of the respondents, was to improve the ergonomics of the employees, reduce injuries, and create a better working environment. Both Cimini et al. (2019) and Loos et al. (2016) discussed how important ergonomics is for employees, and if that is not considered it can lead to numerous health problems. One respondent gave an example of employees having to lift heavy boxes, weighing 30-40 kilograms, and two respondents described how employees sometimes have to manage articles at a high level, hurting their necks. Cimini et al. (2019) and Kadir et al. (2019) discuss that ergonomics could be improved by Industry 4.0 technologies, since heavy and dangerous tasks become automated. There is an agreement between respondents and the mentioned authors that it is important to consider ergonomics, and that unmanned vehicles can help with that.

In addition to ergonomics, safety for employees and customers was discussed by all of the respondents although there was no interview question specifically addressing it. This indicates the importance for IKEA to consider safety. Moreover, a majority of the respondents described that safety in store environments is a priority for IKEA, and one respondent emphasized that IKEA will not use any automation technology in a store if it is not safe. The respondents meant safety in the sense that the technology should not hurt people. Safety between unmanned vehicles and humans was also discussed as an important factor in the literature (Cimini et al., 2019; Custodio and Machado, 2020; Erol et al., 2012; Kirks et al., 2018; Krkoška et al., 2017; Löcklin et al., 2020; Rey et al., 2019; Shackleford et al., 2016; Zacharaki et al., 2020; Zuin et al., 2020). Hence, IKEAs safety concern is in line with what authors believe is important to consider when using unmanned vehicles.

Jost et al. (2018), Löcklin et al. (2020) and Rey et al. (2019) believed that humans and unmanned vehicles can be close together in cramped spaces if the unmanned vehicles can avoid collisions. Therefore, unmanned vehicles must understand humans' intentions to ensure safety (Custodio and Machado, 2020; Löcklin et al., 2020; Zacharaki et al., 2020). One respondent also believed that automation technologies can be safe to use together with humans. Zacharaki et al. (2020) argue that there is no standardized method to achieve safety, but safety should be inherited in the unmanned vehicles' cognition abilities. Both Löcklin et al. (2020) and Rey et al. (2019) suggest using real time localization of humans. For that purpose, CPS/IoT could be used to digitize data and connect humans and unmanned vehicles (Santos et al., 2017), and thereafter big data analysis can be used to efficiently manage this data exchange (Liu et al., 2018; Zhang et al., 2017), and the data can be stored in a cloud (Nguyen et al., 2020). As previously mentioned in section 5.2.1, *Systems*, Tran-Dang et al. (2020) argued that cloud can be negative in the sense that using central computational power increases latency in systems, which can affect the management of real time data, and also that there is a risk of more computational errors. Hence, it is important that it works technically for safety be assured when unmanned vehicles are located together with humans.

Authors agreed that unmanned vehicles should be aware and adjust to humans, but similarly, Löcklin et al. (2020) emphasized that humans must understand what an unmanned vehicle intends to do as well. For that purpose, humans can use their senses and knowledge (Löcklin et al., 2020). However, based on the findings from Zuin et al. (2020), it is challenging for unmanned vehicles to avoid humans as their movements are unpredictable. In addition, Zuin et al. (2020) problematized that dangerous interaction happens since employees rely on unmanned vehicles to stop when detecting the workers. In addition, Krkoška et al. (2017) described the challenge of using unmanned vehicles in areas where people are uninformed and not aware of them. Those persons do not know how to act in such environments (Krkoška et al., 2017). It is possible to think of customers as uninformed, and they are not as educated as employees on how to act together with unmanned vehicles. One respondent believed that IKEA is not ready to use unmanned vehicles in the same space as customers since accidents can happen. Moreover, one respondent said that customers can sometimes be a hindrance in stores when using unmanned vehicles. IKEA could for example solve this by informing the customers about the unmanned vehicles, or by also connecting the customers to the unmanned vehicles by CPS/IoT, as Liu et al. (2018) and Santos et al. (2017) described.

Krkoška et al. (2017) and Zuin et al. (2020) found that unmanned vehicles can be safe, but it impacts their productivity and utilization, as they have to stop for humans. Similarly, one respondent believed that safety can be assured, but in that case, the automation technology is slow due to the high safety requirement. In that sense, the respondent argued that the automation technology can improve the ergonomics and safety of employees, but can be inefficient in the long term. Another respondent also raised concern about a trade-off between being efficient and at the same time adapting to the employees, their needs, and the customers' needs. Based on this, findings from the literature review and respondents agreed on this trade-off.

Krkoška et al. (2017) concluded that unmanned vehicles can instead be used where there are no people, or move during times when they are at least expected to collide with the people. Half of the respondents also believed that it is important to physically separate humans and unmanned vehicles to ensure a safe environment in stores. In addition, half of the respondents explained that unmanned vehicles can be used in stores when they are closed for customers. That way, they would not have to stop as often due to customers in the store, which might also increase the productivity of the unmanned vehicles and enable IKEA to be on time with their replenishment and logistics operations before opening time, which was one concern raised by several respondents. Hence, both Krkoška et al. (2017) and respondents agreed that to be safe, but at the same time productive, unmanned vehicles should be separated from humans. In addition, it would increase the productivity and utilization of unmanned vehicles as they are not disrupted and have to stop (Krkoška et al., 2017; Zuin et al., 2020).

Two factors were found when analyzing the empirical findings about humans and the literature. First, *Benefits of improved ergonomics* is a factor to consider since unmanned vehicles will reduce dangerous and heavy tasks. Ultimately, it also leads to a safer working environment for the employees. Second, it is important to consider *The degree of coexistence with humans* for IKEA, since they have both employees and customers in their stores. IKEA can have unmanned vehicles together with humans, but then it is important to avoid collisions. In that case, it is important to mitigate the risk of unpredictable movements from customers and employees, which could be done by educating them. Another solution could be to separate the unmanned vehicles and humans. However, it is important to acknowledge the trade-off between the safety and productivity with unmanned vehicles. The factors are found below in table 5.8.

Benefits of improved ergonomics
The degree of coexistence with humans

Table 5.8: Factors - Ergonomics and Safety

6

Conclusion

6.1 Answering the research question

This study originated from a problem identified at IKEA and the lack of literature on what to consider if using unmanned vehicles in stores. To reap the benefits of unmanned vehicles, additional research on the topic was needed. Hence, the purpose was to get an overview of how unmanned vehicles would affect IKEA's organization, and the research question was *'What are the factors that IKEA should consider to use unmanned vehicles in stores?'*. To answer the research question and fulfill the purpose, a Research Paradigm was defined, and an abductive approach was used together with a qualitative research strategy by collecting data from respondents and the literature. Those findings were then analyzed and compared, which finally facilitated managerial recommendations to IKEA, which will be further described.

This study concluded 13 factors that IKEA should consider to use unmanned vehicles in stores. These were divided into three main groups, which were additionally based on the themes in the thematic analysis. That is, *Automation Objectives*, *IT*, and *Impact on Humans*. The first one, *Automation Objectives*, includes what to expect and what to consider overall to reap the benefits of unmanned vehicles. The second one, *IT*, defines what to consider in terms of new technology needed to use unmanned vehicles. That is, how to use data and integrate different systems. The last one, *Impact on Humans*, considers what effect unmanned vehicles have on employees and customers. The factors are summarized below, in table 6.1, together with their respective group. The managerial implications for IKEA are summarized in these factors, which will be further explained below.

Factor	Group
Defining a strategic purpose	Automation Objectives
Coordination of project	Automation Objectives
Realistic expectations of costs	Automation Objectives
Standardization enables scalability	Automation Objectives
Managing integration with legacy systems	IT
Enabling data through CPS/IoT	IT
Centralizing storage and computation in cloud	IT
Coordinating picking tasks with real time data	IT
Cyber security risks	IT
Managing resistance of employees	Impact on Humans
Matching the requirements of changing roles with skills among the employees	Impact on Humans
Benefits of improved ergonomics	Impact on Humans
The degree of coexistence with humans	Impact on Humans

Table 6.1: Summary of Factors to Consider

The factors found have managerial implications for IKEA as they should be considered to use unmanned vehicles in IKEA's stores. Although, it is important to also remember that using unmanned vehicles might not always be necessary and it is overall important to be certain about the specific benefits that IKEA can gain from using unmanned vehicles. That is, it will have an impact on, for example, employees, IT, and costs. Hence, considering the potential limitations of digitalizing their stores is important to not overestimate the benefits. Therefore, IKEA needs to be aware of this when introducing unmanned vehicles, and in that sense not introduce them because they simply want to digitize their business. This leads to the first factor found in this study.

Defining a strategic purpose. To use unmanned vehicles, IKEA should consider defining a clear purpose of what they want to achieve with the technology. This decreases confusion among actors and the risk of automation projects becoming failures. The purpose should also be aligned with IKEA's corporate strategy to ensure coherence in the organization.

Coordination of project. To increase the likeliness of success when using unmanned vehicles, IKEA should consider how to best manage their projects. This includes having realistic timelines, collaboration with suppliers and methods of testing the project before launching it in a real environment.

Realistic expectations of costs. Since reducing costs is important for IKEA, they should consider having realistic expectations of costs when using unmanned vehicles. This means that they should do a thorough analysis of how using unmanned vehicles would impact their operational costs and weigh it with the costs of using and integrating unmanned vehicles.

Standardization enables scalability. To increase the scalability of unmanned vehicles, IKEA should consider what parts of their operation they can standardize. This could make it easier for them to quickly ramp up the technology but also to easier implement it in different stores.

Managing integration with legacy systems. The integration with legacy systems should be considered by IKEA to use unmanned vehicles, as they use a wide variety of different systems and that several of them might be outdated. This could create difficulties for unmanned vehicles to communicate with legacy systems, and thus impacting the effectiveness of them.

Enabling data through CPS/IoT. By connecting the digital and physical world through CPS/IoT, a large amount of data would be generated that could increase insights from analysis. This could increase the efficiency of unmanned vehicles and is therefore a factor IKEA should consider.

Centralizing storage and computation in cloud. By centralizing management of data in the cloud, the local need for IT infrastructure would not be as substantial to use unmanned vehicles. Moreover, it would increase the accessibility of data.

Coordinating picking tasks with real time data. By leveraging the data generated from CPS/IoT, big data analysis could optimize the picking tasks to address complex order patterns. In this way, it could increase the operational effectiveness of unmanned vehicles.

Cyber security risks. As using unmanned vehicles would increase the potential entry points for digital security breaches, IKEA should consider the risks it might entail. This is especially important if using CPS/IoT, and IKEA should involve employees at all levels in the organization to be aware of cyber security risks.

Managing resistance of employees. To use unmanned vehicles, IKEA should consider how to address potential resistance among employees. This could be done by involving employees in automation projects and by increasing employees' trust in the technology.

Matching the requirements of changing roles with skills among the employees. When processes are automated the employees' roles and tasks change, requiring new sets of skills to perform the new tasks. To use unmanned vehicles, IKEA should therefore consider what skills are required for new roles and how to match them with the employees.

Benefits of improved ergonomics. By using unmanned vehicles, several dangerous and heavy tasks could become automated. This could reduce injuries and overall increase the contentment of employees, and is, therefore, something for IKEA to consider.

The degree of coexistence with humans. For IKEA to use unmanned vehicles, they need to consider the implications for safety in the context of the coexistence between the unmanned vehicles and humans. This is especially true since there are customers in the stores and IKEA should consider how to manage a possible trade-off between the safety and productivity of the unmanned vehicles.

6.2 Research Implications and Limitations

Based on the answer to the research question, this study contributed with knowledge on what to consider if wanting to use unmanned vehicles in stores. In addition to stores, the findings could be applied to warehouses or other areas where unmanned vehicles could be used, and where there are employees, customers, or both. This study has also contributed with more knowledge in regards to Industry 4.0 technologies and automation technologies, as unmanned vehicles are a part of it. To this end, this study has further developed and researched areas mentioned by Kagermann et al. (2013), thus helping organizations overall to use unmanned vehicles.

However, this study has limitations as well. Considering the thirteen factors does not guarantee success in using unmanned vehicles, as these factors have not been tested in this study. That is, factors were based on the concerns by IKEA and findings in the literature, but were not tested. Furthermore, no difference in degree of importance or possible synergies between factors have been researched. Regardless, these factors have been found to have implications for IKEA and should therefore be considered to increase the probability of success when using unmanned vehicles.

Moreover, this study was based on the current literature and IKEA's current knowledge about unmanned vehicles. Hence, this study might be outdated in the future if IKEA gains more knowledge about the topic. In addition, since Industry 4.0 overall is an emerging trend and research area, new articles could be published in the future, again making this study outdated in the future. That is, as new technology was the focus in this study, the technology might develop in the future. To exemplify, the term unmanned vehicles was used in this report due to the lack of clear distinctions between AGVs and AMRs in the literature. If this changes in the future, this study might as well be outdated, and research would instead be done exclusively on modern AGVs or AMRs. Moreover, the factors might change depending on the development of, for example, new technology or regulations. Finally, the study was done during current Covid-19 restrictions in Sweden, which meant that the authors of this study were not able to visit any ongoing automation project at IKEA. This might have impacted the authors' understanding of the factors to consider.

Another limitation concerns that it was a single case study, aimed at answering a research question focused on IKEA. Although, as previously discussed, the findings could be applied to other organizations as well, with the same or similar peculiarities as IKEA. Moreover, this study focused on IKEA's Ingka stores, which might have implications on using the factors on other stores within IKEA. However, the authors of this study argue that factors concerning *Automation Objectives* and *Impact on Humans* should apply to other stores, but *IT* might be somewhat different depending on the WMS, as previously discussed in section 3.5.2, *Transferability.*

An additional important discussion regards how well literature connected to Industry 4.0 and automation technologies can answer a research question focusing on unmanned vehicles. As previously mentioned in *Concepts in Focus*, in section 1.1.1, there is a lack of literature on unmanned vehicles. Hence, as Industry 4.0 and automation technologies include unmanned vehicles, the authors of this study concluded that such theory was applicable to answer the research question. However, the reader needs to be aware of this potential limitation. Moreover, as the majority of the literature described unmanned vehicles in the context of warehouse automation, and not stores, one could question how applicable that literature is to the research question. However, this study closed this gap by comparing the current literature with the empirical findings from IKEA, that were based on the perspective of a store and a warehouse. Thereby, additional knowledge on what to consider to use unmanned vehicles in the context of a store was created in this study.

6.3 Future Research

Based on the findings and the limitations of this study, future research on the matter could further immerse in the topic of unmanned vehicles. Overcoming potential limitations and develop new knowledge regarding unmanned vehicles, automation technologies, or overall Industry 4.0 in a store context could be done. Thereby, the authors of this study recommend the following:

- Future researchers could replicate this study in the future, to see if the factors have changed as a result of the development of new technology and new updated literature. It could also be done using another research strategy, such as quantitative or mixed, which might result in different factors.

- A different sample could be used, such as interviewing customers in the store to get a sense of their reaction towards unmanned vehicles. In addition, focusing on other stores than Ingka stores could be a topic for future research, and thereafter compare those findings with the findings of this study.

- Future researchers could study unmanned vehicles at another organization than IKEA, or as a multiple case study to compare different organizations.

- Finally, after Covid-19, future researchers could immerse more in the topic as restrictions might be removed. Thus, a more complete understanding of the issue could be achieved, by more thoroughly observe the context where the vehicles could work.

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Appendices

A Interview Guide

Introduction

- What is your role today and what kind of responsibilities do you have?
- How long have you been working for IKEA and in your current role?

Experience

- What is your experience in automation?
  - Could you describe any challenges?
  - What would you say specifically went well?

Project Process

- In automation projects, are there initial visions before starting?
- To what degree would you say that original plans in automation efforts are carried out?
  - Did you have to make any changes in the plan?
- In hindsight, what have you learned from previous automation efforts that you would do differently today?

Automation in Stores

- Why does IKEA work with automation in stores?
- What is your view regarding using AGV/AMR in stores?
- What do you believe are fundamental requirements for IKEA to use AGV/AMR in stores?

- Do you already fulfill any of those requirements at IKEA?
- What factors do you believe make automation challenging?
- How does automation work in regards to employees?
- How do you measure the success of automation and how is it continuously being evaluated?
- Have you done any adjustments to apply automation?

Software

- How well do the automation function with existing IT systems?
- Did you have any digital strategy when implementing the automation?
- Did you face any challenges regarding the software?

Final Question

- Is there something you think we should have asked you about that we haven't?

B Thematic Analysis

- Automation Objectives
  - Projects
    * Execution
    * Exploration
    * Pilot
    * Preparation
    * Suppliers' role
    * Vision
  - Costs
    * Associated costs
    * KPIs
    * Layout
    * Measure outcome
  - Scalability
    * Paper pallet
    * Quality
    * Range
    * Scalable solution
    * Standardization
- IT
  - Systems
    * Complexity AGV and AMR
    * Customer effect

    - Order Volume Flow
    - Warehouse Management System
  - Data
    - Data availability
    - Data importance
    - Prediction & analysis
    - Real time data
- Impact on Humans
  - Impact on Employees
    - Changing tasks
    - Coworker effect
    - Inclusion
    - New skills
    - Value added activities
  - Ergonomics and Safety
    - Human and automation collaboration
    - Improved working conditions
    - Layout
    - Open or closed store