



**LUNDS**  
**UNIVERSITET**

**The Potential Use of Autonomous Delivery Vehicles in Last Mile Delivery: *A Diffusion of Innovations Approach with an IKEA Perspective***

Department of Service Studies

SMMM40: Service Management Master's (Two Years) Thesis

18/05/2025

Thesis Pair 12

Ceren Özel

Md Shadman Azad Shuvo

Supervisor: Klas Hjort

## **Abstract**

This thesis explores the possible points of use for autonomous vehicles (AVs) in the last mile delivery context. Motivated by the growing demand for efficient, scalable and customer centric delivery solutions, this thesis identifies the pain points in last mile delivery and evaluates the AV features required for application in the last mile delivery. It employs a qualitative approach and incorporates semi-structured interviews and triangulation-based document analysis to uncover operational challenges and opportunities for innovation. This study applies the Diffusion of Innovations (DOI) Theory, which describes the process of how an innovation spreads over time, to examine the potential adoption of AVs in urban logistics environments. The findings demonstrate how the approach reveals key pain points and aligns AV features with stakeholders' expectations. This points to significant potential for broader application in urban mobility and logistics innovation. The study contributes to the evolving field of last mile deliveries by providing both theoretical and practical use potential for integrating autonomous vehicle solutions.

**Keywords:** last mile delivery, last mile delivery innovation, autonomous vehicles.

## Acknowledgements

This marks the end of our journey as students of Service Management, Supply Chain Management at Lund University and we are elated to present this master thesis. We also would like to take this opportunity to thank everyone without whom this journey and this thesis would not have been possible.

First and foremost, we extend our earnest gratitude to **Klas Hjort**, our thesis supervisor, whose guidance and patience have been nothing short of remarkable. Thank you for helping us navigate this process with clarity and calm even when we were confused. Your feedback helped us grow not just as researchers but as critical thinkers. We also want to thank you for always making the time for us, even when time was clearly in short supply.

We are equally grateful to **Nynke Mensonides**, our IKEA mentor, for her enthusiasm, encouragement and support. Thank you for believing in our work and going the extra mile to make time for us, online or in person. Our heartfelt thanks also go to **Marlein Wiertsema** and **Stefan Eriksson** whose experience, honesty and generosity made this collaboration productive as well as enjoyable.

We would also like to thank the IKEA employees from all over the world who took the time to do interviews with us. We are grateful for your experiences and insights.

Special thanks to our wonderful families as they supported us unconditionally even from afar. Despite the distance, your love, reassuring calls and patience kept our spirits high. Although we are fairly certain you didn't always know what we were talking about, your smiles and supportive "sounds wonderful" responses were exactly what we needed.

To our incredible friends, thank you for being the much-needed breath of fresh air during this marathon. Your presence kept us balanced and was a reminder that the world exists beyond deadlines and literature reviews.

Thank you all.

With gratitude,



**Ceren Özel**



**Md Shadman Azad Shuvo**

## Contents

|   |    |
|---|----|
| 1. Introduction.....                                      | 1  |
| 1.1. Research Background .....                            | 1  |
| 1.2. Research Problem .....                               | 3  |
| 1.3 Research Aim and Questions .....                      | 4  |
| 1.4 Thesis Structure .....                                | 5  |
| 2. Literature Review.....                                 | 6  |
| 2.1 E-Commerce.....                                       | 6  |
| 2.1.1 Shift in Demand and Expectations .....              | 7  |
| 2.2 Last Mile Delivery .....                              | 8  |
| 2.2.1 Importance of Last Mile Delivery .....              | 9  |
| 2.2.2 Different Methods in Last Mile Delivery .....       | 10 |
| 2.2.3 Alternative Delivery Methods .....                  | 11 |
| 2.3 Autonomous Vehicles .....                             | 11 |
| 2.4 Autonomous Vehicles for Last Mile Delivery .....      | 12 |
| 2.4.1 Laws and Regulations .....                          | 13 |
| 2.4.2 Urban Infrastructure .....                          | 15 |
| 2.4.3 Customer Acceptance.....                            | 15 |
| 2.5 AV Concepts in Development.....                       | 16 |
| 3. Theoretical Framework.....                             | 17 |
| 3.1 Diffusion of Innovations (DOI) Theory.....            | 17 |
| 3.1.1. Autonomous Delivery Vehicles as an Innovation..... | 18 |
| 3.2 Critiques of the DOI Theory.....                      | 20 |
| 3.3. Other Theories Used in AV Research .....             | 21 |
| 4. Methodology.....                                       | 22 |
| 4.1. Research Design .....                                | 22 |
| 4.2. Research Methods.....                                | 23 |
| 4.2.1 Semi-Structured Interviews.....                     | 23 |
| 4.2.3 Thematic Analysis and Coding.....                   | 25 |
| 4.3 Methodological Triangulation .....                    | 26 |
| 4.3.1 Document Analysis .....                             | 27 |
| 4.4 Ethical Considerations.....                           | 28 |
| 4.5 Limitations.....                                      | 28 |
| 5. Analysis .....   | 30 |
| 5.1 Pain Points in Last Mile Delivery.....                | 30 |

|   |    |
|---|----|
| 5.1.1 Balancing Trade Offs.....                       | 30 |
| 5.1.2 The Amazon Effect.....                          | 32 |
| 5.1.3 Fill Rate Utilization.....                      | 33 |
| 5.1.4 Current and Expected Labor Issues.....          | 35 |
| 5.1.5 Challenges with Electrical Vehicles .....       | 36 |
| 5.1.6 Damage .....                                    | 37 |
| 5.1.7 Weight and Size Challenges .....                | 38 |
| 5.1.8 Expected Legislative Changes.....               | 39 |
| 5.1.9 Issues Stemming From Customers .....            | 40 |
| 5.1.10 Operational and Planning Challenges .....      | 40 |
| 5.2 Desired Autonomous Vehicle Features .....         | 41 |
| 5.2.1 Capacity to Cover the Entire Product Range..... | 41 |
| 5.2.2 In Transit Product Safety Features .....        | 43 |
| 5.2.3 Order Segmentation.....                         | 44 |
| 5.2.4 Vehicle Safety Features .....                   | 46 |
| 5.2.5 Handover Support Features .....                 | 47 |
| 5.2.6 Optimized Routing .....                         | 48 |
| 5.2.7 Tracking and Visibility Features.....           | 49 |
| 5.2.8 Sufficient Range .....                          | 50 |
| 5.2.9 Customer Interaction Features .....             | 51 |
| 5.2.10 Flexibility in Operations.....                 | 52 |
| 5.3 Findings From the Document Analysis .....         | 53 |
| 6. Discussion.....                                    | 54 |
| 6.1 AV Features to Address Pain Points in LMD.....    | 54 |
| 6.2 Theoretical Implications .....                    | 56 |
| 6.3 Practical Implications .....                      | 59 |
| 6.4 Limitations.....                                  | 61 |
| 6.5 Suggestions for Future Research .....             | 61 |
| 7. Conclusion .....                                   | 63 |
| References.....                                       | 64 |
| Appendices.....                                       | 76 |

## **1. Introduction**

*This section introduces the research topic which is the potential use of autonomous vehicles in last mile deliveries. It outlines the relevance of the topic and defines the context in which the topic is situated. It presents the background, identifies the research gaps, and explains the motivation behind the research. This section also highlights the research objectives and questions, providing a guide for the flow of the thesis. It aims to clarify the contribution this study seeks to make to the supply chain and autonomous vehicles fields.*

### **1.1. Research Background**

After the COVID-19 pandemic, e-commerce experienced a boom, with revenue from e-commerce activities jumping from \$2.56 billion in 2020 to \$3.21 billion in 2021 (Statista, 2025). The market continues to grow, with revenues expected to reach a staggering \$5.88 billion by 2029 (Statista, 2025). In addition to increasing demand, customer expectations are also changing as they demand faster, more flexible and predictable deliveries with multiple methods for receiving the goods (Tadić & Veljović, 2020; Alverhed et al. 2024). Due to expectations from customers, many companies are looking for ways to respond to these trends. However, significant problems in the e-commerce market hinder companies that aim to provide the best service to customers and lower operational efficiency.

Responding to customer expectations requires increasing the flexibility and capacity of last-mile deliveries. However, many vehicles used in deliveries globally suffer from low levels of technology, with less efficient engines and old control systems, especially in developing countries (Mittal et al. 2018). Outdated vehicles require more frequent maintenance checks and usually generate high operating costs due to low levels of fuel efficiency (Mittal et al. 2018). As a result of these issues, deliveries often get delayed and disrupt the entire supply chain; causing poor customer relations, additional costs, lost revenues and decline in the market share in the face of competition (Benallou, 2024). Moreover, the shortage of drivers has become a chronic issue in the field especially during and after the COVID-19 pandemic and put companies providing last-mile delivery services in a challenging position (Crayton & Meier, 2017).

With sustainability gaining prominence in recent years, customers have started to consider this element in addition to flexibility and sufficient capacity. Modern consumers increasingly demand rapid, sustainable delivery services, driven by urban living, service alternatives and environmental awareness (Wang & Sarkis, 2021). Logistics providers and retailers are prompted to respond with innovations like micro-fulfillment centers, cargo bikes, and innovative solutions which enhance efficiency and align with sustainability goals (Lee et al., 2023). Alternative delivery models such as parcel lockers, click-and-collect, and curbside pickup also emerged to further improve reliability, reduce failed deliveries, and support environmental objectives (Vakulenko et al., 2018; Molin et al., 2022; Encarnación & Amaya, 2024).

In recent years, the last mile field saw significant changes in delivery flows as well. While offline channels were traditionally favored by customers, there has been a significant surge in online orders across all product categories (Lyons & McDonald, 2022; Merkert et al 2022). Heavy, oddly shaped and oversized products have also become an important share of home deliveries (Peinkofer et al., 2020). However, traditional parcel flows often lack infrastructure for the necessary handling, larger vehicles, tailored delivery schedules and additional labor for setup (Peinkofer et al., 2020; Ray & Paul, 2023). The challenges are further exacerbated with restricted and limited parking, failed deliveries and rising operating costs (Allen et al., 2018; Jiang et al., 2018). Moreover, external operational stressors such as urban freight traffic, intensifying congestion, emissions, and the growth of the urban population have begun affecting the field (Ciobotaru & Chankov, 2021).

Given all these developments and shifts in the field of last mile delivery, decision makers are preparing to introduce regulations on global and local scales (Raghunatha et al. 2023) Various city authorities are working on implementing or have implemented regulations such as low emission zones and delivery restrictions, pushing firms to adopt cleaner vehicles and efficient routing (Calabrò et al., 2019; Priscilia et al., 2024). Restricting or taxing the use of diesel delivery vehicles in the near future is a frequent topic of discussion (Cheng & Lin, 2024).

Such points of consideration have led professionals to look for new, compliant and more efficient ways to enhance their last-mile delivery operations. Autonomous Vehicles (AVs), which are widely discussed with the rapid advancement of technology, are often cited as a viable solution to such challenges. AVs which can operate without any or minimal input from a driver are used today in

many different fields ranging from military missions and housekeeping tasks to industrial operations (Miranda et al. 2022). Such vehicles are also in use for last-mile deliveries. Small delivery robots and aerial drones have been used for food, grocery, and prescription deliveries during and after the pandemic (Srinivas et al. 2022). Autonomous trucks for transporting heavier and more fragile goods are also being tested and deployed on a small scale in certain countries.

Current research shows that AVs used in last-mile delivery operations can provide efficiency in many different ways. AVs can reduce the dependency on human drivers, thereby improving working conditions for remaining employees and allowing for a more flexible workforce structure. Although the results may vary depending on service regions and their characteristics, they can contribute to reducing major operational costs (Lemardelé et al. 2021) through reducing fuel costs (Schuster et al. 2023; Benallou et al. 2024); empty driving periods (Alverhed et al. 2024) and carbon emissions (Helmers & Weiss, 2017; Paddeu & Denby, 2020). The potential to address the outlined challenges leads AVs to emerge as a promising innovation and attract significant interest from businesses and researchers. Despite this, there seems to be a gap in understanding business-related impacts of the use of AVs.

## **1.2. Research Problem**

Several operational issues such as labor unavailability, outdated delivery practices, lack of infrastructure and underutilization of vehicles challenge the efficiency of the flows (Wang et al. 2021; Srinivas et al. 2022). In the face of all these challenges, logistics providers and retailers are pressured to innovate to enhance their processes. One of the most prominent emerging solutions is the introduction of autonomous vehicles into the last mile delivery field. The biggest driver for AV implementation for last-mile deliveries is the desire to create more flexible, compliant and efficient delivery flows that can adapt to rapidly evolving customer demands and expectations. Although AVs are in use for customer deliveries in fields such as health and groceries (Srinivas et al. 2022); there is lack of research on their potential use for the delivery of heavy and bulky items.

As of 2025, many autonomous delivery vehicles of different features, shapes and ranges are currently being designed, manufactured or tested. Retail companies such as IKEA are working to introduce these vehicles into everyday use, especially in markets like China and the US (Ingka

Group, 2024). However, suppliers of autonomous vehicles do not follow a standardized approach or guide in designing and manufacturing vehicles to be specifically for delivery purposes (Sever & Contissa, 2024). This makes it difficult for early adopters of the technology to find vehicles that can respond to the needs of their delivery processes. Retailers with wide product ranges, such as the Swedish retailer IKEA, that also sell heavy and bulky goods are especially interested in the topic.

The studies on AVs predominantly focus on the technical characteristics of the vehicles such as their design, range, energy source, navigation and integration with existing systems (Alverhed et al. 2024). Although there are studies conducted on customer acceptance, sustainability and profitability of implementing AVs, other business aspects remain largely under-explored. In particular, there is a research gap on how AVs can be integrated into last mile delivery processes and what kind of features or capabilities they should have to address the needs of customer deliveries. Providing answers to these questions can contribute to the research on the future of last-mile deliveries and the creation of new business models. The findings can also act as a guide for businesses wanting to enhance their delivery processes.

### **1.3 Research Aim and Questions**

This research aims to understand the day-to-day operational challenges professionals encounter with last-mile deliveries (e.g. failed deliveries, lack of infrastructure, underutilization) specifically for heavy and bulky items such as furniture, and identify what kind of capabilities and qualifications AVs should have in order to adequately, sustainably and effectively address these challenges. In order to identify the pain points, interviews were conducted with the delivery professionals of IKEA, the Swedish retailer. The findings were triangulated with a document analysis to evaluate the current landscape in terms of what is available and what is not. Two research questions that align closely with the purpose of this thesis have been identified.

*RQ1: What are the main operational challenges in last mile delivery of heavy and bulky items, according to the perceptions of last mile delivery professionals?*

*RQ2: What kind of specific attributes and capabilities should autonomous delivery vehicles possess to effectively address these challenges?*

## **1.4 Thesis Structure**

The structure of this thesis is designed to guide the reader through the research process, starting with the problem formulation to final conclusions. The first chapter introduces the topic, establishing the relevance and objective of the study and outlines the research questions. The second chapter presents a comprehensive review of the existing literature, identifying trends, gaps that frame the research for the use of AVs in LMD. Chapter three includes the details of the methodology, the data collection process, design of the approach and the method of analysis. The fourth chapter discusses the theoretical framework employed to examine the results, the rationale behind the selection of the theoretical framework and critique. In chapter five, the data collected in the study are presented and analyzed through the lens of the theory chosen, and the findings are discussed. The sixth chapter offers reflections on the contributions in both theoretical and practical fields, limitations and proposes directions for future research. Final chapter includes an overarching concluding remark for the entire study.

## **2. Literature Review**

*This section provides background information for the reader on the main topics presented in the thesis. Findings from the relevant literature on e-commerce, last mile deliveries, alternative delivery methods, and autonomous vehicles are discussed. Research gaps identified from previous research are highlighted.*

### **2.1 E-Commerce**

The exponential growth of e-commerce over the past decade has transformed the logistics landscape significantly, rendering heightened importance on supply chain and last mile delivery operations (Uvet et al., 2023). Driven by rapid technological advancements, increased internet user penetration, and shifts in consumer expectations, the e-commerce sector has emerged as a crucial catalyst for innovation in delivery logistics (Corejova et al., 2022). The acceleration of online retail boom in COVID-19 pandemic has drastically altered the traditional supply demand balance prompting logistics providers to rethink their operational models and delivery strategies (Mohammad et al., 2023). This growth has not only altered market dynamics but has influenced retail formats and competitive models as well. Traditional brick and mortar retailers are integrating digital platforms to complement physical operations and are adopting omni-channel strategies to respond to the modern consumer's preference for convenience and immediacy (Ratchford et al., 2022). Such developments necessitate a reevaluation of existing logistics infrastructure and delivery paradigms to address issues of scale, sustainability, and service delivery (Mohammad et al., 2023).

The proliferation of e-commerce has also led to the diversification of product categories sold online ranging from groceries, household goods, electronics to medical supplies; many of these require timely and reliable delivery mechanisms (Corejova et al., 2022; Uvet et al., 2023). In addition, the process of integrating particularly heavy, fragile and oddly-shaped products into delivery flows has also accelerated (Peinkofer et al., 2020). Consequently, logistics providers are faced with the challenge to facilitate these variations while maintaining cost efficiency, service quality and environmental responsibilities, making the operational complexity to become a defining feature of modern last mile logistics and directly influence the evolution of consumer expectations (Lu et al., 2023).

Furthermore, the e-commerce ecosystem has spawned new roles and partnerships between platform providers, retailers, logistics operators and consumers themselves, reshaping the very concept of value creation in delivery logistics (Kundu et al., 2025). Sole focus on transactional efficiency is no longer sufficient, instead value is increasingly co-created through personalized delivery experiences, flexible options and real time communication throughout the delivery process (Merkert et al., 2022, Kundu et al., 2025). The expectation on last mile delivery has thus grown in complexity, not only in technical execution but also in relation to consumer engagement and satisfaction.

### **2.1.1 Shift in Demand and Expectations**

Consumer expectations have been redefined with the rise in e-commerce, especially in terms of delivery lead time, flexibility and reliability. Modern consumers now expect delivery solutions not only timely and accurate in nature but tailored to their individual requirements such as delivery time slots, location flexibility and level of interaction (Lu et al., 2023). In urban contexts, same day or next day delivery is no longer exceptional but is rather considered a baseline service standard (Pahwa & Jaller, 2022). This shift has compelled service providers to explore operational innovations such as dynamic routing and decentralized fulfillment centers (Boysen et al. 2020; Qiu et al., 2021).

At the core of this shift lies the increasing importance of delivery flexibility. Consumers opt for options that best cater to their schedules and lifestyles ranging from delivery to homes, lockers, retail stores or even the trunks of their vehicles (Kundu et al., 2025, Pourmohammadreza et al., 2025). The traditional one size fits all model of home deliveries has been rendered obsolete by the demand for these customized delivery solutions designed to align with personal preferences (Merkert et al. 2022). Research has shown that the availability of delivery options significantly influences consumer satisfaction and repeat purchasing tendencies, hence making it a competitive differentiator (Milioti et al., 2020).

The need for convenience has expanded beyond the speediness of delivery to include the mode and method of deliveries. Some customers prefer direct contactless home delivery for privacy and health concerns, while others value the autonomy in picking up parcels at designated locations on

their own schedule (Madleňák & Madleňáková, 2020). The divergence in preference underscores the necessity for delivery systems capable of supporting varied customer profiles and socio-demographic contexts. Simultaneously, consumer expectations have evolved in terms of delivery transparency and tracking. The ability to monitor package location in real time, receive status updates and ability to reschedule deliveries has become standard practice being enabled with digital interfaces and IoT (Uvet et al., 2023; Raj et al. 2024). Such transparency reduces anxiety of anticipation, increases engagement and further enhances the trust in the service provider. Hence, digitalization of the delivery process is an efficiency driver as well as a customer retention tool (Ratchford et al., 2022).

The demand to be sustainable has become prominent as a central expectation among consumers, especially in European markets. As the customer base becomes more environmentally conscious, delivery services face the amplified necessity to reduce carbon footprint, use electric vehicles and minimize packaging waste (Paddeu & Denby, 2021). Consumers often factor in a company's ecological footprint while making an online purchase, indicating sustainability being a part of the perceived value proposition of the delivery services (De Maio et al., 2024; Garus et al. 2024). Retailers such as IKEA have embedded environmental considerations within their delivery services, showcasing the integration of corporate social responsibility into logistics design (IKEA, 2025).

This shift in demand has prompted firms to invest in more modular, scalable and adaptable delivery infrastructures, the rise of platform-based logistics services with third-party logistics providers managing last mile operations is a manifestation of this evolution (Monios & Bergqvist, 2019; Yu & Puchinger, 2024). These platforms enable real time coordination across stakeholders, optimize asset utilization, and facilitate the integration of emerging technologies such as autonomous vehicles, drones and smart lockers (Boschetti & Novellani, 2023; De Maio et al., 2024; Katiyar et al. 2024).

## **2.2 Last Mile Delivery**

Last Mile Delivery (LMD) in concept has evolved significantly, both in terms of scope and complexity in response to the higher demands from the rise of e-commerce and shifting customer expectations (Mohammad et al., 2023). Once viewed as the terminal stage in the supply chain,

LMD was once focused exclusively on delivering goods from a distribution center to the end customer's doorstep. However, this limited view no longer suffices where customers demand convenience, speed, flexibility and environmentally conscious practices (Vakulenko et al., 2018; Boschetti & Novellani, 2023). Recent literature also suggests that LMD has become the most expensive part of the supply chain (Tadić & Veljović, 2020; Janinhoff et al. 2024).

Research underscores that LMD represents a strategic function determining customer satisfaction and operational competitiveness, not just a logistical challenge (Pahwa & Jaller, 2022). LMD has also transitioned from a unidirectional, courier controlled process into a more dynamic and participatory model. Customers no longer being passive recipients of goods actively influence delivery parameters, such as time windows, delivery locations and modes of delivery (Pourmohammadreza et al., 2025). This evolution prompts scholars and practitioners to reframe LMD into a service experience not only as a logistical activity, becoming a point of value co-creation between business and consumers (Merkert et al., 2022).

### **2.2.1 Importance of Last Mile Delivery**

LMD plays a crucial role in shaping the customer's experience and has come to increasingly be treated as a strategic differentiator in the competitive landscape of retail logistics (Pahwa & Jaller, 2022). While the upstream segments of the supply chain focuses on bulk movement and cost efficiency, the last mile is inherently fragmented, customer specific and operationally challenging (Lyons & McDonald, 2022; Boschetti & Novellani, 2023). Such fragmentation is more visible in urban environments with high population density, traffic congestion and parking limitations which all pose constant operational barriers (Ostermeier et al., 2023).

Furthermore, LMD in definition has undergone a transformation to become encompassing out of home deliveries (such as parcel lockers or pick up stations), crowd sourced deliveries and autonomous systems; all of which rely heavily on different infrastructural setups and business logic (Janinhoff et al., 2024). The pandemic has really amplified the transformation as contactless deliveries and customer directed handoffs locations have now become the newly accepted norm (Wadud et al., 2016).

Operationally, LMD cost can be prohibitive if not managed efficiently. Inefficiencies are commonly spawned through failed deliveries, long idle times and unoptimized routings, all of which increase operational expenses and reduce environmental performance (Archetti & Bertazzi, 2020). Moreover, LMD's importance is no longer confined to economic or operational metrics but also carries social and environmental weight, as stakeholders now assess LMD systems in terms of emissions, traffic impacts, and labor conditions, prompting a reevaluation of delivery methods that were once deemed efficient but are now viewed as unsustainable (Silva et al., 2022). In short, LMD has emerged as a focal point in the discussion of urban resilience, carbon neutrality and digital innovation (Ostermeier et al., 2023; De Maio et al., 2024).

### **2.2.2 Different Methods in Last Mile Delivery**

The last mile delivery methods reflect the sector's response to the varying demands of consumers and infrastructural contexts. While home delivery remains dominant, alternative solutions such as out of home delivery locations (OOHDLs), Parcel Lockers, mobile parcel lockers, click and collect services and autonomous delivery systems have gained traction (Vakulenko et al. 2018; Schepis et al., 2023; Kötschau et al. 2024).

To systematically analyze these options, a comparative framework can be established using IKEA's delivery offerings as a baseline. For instance, IKEA currently offers home delivery, in store collections, and third-party parcel locker delivery which collectively reflect various logistical strategies and infrastructure dependencies (IKEA, 2025). Each method presents unique advantages and limitations. Home delivery, while offering convenience, suffers from high operational costs and environmental impacts (Tadić & Veljović, 2020). In contrast, parcel lockers and click and collect models offer scalability and lower emissions but require customers to take an active role in the logistics chain (Kötschau et al., 2023; Kötschau et al., 2024).

Infrastructure is a critical determinant for the feasibility and efficiency of LMD types. High urban density areas can support lockers, whereas rural and suburban zones could lack the infrastructure for fixed drop off points or rely on mobile solutions (Corejova et al. 2022). Moreover, different regions in Europe vary greatly in their infrastructural readiness; while countries like Germany, Netherlands and Sweden have higher penetration of parcel lockers, other areas are still heavily dependent on traditional courier-based models (Corejova et al. 2022).

### **2.2.3 Alternative Delivery Methods**

With mounting complexities with labor intensive models, firms actively explore technology driven alternatives for last mile deliveries. Two of the innovative solutions in the sector that have emerged in the recent years are crowdsourcing and gig economy. Although these solutions were considered promising, these models often suffer from labor instability, regulatory uncertainty and ethical concerns, making them unsuitable for long term amid global driver shortages (Mittal et al., 2018).

The sector is pivoting towards autonomous and electrified delivery models, which include electric delivery vehicles, delivery robots, unmanned aerial vehicles (UAVs), and hybrid truck drone systems (Qiu et al., 2021; Boschetti & Novellani, 2023; Katiyar et al. 2024; Chen et al., 2025). Each alternative offers distinctive operational benefits. Electric vehicles (EVs) powered with renewable energy sources significantly reduce greenhouse gas emissions (Siragusa et al. 2020). Delivery robots can operate continuously and independently, alleviating labor shortages and enhancing scalability in urban areas (Alverhed et al. 2024). Drones are considered another promising solution particularly for small, urgent or high value deliveries (Garg et al. 2023) Despite limitations in payload and weather sensitivity, they offer unparalleled speed and accessibility in certain use cases such as medical supply delivery or rural access (Chen et al., 2025).

Nevertheless, these innovations are not without challenges. Legal frameworks, infrastructure readiness, and public trust remain significant barriers to widespread adoption (Channon et al., 2019; Lee & Hess, 2020; Sever & Contissa, 2024). Despite these hurdles, the ongoing evolution of LMD reflects an industry transition, one that is moving rapidly toward intelligent, adaptive and sustainable delivery solutions capable of meeting the multifaceted demands of the digital economy (Mohammad et al., 2023; De Maio et al., 2024).

## **2.3 Autonomous Vehicles**

The advent of autonomous (driverless) vehicles (AVs), has triggered a paradigm shift across various sectors ranging from personal mobility to logistics, public transportation and emergency services (Channon et al., 2019; Kouroutakis, 2019). In logistics, AVs hold the potential to redefine the efficiency and reliability of last mile deliveries by enabling continuous, human free operations,

reducing labor dependency, and improving environmental performance (Schlenger et al. 2020). These vehicles can encompass a broad range of technologies including autonomous delivery robots (ADRs), autonomous trucks, unmanned aerial vehicles (UAVs), and mobile locker carriers; all of which now at different stages of development and regulatory integration (Qiu et al., 2021; Katiyar et al. 2024; Chen et al., 2025).

AVs can be defined by their ability to perceive surrounding environments, make navigational assessments, and execute tasks with minimal to no human intervention (Schlenger et al. 2020). The development of these vehicles is reliant on convergence of technologies such as machine learning, computer vision, LIDAR, GPS systems and robust software integration capabilities for processing complex infrastructure layout in urban environments (Schepis et al., 2023; Al-Malki et al., 2024). The Society of Automotive Engineers (SAE) categorizes vehicle automation into six levels (0-5), with levels 4 and 5 representing high and full automation respectively, enabling vehicles with ability to drive in most or all environments (Sever & Contissa, 2024). While Level 1 vehicles only have driver assistance features, Level 5 vehicles are expected to operate completely without the presence of humans (SAE International, 2021). Currently, laws and regulations only allow Level 4 vehicles to be tested and deployed (Schepis et al. 2023).

Apart from private transportation, logistics has emerged as a rich ground for AV deployment for the repetitive nature of delivery tasks along with the growing urgency to address labor shortages and environmental concerns (Srinivas et al. 2022). From a systematic perspective, AV integration into last mile delivery possesses the potential to decouple logistics operations from the labor market fluctuations, reduce total cost per delivery, while supporting scalable and modular infrastructure models (Boschetti & Novellani, 2023; Ostermeier et al., 2023).

## **2.4 Autonomous Vehicles for Last Mile Delivery**

AVs are increasingly finding applications in LMD where their operational advantages are mostly evident. The logistics industry trend to adopt AVs is driven by multiple converging issues such as escalating labor shortages, consumer demand for rapid and contactless deliveries and the urgency to lower emissions (Srinivas et al. 2022) For this reason, AVs such as ground based delivery robots

and autonomous vans have emerged as prototypes for new logistical ecosystems in urban areas (Boysen et al., 2018; Chen et al., 2025).

Autonomous trucks, which can serve on certain highways for intercity transportation, have started to be used as pilots for companies to transport B2B or in-house cargo (Fritschy & Spinler, 2019). Such delivery systems are among the most documented and tested configurations in the LMD field. Another concept emerged where companies utilize conventional delivery trucks as “motherships” from which autonomous ground robots are deployed to fulfill deliveries to customers (Ostermeier et al., 2023). Boysen et al. (2018) demonstrated that such hybrid configurations are able to significantly reduce congestion in city centers as they are designed to optimize drop off points and utilize robots for high-density short-range deliveries.

UAV or drone delivery systems also represent another autonomous alternative, while they still remain in an earlier phase of integration due to air traffic regulation, limited payload capacity and safety concerns (Katiyar et al. 2024). Drones are frequently used especially for food delivery or for groceries. They have also demonstrated significant potential in rural hard to reach areas with notable pilot projects highlighting the effectiveness of hybrid truck drone systems in lead time in time sensitive deliveries such as perishables (Schwerdfeger & Boysen, 2022).

We identified three key requirements for integrating autonomous vehicles into delivery systems: the presence of the necessary laws and regulations; adequate infrastructure and customer acceptance.

#### **2.4.1 Laws and Regulations**

Expansion of AVs into public and commercial spaces has provoked significant regulatory attention in both national and international scale. However, substantial fragmentation remains in AV policy frameworks, particularly in the context of use in last mile logistics (Pattinson & Chen, 2019). Regulatory policies vary drastically across regions, often lagging with technological advancements creating uncertainty to stakeholders seeking to adopt or invest in AV systems (Lee & Hess, 2020; Tran & Le, 2022; Chen et al., 2025). One of the most important points identified in the literature is the lack of specific regulations for autonomous vehicles in many countries. Many countries issue decisions on autonomous vehicles by amending existing traffic regulations or vehicle laws (Tran

& Le, 2022) In several countries, autonomous vehicles do not possess a legal personality, making it a challenge for AV manufacturers to obtain permits for autonomous vehicle testing (Punev, 2020). The issue of legal personality also causes institutions and organizations to hesitate to recognize autonomous vehicles (Punev, 2020).

Specifically in Europe, AV regulation has been approached with caution, with countries such as Germany and Sweden developing pilot programs to test frameworks only within strict supervision (Hansson, 2020). Germany's 2017 legislation permits level 4 autonomous driving under defined environmental conditions but requires a fallback human operator and data recording (Hansson, 2020; Sever & Contissa, 2024). On the other hand, The United Kingdom's Automated and Electric Vehicles Act of 2018 lays the groundwork for insuring autonomous vehicles and clarifying liability, though implementation gaps still persist (De Maio et al., 2024).

Cross border harmonization in the EU is an ongoing challenge. Existing efforts to standardize testing protocols, data sharing mechanisms and seamless integration are hindered by disparities in infrastructure readiness and legal definition of autonomy (Pattinson & Chen, 2019; Lee & Hess, 2020). For instance, real world testing is permitted in some jurisdictions while being banned in others, making it difficult to establish consistent innovative environments across member countries (Pattinson & Chen, 2019; Uvet et al., 2023; Channon et al., 2019).

Beyond Europe, regulatory trajectories also diverge, as for ASEAN countries AV legislation is still in its infancy, lacking coherent safety protocols or technical standards (Tran & Le, 2022). A comparative analysis suggests these regions could stand to benefit from the European regulatory approach (Tran & Le, 2022). Additionally, regulatory emphasis is placed increasingly to include more than vehicle operation but data privacy, insurance, liability, and AI accountability as well (Channon et al., 2019; Chen et al., 2025).

Globally, experts urge for the development of a multi stakeholder, modular regulatory framework with the ability to adapt to rapid technological advancement and varying legal environments (Channon et al., 2019; Kouroutakis, 2020,). However, until such frameworks become widely adopted, regulatory asymmetry will continue to be a barrier to the commercial scalability of AV technologies (Lee & Hess, 2020; Sever & Contissa, 2024; Chen et al., 2025).

### **2.4.2 Urban Infrastructure**

The deployment of AVs in last mile logistics remains deeply contingent on the readiness of adaptability to urban infrastructure (Corejova et al., 2022; Ostermeier et al., 2023; Al-Malki et al., 2024). Infrastructure in this context not only includes physical roads, but also charging stations, data connectivity, smart traffic systems, and human centric interaction zones (Monios & Bergqvist, 2019; Al-Malki et al., 2024). To support the interdependent nature of AVs and the urban ecosystem means that cities must undergo significant changes to support emerging delivery modalities (Tran & Le, 2022). Such pilot projects underscores the importance of co-design between urban planners and technology developers to avoid infrastructural mismatches (Monios & Bergqvist, 2019; Corejova et al., 2022; Tran & Le, 2022; De Maio et al., 2024).

Electric AVs add another layer of complexity, requiring widespread deployment of charging infrastructure preferably powered by renewable energy (Paddeu & Denby, 2021). Public private partnerships are crucial here, as this would allow for resource sharing, standardized protocols, and coordination in implementation timelines (Al-Malki et al., 2024).

### **2.4.3 Customer Acceptance**

Despite technological feasibility, the ultimate success of AVs in LMD is heavily reliant on customer acceptance and behavioral adaptation (Milioti et al., 2020; Merkert et al., 2022; Lu et al. 2023). Consumer trust in autonomous systems is still evolving and is influenced by factors such as perceived reliability, safety, privacy and user interface quality (Merkert et al., 2022; Lu et al. 2023)

Studies show acceptance varies significantly across demographic groups. Younger, tech savvy consumers are likely to embrace AV delivery, especially if accompanied by real time tracking, contactless interactions and customizable delivery options. While older individuals or ones with limited digital access express skepticism about safety, data use and lack of human interaction (Milioti et al., 2020; Lu et al. 2023; Kundu et al. 2025). Syncretic value in urban deliveries emphasizes that interaction with delivery personnel is part of service value for some customers, while others prioritize anonymity and efficiency. This duality poses a challenge for logistics

providers having to design AV services to be flexible enough to accommodate both user archetypes (Merkert et al., 2022; Lu et al. 2023).

## **2.5 AV Concepts in Development**

A number of autonomous delivery vehicle concepts are currently under development or have been deployed in a limited scale in practice. One example is mobile parcel lockers, where the parcel locker concept is combined with autonomous vehicles. Mobile parcel lockers and hybrid truck locker systems have shown promising results from cost perspective. Recent studies have indicated that mobile lockers can be effective in reducing failed delivery attempts and operational costs, when integrated with modern day demand forecasting and routing algorithms (Kötschau et al., 2023; Kötschau et al., 2024).

The use of the platooning system used in intercity truck deliveries for the last mile is another concept that has attracted the field's attention. Platooning is a system in which a non-autonomous truck is followed by multiple autonomous trucks to form a convoy (Martínez-Díaz et al. 2021; Hou et al. 2023) Although it does not provide a fully autonomous setup, this concept enables more sustainable and cost-efficient solutions as the load carried increases according to the number of trucks in the convoy (Hou et al. 2023). A new study focuses on adapting the platooning concept to last mile deliveries. In this model, electric autonomous delivery vehicles work in platoons to efficiently travel from distribution centers located outside the city to specific drop-off points on the outskirts of the city (Lupi et al. 2025). The vehicles leave the platoon upon arrival and proceed independently to complete their last-mile route. The aim is to combine the energy-saving and traffic flow advantages of platooning with the adaptability required for urban delivery (Lupi et al. 2025).

### 3. Theoretical Framework

*This section informs the reader about the main theoretical basis of the thesis, which is the Diffusion of Innovations (DOI) Theory. Main attributes presented in the theory and how they are applied in the case of AVs are discussed. Main critiques of the theory are brought up to provide a more reflexive view. Alternative theories used in AV research are also presented. Based on the discussion, there is a need for innovative solutions in the last mile delivery field and autonomous vehicles emerge as promising innovations in the arena. Hence, this dissertation evaluates the technologies from the perspective of the Diffusion of Innovations Theory.*

#### 3.1 Diffusion of Innovations (DOI) Theory

This study uses the Diffusion of Innovations (DOI) Theory as the theoretical basis. The theory was developed by Everett Rogers in 1962 and has been used to evaluate the spread of innovation across many different fields such as health, education, agriculture, communication and technology (Greenhalgh et al. 2004). The underlying premise of the theory is that innovation cannot be adopted by everyone at once, but will spread in predictable patterns across different adopters and social systems (Rogers, 2003). Rogers (2003) defines the 5 key elements of the theory through explaining that “diffusion is a process where (1) *innovation* is (2) *communicated* using (3) *communication channels* (4) *over time* (5) among *social systems*. (p. 41). Factors such as the characteristics of the innovation, the nature of the social system and how well the information has been communicated affect the adoption rate and speed of an innovation (Rogers, 2003). One of the key barriers to adopting innovation is uncertainty, and technological advancements reduce uncertainty through establishing cause-effect relationships to enhance problem-solving (Rogers, 2003). Hence, addressing the possible results of an innovation leads to a faster adoption process. DOI defines 5 perceived attributes of innovations to help explain the difference in rates of adoption: Relative advantage, compatibility, complexity, trialability, and observability (Rogers, 2003). Each of the characteristics represents different aspects in shedding light on the variation in the pace of adoption. A description of each attribute is presented below.

**Relative Advantage:** The degree to which an innovation is perceived as better than the idea it replaces (Rogers, 2003). The comparison might be in economic or social terms. The innovation does not necessarily have to be “objectively better” than its predecessor, but it should be perceived

as such by the social system. This attribute assumes that the greater the perceived value, the faster the adoption process will be (Greenhalgh et al. 2004).

**Compatibility:** The degree to which an innovation is perceived as compatible with pre-existing values, previous practices and the needs of potential adopters (Rogers, 2003). This aspect explains that ideas or innovations that are compatible with existing systems have the potential to spread faster (Greenhalgh et al. 2004).

**Complexity:** The degree to which an innovation is perceived to be difficult to comprehend or use (Rogers, 2003). Innovations that are well-understood by social systems have a higher rate of adoption whereas complex ideas spread at a slower rate.

**Trialability:** The degree to which an innovation can be tested or experimented with (Rogers, 2003). If new ideas are triable using an installment plan, they will generally be adopted quickly.

**Observability:** The degree to which an innovation's results are obvious to others (Rogers, 2003). If the results of an innovation are visible to a social system, the innovation will spread faster.

Since innovations are not adopted by all individuals or organizations at the same time, diffusion theorists divide adopters into different groups according to the timing and characteristics of their adoption behavior (Rogers, 2003; Greenhalgh et al. 2004). The first group are the *innovators*, who develop and produce the idea or technology. Once the innovation starts spreading, *early adopters* who are referred to as “change agents” begin experimenting with the concept. The innovation then spreads to the *early majority* who adopt the technology right before it gains mainstream adoption. The *late majority* join the adoption process right after an average member of the system. Finally, *laggards* become the last in a social system to adopt the innovation and join after a lengthy and slow process (Rogers, 2003).

### **3.1.1. Autonomous Delivery Vehicles as an Innovation**

Autonomous vehicles are considered a relatively new technology to be offered as a solution in supply chain management. The real-life application of AVs within last-mile delivery is scarce, and the number of conceptual studies on the topic is growing fairly recently. DOI Theory explains that the perceived newness of a new idea or technology determines the reactions to it and that if an idea

or a technology is perceived to be new, it is an innovation (Rogers, 2003). Thus, although AVs are a concept that has been actively discussed for more than a decade, they are perceived as relatively new by social systems in the field of last-mile delivery and can be considered as an innovation. Therefore, Rogers' definition can be applied to the topic as follows: AVs (the innovation) are communicated through various channels (e.g. pilot testing, R&D efforts, searching for AV suppliers) with the goal of being adopted for last-mile deliveries over time to a social system (companies, customers, logistics service providers etc.).

DOI Theory emerges as a good fit for this dissertation as it seeks to explain how, why, and at what rate autonomous vehicles are spreading in the field of last-mile deliveries and what conditions are required to ensure a successful adoption. Instead of taking a technical stance and evaluating the technological features of the vehicles, the DOI theory guides the research to take an organizational approach and determine what kind of benefits organizations expect to derive from AVs. The 5 perceived attributes of an innovation help provide a framework to answer the research question, “*What kind of specific attributes and capabilities should autonomous delivery vehicles possess to effectively address these challenges?*”. This study uses the following framework adopted from Rogers’ 5 attributes to identify themes in the interviews and document analysis.

| <b>DOI Attribute</b>      | <b>Guiding Questions</b>   |
|---------------------------|--|
| <b>Relative Advantage</b> | Do autonomous vehicles used in last-mile delivery offer advantages over traditional methods (e.g., diesel-powered trucks)? (considering factors such as cost-efficiency, operational range, delivery speed, and reduced dependency on human labor) |
| <b>Compatibility</b>      | Are AVs compatible with existing regulations, daily logistics operations, infrastructure, and stakeholder expectations within the current supply chain environment?  |
| <b>Complexity</b>         | How complex are AVs perceived to be by industry professionals? How easy or difficult is it to integrate them into existing delivery processes and systems?   |
| <b>Trialability</b>       | To what extent can AVs be tested before full-scale implementation? Are there opportunities to pilot different levels of autonomy in real-world delivery contexts?  |
| <b>Observability</b>      | Will the benefits of adopting AVs, such as increased efficiency, sustainability, or customer satisfaction, be easily visible and measurable to company stakeholders and customers?   |

**Table 1:** DOI attributes for AVs, (adopted from Rogers (2003)).

### 3.2 Critiques of the DOI Theory

Although identified as a suitable theory for this study, the DOI theory has limitations that have been identified by certain researchers. The first criticism is that the theory suggests that innovations diffuse too linearly. Because of this assumption, it is emphasized that feedback loops in the diffusion process are almost completely absent (Lyytinen & Damsgaard, 2001). In addition, researchers criticize that the theory is too people-oriented, stating that organizations are more driven by external pressures to accept innovations than individualistic factors (Lyytinen & Damsgaard, 2001; Wejnert, 2002). The last criticism is that the theory ignores certain social, economic and regulatory factors in the diffusion process (Lyytinen & Damsgaard, 2001; Wejnert, 2002). Keeping these limitations in mind is important for interpreting the results of the research. However, it is important to note that this research does also consider external pressures and uses

the triangulation method to combine thoughts of professionals with “state of the field” reports to obtain a broader view.

### **3.3. Other Theories Used in AV Research**

Articles on autonomous vehicles in the supply chain have drawn on many theories other than DOI. Since the subject of autonomous vehicles is a topic that can be addressed from many aspects such as acceptance, sustainability, technological features and regulations from a business perspective; it is possible to view the literature from different perspectives. Nevertheless, in the field, some theories are utilized more than others and stand out. The most prominent and frequently used theory in AV research is the Technology Acceptance Model (TAM). Developed by Fred Davis, TAM is one of the most popular theories in information technologies and aims to shed light on the motivations of individuals in accepting new technologies (Koul & Eydgahi, 2018). The model suggests the acceptance of a technological development is decided by two main factors: Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) (Davis, 1989) PU is the belief that using the technology will enhance a person’s way of completing a task; whereas PEOU is the degree to which a person believes the technology will be easy to use. Because TAM includes only two main dimensions, it is often applied in combination with other theories to provide a more comprehensive understanding of technology adoption. DOI and TAM are frequently combined in autonomous vehicle (AV) research, as they complement each other in addressing distinct theoretical and empirical gaps. For example, Yuen et al. explored the factors influencing customers’ adoption of Automation Level 5 AVs (2020). They have employed DOI attributes as antecedent factors shaping the two primary dimensions of TAM (Yuen et al. 2020). Similarly, Ganjipour & Edrisi used DOI and TAM along with Norm Activation Model (NAM) to explore customers’ intention to adopt sidewalk autonomous delivery robots (SADR) (2023). They have also employed DOI attributes as antecedents to the attributes of other theories. In our research, we investigated TAM as a potential framework. Given that the DOI theory offers a comprehensive framework for understanding the adoption process, we chose to employ it independently rather than using its attributes merely as antecedents within TAM. We considered DOI sufficient on its own to address the objectives of this study without the need for integration with TAM. Moreover, since this study takes a business perspective rather than seeking to evaluate the opinions of customers, the TAM framework was ultimately decided against.

## **4. Methodology**

*This section outlines the research design, data collection methods, and approaches utilized to address the research questions. It presents the rationale behind the chosen methodology and how it aligns with the objectives of the study. By detailing the process, this section ensures the transparency, reliability, and validity of the research and provides a basis for the interpretation of results.*

### **4.1. Research Design**

The main objective for conducting qualitative research is to gather insights on topics through engaging with places and social actors (Clark et al., 2021). As this dissertation aims to explore how autonomous vehicles can support last mile deliveries, it adopts a qualitative research design. The research does not aim to come up with definitive answers to the research questions, rather seeking to explore how last-mile delivery professionals in the field perceive the challenges in the field and how autonomous deliveries could potentially contribute to solving the issues. Hence, as the authors, we take an interpretivist stance, taking into account that perceptions among professionals will vary (Clark et al. 2021) Similarly, since the topic of autonomous delivery is rapidly evolving, and expanding in scope to include more actors and multiple perceptions, we believe a constructivist ontological approach, which explains that social phenomena and their meanings are created continuously by social actors is a good fit for the dissertation (Clark et al. 2021).

This study follows an inductive approach as it aims to find emerging themes in interviews to come to conclusions about how AVs can enhance delivery processes. Inductive reasoning seeks to find patterns to explain a new phenomenon rather than trying to test existing phenomena through the lens of a theory (Clark et al. 2021). This study uses the DOI theory to frame interview questions and make sense of the findings, not to test or confirm the theory itself. The five attributes for the adoption of an innovation mentioned in the DOI theory are used to evaluate the results of the study.

This study benefits from qualitative research methods as it explores the perceptions and opinions of last-mile delivery professionals to explore the potential use of autonomous vehicles. Semi-structured interviews and document analysis were the two methods used to have a deeper understanding of the topic. Semi-structured interviews were conducted with the aim of identifying

the pain points professionals encounter with last mile deliveries (*RQ1*) along with a document analysis to understand what kind of capabilities AVs should have in order to address these pain points (*RQ2*).

## **4.2. Research Methods**

### **4.2.1 Semi-Structured Interviews**

In this study, semi-structured interviews were conducted to gain a deeper understanding from the perspective of last-mile delivery professionals within IKEA. Semi-structured interviews are guided by a pre-determined set of questions but allow the interviewer to be flexible and ask questions beyond the interview guide. (Clark et al. 2021). Qualitative studies that aim to explore the ideas and opinions of the interviewees usually opt for the semi-structured approach (Clark et al. 2021). Since the aim of this dissertation was to identify the pain points professionals encounter in last-mile delivery and prompt interviewees to think about the topic of autonomous vehicles on a deeper level, this approach was chosen. An interview guide that is in line with the framework of the Diffusion of Innovations Theory was created before the interviewing process. 23 open-ended questions with themes such as deliveries, customers, automation, and autonomous vehicles were prepared. Some of the questions were related to challenges in current last-mile delivery processes (e.g. failed deliveries, high costs, inefficiencies), while others were aimed at gauging professionals' future expectations and aspirations for potential autonomous last-mile delivery processes. Probing questions were also asked occasionally to add depth to the topic and to clarify what the professionals thought. We ensured both of the interviewers were present during the interviews so that one could take notes and probe while the other was asking a pre-determined set of questions.

10 semi-structured interviews were conducted with 10 IKEA professionals from different countries between the dates 1st of April - 25th of April. The interviewees were identified with the help of a contact person within IKEA. The duration of the interviews ranged from 40 minutes to 83 minutes, depending on the talking pace of the interviewees and the number of probing questions asked during the interviews. The interviews were conducted through the Zoom platform as the participants were located in different countries. Although the titles of the participants varied within IKEA, we focused on selecting fulfillment managers who work closely with customers and oversee

the entire process in the last mile; and project managers whose task is to enhance and optimize processes. Below is a table that shows the details of the interviews.

| Participant Number | Experience (in years) | Country of Employment    | Job Title   | Interview Date | Interview Platform | Interview Duration |
|--------------------|-----------------------|--------------------------|---|----------------|--------------------|--------------------|
| Participant 1      | 34                    | The Netherlands          | Project Implementation Manager Zero Emission Delivery   | 01/04/2025     | Zoom               | 45:25:00           |
| Participant 2      | 25                    | United States of America | Multi Channel Network Project Manager                   | 01/04/2025     | Zoom               | 44:21:00           |
| Participant 3      | 15                    | China                    | Fulfillment Project Implementation Manager              | 02/04/2025     | Zoom               | 50:45:00           |
| Participant 4      | 14                    | Germany                  | Fulfillment Sourcing Manager                            | 09/04/2025     | Zoom               | 52:31:00           |
| Participant 5      | 6                     | United States of America | Project Implementation Manager Zero Emission Delivery   | 09/04/2025     | Zoom               | 01:23:14           |
| Participant 6      | 10                    | Germany                  | Service Fulfillment Manager                             | 11/04/2025     | Zoom               | 45:45:00           |
| Participant 7      | 18                    | Sweden                   | Service Fulfillment Manager                             | 16/04/2025     | Zoom               | 59:09:00           |
| Participant 8      | 28                    | Belgium                  | Fulfillment Development & Multi Channel Network Manager | 16/04/2025     | Zoom               | 48:51:00           |
| Participant 9      | 10                    | France                   | Project Implementation Manager Zero Emission Delivery   | 23/04/2025     | Zoom               | 01:02:15           |
| Participant 10     | 17                    | Finland                  | Fulfillment Project Implementation Manager              | 25/04/2025     | Zoom               | 40:35:00           |

**Table 2:** Interview participants details

#### 4.2.1.1 Sampling

- a. **Purposive Sampling:** Purposive sampling was used as the main sampling method while identifying potential interviewees. This type of sampling involves choosing people who would fit the requirements of the study the best according to previously defined characteristics (Clark et al. 2021). For this study, IKEA professionals who work as logistics and transport managers, customer fulfillment specialists and route planners were the designated sample to be reached out to. Initially, we identified 8 countries to reach out to as those countries were considered early adopters of the technology based on our previous research. The countries were: China, the Netherlands, Germany, France, Sweden, Singapore, Spain, and the United States of America. The key requirements for potential interviewees were; having 5+ years of experience, working closely with last mile deliveries and working in the 8 previously chosen countries. Having prior knowledge of autonomous vehicles was not a must but was considered a plus as we recognized finding experts could prove challenging due to the novelty of the topic. People with similar titles and job

descriptions were identified through a contact person working at IKEA. A survey that included questions on their expertise, field of work, and their prior knowledge on autonomous vehicles were sent out to potential interviewees through email. Once they filled out the form, we reached out to them individually to propose an interview date and time. 7 people were chosen and interviewed through the purposive sampling method.

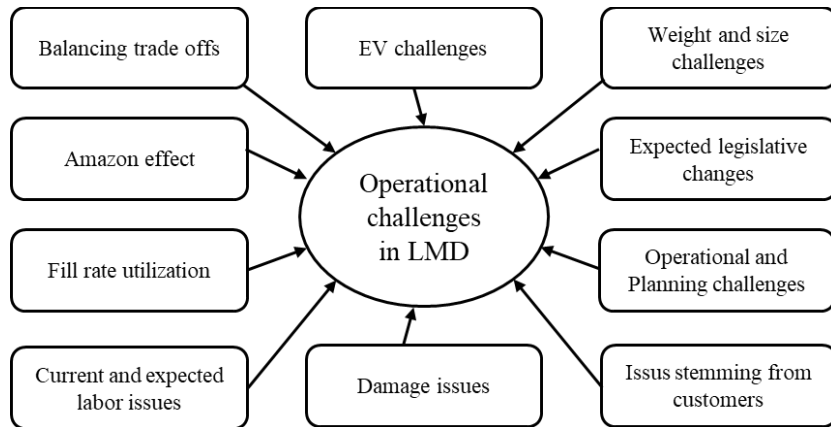
- b. **Snowball Sampling:** Due to the time constraint of the thesis and the interviewees' busy work schedules, finding a time frame to interview with us proved to be difficult for some professionals. Hence, we had to use the snowball sampling method to find more people to interview. Snowballing is a sampling method where the interviewers ask participants to recommend other participants whom they think could be a good fit for the study (Clark et al. 2021). After conducting 7 interviews, we began sending more emails to people from different countries, and the people we have previously interviewed to ask if they could connect us to professionals who might fit the requirements of the study. We contacted and interviewed 3 more participants through the snowballing method.

#### **4.2.3 Thematic Analysis and Coding**

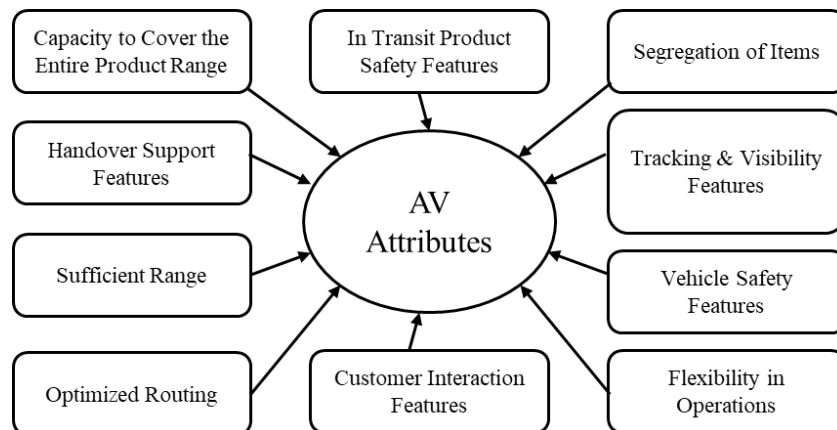
The interviews were coded using the Thematic Analysis (TA) method, developed by Braun and Clarke (2006). TA is a qualitative data analysis method that aims to identify, analyze and report patterns, so called "themes" in the data (Braun & Clarke, 2006). It was chosen as the appropriate method to evaluate interviews in this study due to its flexibility and ability to fit into any theoretical framework without being bound to theory itself, unlike other methods such as discourse analysis or grounded theory (Braun & Clarke, 2006).

TA follows a six-step approach to identify themes within transcriptions. In the first step, the researchers familiarize themselves with the interviews to see if there are points that could potentially be relevant (Braun & Clarke, 2006). In accordance with this approach, we began identifying initial patterns during the interviews and while reading the transcripts to highlight the most frequent comments. In the second step, we decided on initial themes such as the challenges of home delivery, the intensity of competition in the market, and trade-off decisions professionals have to make. The third step recommends searching for more themes in the text while keeping an open mindset (Braun & Clarke, 2006). We ended up with 453 codes after coding all 10 interviews.

This set of codes included insights on both the pain points in deliveries (*RQ1*) and AV capabilities (*RQ2*). In the next step, we reviewed the codes and categorized them to 63 frequently appearing pain points for *RQ1* and 44 expected AV capabilities for *RQ2*. After labeling the categories that are in the same direction, we ended up with 20 themes, 10 for each research question. Microsoft Excel was used for the entirety of coding and thematic analysis. Below are depictions that show the themes.



**Figure 1:** Pain points in LMD



**Figure 2:** Desired AV attributes

### 4.3 Methodological Triangulation

This study benefits from methodological triangulation, a method developed by Denzin in 1978, where different research methods are used to understand and explain a phenomenon (Flick, 2014). It is used with the aim of enriching the findings and moving beyond the epistemological potential of a single method (Flick, 2014). Semi-structured interviews and document analysis were the

chosen methods for this approach. Although interviews provide direct insights from people who manage deliveries firsthand, we believe that a document analysis could be beneficial in showing what the future of the supply chain and AV fields will look like. Hence, the results obtained from the interviews were triangulated with a document analysis to answer the research questions and put the study on a more solid foundation (Flick, 2014).

#### **4.3.1 Document Analysis**

A document analysis was conducted to support and contextualize the findings emerging from the interviews. 53 documents, which include reports from global consultancy firms such as KPMG, McKinsey & Company and EY; regulatory directives and policy papers from governmental bodies, indexes and state of the field reports from international organizations; and briefings on the future of the AV field published by AV manufacturers were identified. To ensure relevance to current industry practices and developments in the field, only documents published from 2015 onwards were included in the analysis. Documents were downloaded from the official web pages of companies and organizations, by searching keywords such as “autonomous delivery”, “autonomous vehicles” and “last-mile delivery”. Documents were then evaluated on criteria such as their relevance to the last mile delivery field, the quality of the findings, and their potential in contributing to answering the research questions. We ensured trustworthiness and reliability by using documents published by credible sources and prioritized documents published in the last five years during our evaluation. Many of the documents used are United States and China based because government backed AV efforts in those countries are more advanced compared to other regions. After the evaluation, 27 documents were ultimately chosen for the analysis. The documents were reviewed for each of the individual codes identified through the thematic analysis of the interviews, and relevant excerpts that match the codes were identified. Excerpts from the documents were used to support or contrast the findings in the “Desired Autonomous Vehicle Features” section of the analysis. The documents were evaluated using the same thematic framework as the interviews and used to deepen the scope of the analysis. A separate section in the analysis discusses the common findings of the documents. The insights were aimed at supporting the findings of the interviews and to validate the understanding of the research questions. The details of the documents used in the analysis can be found in the appendix.

#### **4.4 Ethical Considerations**

Ethical guidelines were followed diligently throughout the study. The interview guide was prepared carefully so that it would not include any sensitive or overly personal questions. Interviewers gave a short brief to participants before each interview about the ethical requirements of the department and obtained verbal consent. Each participant was informed of the purpose of the research and their rights including the options of skipping questions or withdrawing at any point void of consequences. They were also informed on how, where and how long the information will be stored. Anonymity was ensured to participants by assigning numerical identifiers (e.g., Participant 1, Participant 2). Interviewers kept a polite and friendly tone and respected the opinions of the participants.

Written consent was also obtained from the participants using the template provided by the university. Information disclosed in the interviews was treated as strictly confidential. Interview recordings were stored locally on the interviewers' portable devices without internet connectivity and were not uploaded to any cloud storage at any time, to ensure data privacy. The transcriptions of the interviews were completed by the interviewers themselves and were not shared with anyone else. The utmost endeavor was made to ensure all procedures aligned with the departmental ethical standards of Lund University.

Online meeting platform Zoom was used to conduct interviews as Lund University provides full access to all features to students. Zoom provides the option of holding meetings that are end-to-end encrypted and only accessible through private links (Zoom, 2025). The platform enables the meetings to be recorded in cloud or locally and does not share the information with third parties (Zoom, 2025). For these reasons, the GDPR policy of Zoom was deemed sufficient for this dissertation. All participants were made aware that they were being recorded and that the platform is compliant with privacy policies.

#### **4.5 Limitations**

This study acknowledges several limitations to be considered. Firstly, the research is constrained with the limited number of interviews, reducing the generalizability from the full extent as well as

the depth of the insights obtained. Due to the complexity and novelty of AVs, participants' limited knowledge acted as an additional constraint. Firsthand experience with AV technology would have further enhanced the richness of the empirical data. The fact that the study was conducted with only participants from IKEA limited the diversity of perspectives in the data as well. This narrow focus may potentially limit the findings beyond the context of the organization and in turn restrict its external validity. The timeframe allocated for the research constituted a significant ceiling, as it prevented a more comprehensive evaluation of views and experiences. Difficulty in accessing respondents further compounded the limitations, leading to potential bias in the participant pool and data representativeness. Lastly, the technical assessment within the thesis is inherently general and may lack detailed focus due to the lack of technical expertise of the researchers. In regard to these constraints, the findings should be considered indicative rather than conclusive. Hence, future research could be designed to address and conclude more definitively.

## 5. Analysis

*This section presents the findings of the study and aims to answer the two research questions: “What are the main operational challenges in last mile delivery of heavy and bulky items, according to the perceptions of last mile delivery professionals?” and “What kind of specific attributes and capabilities should autonomous delivery vehicles possess to effectively address these challenges?” by triangulating the emerging themes from the interviews with the findings from the document analysis.*

### 5.1 Pain Points in Last Mile Delivery

#### 5.1.1 Balancing Trade Offs

The pain points discussed by participants during the interviews overlap with the existing literature on last mile delivery challenges. Balancing trade-offs regarding delivery decisions seem to be the most prominent issue that professionals deal with on a daily basis. 6 key trade offs emerge in the interviews, which collectively depict the systematic tensions at play for optimizing the last mile logistics.

Trade-off decisions regarding capacity and demand come up repeatedly to be highlighted as a core operational challenge. Participant 7 terms capacity as *“a perishable commodity”* and stated that delivery demand peaks in specific times while unused capacity during other times is wasted. This remark highlights the difficulty of achieving granular real time forecasting to ensure resources are matched precisely with demand. This situation is further impacted by local fluctuations and time-sensitive expectations. This is tied closely to the issues of balancing capacity and volume forecasts. Participant 10 addresses the spatial mismatches they face with parcel lockers by stating:

*“The locker size is quite limited, /.../ capacity is not matching the volume.”*

He goes on to elaborate that even where infrastructure exists, misalignment between the volume of parcels and the physical capacity to hold them causes bottlenecks. The codes together bring forward a logistical fragility; without accurate forecasting and adaptable infrastructure, underuse or overload is inevitable.

Another point to be considered is the cost versus customer needs trade-off, which is articulated by Participant 7 as he states,

*“If we are not able to get enough revenue from the customer, for the cost that we have to bear it slowly starts to become unsustainable”.*

He also emphasized the challenges in balancing profitability with competitiveness and expectations. However, he proceeded to state curbside delivery as a solution that *“gives the best value for money to the customer and is also sustainable for us”*. Such reflections are indicative that alternative service models hold the potential to mediate this tension if designed mindfully.

Another challenge that is brought up by many participants takes center stage while explaining the complexity of cost versus sustainability decisions. Participant 9 stated:

*“We have to find the balance to find a way to achieve our ambition to deliver with zero emission, but also to keep our cost at the same, not to expand to increase our cost too much.”*

Participant 5 echoed this and framed it in a broader value judgement:

*“What are we willing to pay to get there?”*

These reflections suggest while sustainability is a shared ambition, the affordability of it remains uncertain in the field of last mile deliveries.

Technological investments introduce another trade off when it comes to cost, payload, and range related decisions. Participant 5 observed when selecting delivery vehicles,

*“If you have a larger, cheaper battery, price goes down, but then payload goes down too.”*

The price versus speed trade off depicts the customer side of these tensions. Participant 10 explained,

*“We are trying to, of course, to understand what the customers need, whether they need the fast deliveries or the price.”*

His statement reflects a customer segmentation approach, recognizing not all customer value speed nor are all willing to pay a premium for it.

The relevant literature and tradeoffs mentioned by participants show that operational decisions often become multivariable problems with cost savings for one sphere but may undermine functionality in another (Madleňák & Madleňáková, 2020; Gruber et al. 2023). Due to this, professionals often have to focus on a single aspect they would like to improve and plan

accordingly. Thus, we recognize that any innovation that would replace traditional methods in last mile delivery would result in similar trade off decisions to be considered.

### **5.1.2 The Amazon Effect**

As a result of competition in the market, customers' expectations for free, fast and flexible delivery puts pressure on last mile delivery professionals. The influence of the US retailer Amazon on customer expectations emerges as a dominant theme across the interviews, which shapes both how customers perceive delivery services as well as how retailers must adapt to shifting market norms. Participant 2 highlighted that modern customers readily desire the convenience associated with Amazon, stating,

*“They want the convenience of online shopping. They want the convenience of Amazon. They want things to show up at their door.”*

This statement is further echoed by Participant 6 as he observed customers consider the price of delivery to be “*included*” by default, despite having paid for services like Amazon Prime. Amazon prime is a monthly premium paid to access added benefits of use of services including deliveries (Amazon, 2025). Participant 4 further clarified that customers perceive delivery as essentially “*free*”, reinforcing his idea by stating that “*convenience is king*” as the upfront subscription fee is psychologically decoupled from individual deliveries. There is an expectation among customers for free deliveries regardless of the item’s size or attributes or the delivery type. Participant 5 points out the dominant preference for no cost deliveries,

*“They want delivery for nothing, (that) is what they want. And most customers will choose that option if it's available to them.”*

This creates a challenging pricing environment for retailers, affecting companies unable to subsidize logistics at the same scale. Market competition is acknowledged by Participant 7 who stated,

*“...because there are many customers who experience free home deliveries and it is so hard (to compete).”*

Moreover, there seems to be a higher degree of expectation from urban customers compared to rural areas when it comes to deliveries, especially about delivery lead times. Participant 10 states,

*“In the big cities, the lead time is a factor. But in the more rural areas, they are willing to wait.”*

This highlights how customer expectations are shaped by stratified geographical factors as well. Urban populations with higher density prompt elevated immediacy, while rural populations are more tolerant of delays, hinting potential segmentation strategies. This is closely tied to the narrow delivery time expectation as it adds an additional complexity. Participant 9 highlights that catering to precise delivery windows is crucial by stating, *“we need to deliver on the exact time slot that the customer needs”*. Participant 3 adds that current four hours slots are perceived to be insufficient as,

*“Our customer wants, if maybe that can be very precise, (the items to be delivered in) maybe within one hour or within thirty minutes”*

Participant 6 also pointed out that “next day” and “same day” deliveries provided by Amazon puts a strain on competitors offering longer lead times. Participant 4 notes the toll on the delivery staff as they usually *“are rushing like crazy to get the things done.”* Such short lead time delivery expectations also compound the dissatisfaction linked to minor delivery delays from the customers side. Participant 5 remarked that,

*“Our customers are not satisfied because the delivery didn't come at a certain day”*

underlining the perception of delivery services must meet tight, often inflexible deadlines. Participant 6 reinforces this stating,

*“There is always the expectation of the lead time, shortest possible lead time.”*

These remarks show that narrowing acceptable time frames as a practice is both a customer expectation and an internal stressor. Findings in this theme overlap with the existing literature as narrower delivery slots as well as free and fast delivery expectations seem to be the growing trends in the last mile (Tadić & Veljović, 2020; Pourmohammadreza et al., 2025). Taking these into consideration, it can be said that new delivery methods should allow for more flexible schedules that can cater to increasing customer expectations.

### **5.1.3 Fill Rate Utilization**

Fill rate utilization in delivery vehicles is an important challenge that needs to be addressed by last mile delivery professionals on a daily basis (Mohammad et al., 2023). IKEA products are often

oddly shaped and have optimized packages. Such optimizations in product packaging for sustainability and stacking purposes sometimes result in fill rate underutilization when loading products into vehicles. This situation creates challenges to be tackled. When asked how they would create a model with better optimization for the fill rate, Participant 3 discussed how compartmentalization would lower the fill rate. In this ideal model each customer order is pre-packed into a cage-like structure and is handled through an automated process. While this would simplify handling, they acknowledged that,

*“But if we do so, we have to sacrifice our filling rate.”*

By stating this, they illustrate a core trade off between operational smoothness and spatial efficiency, as pre-packing for convenience reduces the ability to stack, ultimately resulting in wasted space in the vehicle.

The broader challenge of reaching a higher fill rate is discussed by Participant 8, as he states that optimization efforts are hindered by packaging and transport units by reducing usable space. This is however contrasted by Participant 4 who notes that,

*“We have standby trailers, which are filled within a day and a half. So we can optimize the filling rate.”*

By stating this, he is suggesting that when scheduling allows, fill rates can be improved.

Finally, inefficient stacking which makes processes inefficient further limits volume optimization. Participant 4 explained that when loading boxes, *“some are high and some are not high, so you never load the entire volume”*. This statement emphasizes the impact of irregular package dimensions that prevents full spatial utilization. He also noted that weight remains a limiting factor as the physical load bearing capacity of the vehicle sets a ceiling on item transportability even if volume is available.

All these points taken into consideration, we can reach the conclusion that due to irregular packaging and inefficient loading practices, optimizing the fill rate is a challenge that needs to be addressed. An innovative delivery vehicle should allow room for the oddly shaped furniture and be designed in a way that would make the loading and unloading processes easier.

#### 5.1.4 Current and Expected Labor Issues

Many respondents spoke about current problems they face regarding labor availability, and almost all of them were confident that this problem will continue in the future. Participant 7 identified this as a known challenge especially in Europe stating that *“in Europe driver shortage is an issue that is still being addressed”*. Many expressed concerns regarding long term trends. Participant 3 noted that younger generations are reluctant to perform physically demanding roles such as loading and unloading, indicating the shortage is likely to intensify as older generations retire. This is in line with the findings of previous studies as researchers saw labor shortage as a chronic issue (Mittal et al. 2018; Mohammad et al. 2023). Participant 5 echoed the systemic nature of the problem while asserting,

*“There's always been a driver shortage, and will continue to be”*.

Participant 2 added how the working conditions aggravate the issues drivers endure,

*“(They work) in very, very warm weather or very, very cold weather, depending on where they're located. It could be in the rain or the snow.”*

Weather challenges combined with the long hours and physical exertion make the job unattractive. He also highlighted the economic instability in the labor force while illustrating how fragile retention can be by stating,

*“People will switch jobs for 25 cents more per hour, and it's very difficult sometimes to keep people unless you're a very attractive employer.”*

Participant 7 conformed to the theme by commenting that,

*“(There is a big) population that may not consider themselves to be suitable or qualified to do the job even though they might be”* implying that such an outlook can further limit the labor pool. These views were reinforced by participants 4, 6 and 10; as they, with similar affirmation, underscored the widespread and consistent nature of the challenge.

High labor costs add a further level of strain, as Participant 8 described Belgium as a *“Labor expensive country”*. Participant 2 further pointed out how urban centers face higher wage demands, making staffing in cities costlier.

Labor shortage for other processes also exists according to participants and this expands the scope further beyond driver shortages, suggesting systemic bottlenecks throughout the process. Participant 8 highlighted that this shortage is now prompting the companies to invest in automation. Participant 4 added that the growing difficulty of “*finding hands to do the work*” positions automation as a necessity for continuity rather than a strategic choice. Recent literature reaffirms the participants’ view by stating LMD innovation is no longer a choice but a result of labor unavailability (Schuster et al. 2023).

Finding workers becomes a systematic challenge that pushes companies to outsource deliveries. This exacerbates the problem of low visibility in last mile deliveries as companies cannot know how delivery employees work. Participant 8 described that increased data visibility somewhat improved operational understanding but that visibility efforts were tied to lack of process control due to outsourcing. Participant 2 states the complexities of providing visibility by stating,

*“It’s very challenging because our model for contracting the drivers has been to contract with a company, and then the company would subcontract to individual drivers.”*

They also discussed how that leads to “*variation in their performance*”. Participant 9 added that although outsourced, “*the driver represents the IKEA brand*” to the customer; pointing out reputational risks tied to external labor. Such disconnect within brand identity and third party execution introduces added complications in maintaining service levels consistent with customer trust. Finally, participants brought up the loss of man hours due to waiting time during deliveries due to numerous handover points within the process.

To sum up, many participants recognize issues related to labor cause inefficiencies and challenges that need to be recognized. Automation, and perhaps the introduction of autonomous vehicles for last mile deliveries could prove beneficial in addressing labor issues and contribute to cost reduction on the company side.

### **5.1.5 Challenges with Electrical Vehicles**

Electrical vehicles are used commonly in last mile deliveries according to participants. Many consider them to be a more sustainable alternative to diesel vehicles. However, they also come with unique challenges. The first challenge regarding EVs is range. According to many participants, ensuring that EVs have the adequate range to cover the entirety of the deliveries is

challenging and many factors affect that. Participant 1 explained how the range of EVs is greatly affected by weather by stating,

*“In the winter, you can deduct 100 kilometers from that range anyway.”*

He is referring to how cold temperatures significantly reduce battery efficiency. He further noted how drivers are often forced to wait for the vehicle to *“recharge during the day”* sometimes in public stations due to lack of infrastructural amenities, further compounding the challenges. Lack of infrastructure limits route flexibility while also increasing operational downtime (Mittal et al. 2018). Participant 3 verified this limitation, suggesting that the problem is widely acknowledged by operators in varied contexts. However, the concern is not universal. As participant 9 implies, depending on the model, EV range can be sufficient. He presents a contrasting perspective, stating for their operation, *“the distance per trip is 200 kilometers”* and that is achievable *“with the quality of EV we have right now”*. Such contrast indicates the adequacy of EV range is highly context dependent. As for shorter urban delivery cycles, present day EVs may perform reliably; while longer routes with cold climate range remain a challenge yet to be overcome with significant progress in technological advancement.

Another point highlighted by participants is that EVs are expensive. Participant 10 highlights how the upfront price of EVs continues to limit scalability as they state,

*“we can't really lease any extra vehicles because the price tag is so high”*, pointing out the structural hurdle in adoption despite long term cost saving possibilities.

Finally, Participant 1 presented a financial and operational bottleneck with waiting for vehicle charging, as they state *“the driver is waiting /.../ which is also costly”* while adding *“cost of power is higher”*; which reflects a dual inefficiency.

Taking all of these points into consideration, it is important that EV technologies are a good alternative to diesels. However, there are some issues that might potentially hinder their use. An innovative solution that might address such pain points could prove beneficial in the field.

### **5.1.6 Damage**

One of the most prominent themes among interviewees was damage to the items during transportation. Participants noted that products go through multiple handling processes at different

points during delivery, making them susceptible to damage. The items usually are moved from IKEA distribution centers to customer distribution centers, and then finally reach the delivery providers' hub to be prepared for the last mile. Since the participants were all IKEA professionals, the unique challenges that arise as a result of the company's vast product catalogue were often discussed. Especially the fragile, heavy and oddly shaped products require detailed planning in transportation processes. Such items might get damaged in transit. The damage is often the result of mishandling issues. Some participants highlighted that damage control is quite costly and time-consuming. Participant 2 stated:

*“If something's damaged, we have to make that right with the customer. That's expensive. Or if we don't pick it properly and they're missing something, then that is expensive for us to fix.”*

Participant 3 underlined how the packaging design of the products affect last mile delivery by saying:

*“/.../ The package is designed for customers... (to be) clicked and then collected by themselves. So the package is not that, I should say, not suitable for so many people to do the handover. So the damage rate also is a challenge for us.”*

### **5.1.7 Weight and Size Challenges**

Another prominent theme was the challenge of delivering big and heavy items. Participants agreed that the delivery of small items does not pose many challenges as customers can use other delivery methods like parcel lockers or click-and-collect. However, heavy items are usually subject to home delivery and the ergonomics of the loading and unloading processes are often hard to manage. A challenge mentioned by many participants is the lack of elevators in customer homes. Participant 6 stated:

*“So, to deliver that one to, let's say, to the fourth floor without an elevator... That's of course pretty tough on our delivery crews, on the delivery crews from our partners. So, yeah, that is, in a way, making things not super efficient. So, it's super manual work, when it comes from wherever you park in front of the customer's home to bring it to the home. We have quite heavy goods.”*

Participant 8 agreed with Participant 6 and also added how this issue affects customer satisfaction.

*“But the biggest challenge, I think, when it comes to delivery is if we have to deliver something into apartments where we need an elevator. For example, to get a delivery that is not the best supported system-wise... This is where the unhappy customer flow is happening the most, I believe.”*

IKEA offers home deliveries with 1 or 2 delivery persons depending on the weight of the items. The exact weight differs among countries, however, according to regulations if an item weighs above a certain point, the company has to hire an additional person to help with carrying the items. Some participants cited this as a challenge that increases labor costs.

### **5.1.8 Expected Legislative Changes**

The most unique of these pain points, and the one that has received the least coverage in the literature, is the impact of future sustainability regulations on the last mile delivery scene. Many participants expect that existing regulations will be altered by governments or legislative bodies to affect the way last-mile deliveries are made. Participants who work in Europe highlighted that they expect deliveries with diesel vehicles will be taxed or limited in the near future. Due to this, replacing diesel trucks with electric ones is the main goal across different IKEA countries. Participant 1 stated:

*“So it's not a choice. We have to go, uh, at least close to 100% percent (at electrifying the routes) at some point in a few years, of course, apart from that, at some point and that will come very soon, we will have the environmental zones in the bigger cities where at some point we just cannot enter the city with diesel trucks, so yeah, and that will be a problem.”*

According to Participant 9, in certain cities in France, regulations are already in place to ensure zero-emission goals are met. Although deliveries with zero-emission vehicles are prioritized by the company, sometimes reaching customers proves challenging due to regulations restricting delivery to certain zones at certain times. Participant 9 brought up how challenging it can be to deliver even small items due to these regulations.

*“The public authority made some restrictions for the last mile deliveries. So we need to provide zero emission deliveries in the center of the city. This is the first restriction. And sometimes, even if you provide zero emission vehicles, in the afternoon, in very specific areas in the center of the city, we can't deliver with a zero emission vehicle. So we can only deliver with a bike. Bike vehicle. You know? So if a customer just wants to make an order to have a pillow, for example, we can't deliver it if we don't provide bike services for this specific area. So this is the kind of restriction that the public authority can make.”*

Many participants are aware of the potential restrictions in the future and are therefore in favor of developing innovative methods for last mile delivery.

### **5.1.9 Issues Stemming From Customers**

Deliveries often get disturbed by issues stemming from the customer's side. Customers ask for specific delivery windows but are not available to receive the items when the delivery is supposed to be made, leading to failed deliveries (Corejova et al. 2022). This situation puts a lot of pressure on last-mile delivery professionals who share the goal of achieving company KPI targets such as a high rate of successful deliveries. Participant 2 stated:

*“The successful delivery percentage is not nearly as high as we would like it to be. I don't know what it is. It might be 90 or 92% but I would say somewhere between 5 and 10% of our deliveries don't get made when they were scheduled and have to be rescheduled.”*

### **5.1.10 Operational and Planning Challenges**

One of the heaviest discussions revolved around planning deliveries. Participants brought up many pain points and practices that affect efficiency negatively. Issues related to fleet planning are

highlighted. Many participants stated that factors such as number of trucks per route, routing, scheduling, capacity restrictions of the existing vehicles and the way the goods are stacked inside the vehicle are crucial points they must consider reaching the highest point of efficiency. External factors such as traffic congestion, accidents, lack of parking spots and the inability to offer certain delivery types due to infrastructure limitations are also challenges professionals have to tackle. Participant 6 talked about how external factors affect deliveries by stating,

*“You have the road planning. And, as soon as something in the journey happens be that a traffic jam, an accident, stuff like that, of course, it disturbs their schedule. And as soon as they're in a hurry. They shouldn't be in a hurry if everything is fine and everything works smoothly.”*

Participant 5 echoes Participant 6 and talks about how intricately they have to plan deliveries by taking into different factors,

*“All these different ZIP codes and things and densities and days of service and cost and, you know... We would analyze all this stuff to death.”*

Participant 10 highlighted the difficulty of serving areas that lack necessary infrastructure,

*“We have a couple of cities that are quite densely populated and quite efficient to deliver. But then we have, Northern part of Finland. It's the same kind of area as in Sweden. There's not much people living there, and the distances are very, very long. It can be 300 kilometers from a city to the customer and then the same 300 kilometers back. And that, delivering with the EV is impossible at the moment because there is no charging infrastructure in place.”*

## **5.2 Desired Autonomous Vehicle Features**

### **5.2.1 Capacity to Cover the Entire Product Range**

Since the participants did not have expertise on autonomous vehicles, they expressed their opinions on the use of autonomous vehicles in deliveries based on their own expectations. Therefore, the suggestions in this section are triangulated with documents from public authorities, private companies and AV manufacturers for further clarification.

With IKEA's product catalogue being so diverse, many expect the ideal autonomous vehicle to have the capacity to fit it all. Participant 6 highlights the necessity by stating,

*“The article sizes and the weight is the biggest issue to address before you move on to the people can be accepting or not”.*

Participant 8 also corroborates that the vehicle should be of dimensions to *“contain the full furniture range”*. These comments underline the possible mismatch between some AV prototypes possibly designed to be small and compact, with the real logistical demands of bulky and somewhat heavier product segments.

In the scope of weight of articles, all participants agreed that different vehicle types are currently in use to cater to various weight necessities. Such consensus suggests that a one size fits all AV solution is not realistic within the current delivery landscape. Instead, a diversified fleet consisting of vehicles and AVs may be required to serve different operational necessities. A researcher from the Victoria Transport Policy Institute backs this point by implying that a single AV that would cover all types of deliveries and different ranges of items cannot exist at the moment (Litman, 2024).

When asked about how the suitable area of the vehicle should be, Participant 4 described the necessary design feature of a viable delivery vehicle to be *“as long as possible, as high as possible, as light as possible”*. The emphasis is placed here on maximizing internal volume while minimizing vehicle weight parameters, which would be vitally required to be compatible with infrastructure and urban roads as well as remaining efficient. This concern is further linked to ideal fill rate utilization in the vehicles during delivery, as Participant 7 asserted that along with various challenges plaguing the fill rate utilization, it is also taken up by *“handling materials”*, suggesting that the usable payload is already constrained with non-product components. Participant 4, on the other hand, added a more optimistic view, *“we can optimize the filling rate”*, indicating how design and procedural improvements may help address such constraints. The proposition is that AV models for delivery should not only carry sufficient cargo space but need to do so in a pristinely space-efficient manner.

Participant 9 reinforced the importance of big payload stating that, “*we need to have a big payload, a big range*” while also stressing the productivity gains with a larger vehicle capacity, “*The payload is very important. we want to have a vehicle, with at least one ton of payload /.../ If you can put more orders in the vehicles, it's better for the operations.*” These emphasize a recurring theme that vehicles must not only move autonomously but also be of scale to be economically viable.

Participant 4 envisions the vehicle to have no lifters, as they added “*it deducts from the payload*” by as much as 300 kilograms. For a delivery context where each kilogram counts, with EVs or AV fleets’ mechanical necessity can pose as a limiting factor reducing usable space and weight.

The last key discussion was related to sustainability. Participant 7 raised a key sustainability related concern with vehicle size noting the issue of vehicle utilization,

“*Is it sustainable to have one truck for one delivery?*”

This question highlighted the inefficiency of underutilized capacity, and the environmental toll associated with oversized vehicles performing small deliveries. This implicitly asserts the necessity to optimize vehicle size to meet operational necessity without inflicting unnecessary environmental impacts.

Based on these points, we can conclude that the professionals expect the ideal delivery AV to be light with a big capacity and the necessary dimensions to cover the entire product range.

### **5.2.2 In Transit Product Safety Features**

In addition to dimensions, participants emphasized that it is important to create setups where products can be transported safely. The cost of the damage control process and the fact that products can be easily damaged due to their packaging were the most discussed issues. Several participants suggested that a setup with sturdy walls, a flat floor and padding to prevent damage to the products would be appropriate. Participant 7 raised the point that they share a dual concern for both customer and product safety by stating, “*safety for the customers, but also the safety of the goods.*”

Participants emphasized the effectiveness of vehicles is essential to ensure product safety in autonomous delivery. Participant 9 highlighted the need for a good height, more accurately adjustable height. He stated a need for higher height for warehouse loading and lower for urban delivery areas to improve navigation, handling and ergonomics, a point that is also supported by Participant 7. Participant 5 noted that internally standing the items upright and strapping them to the walls is often best to ensure damage avoidance, while also acknowledging that it is dependent on delivery context as well. These points stem from similar observations that such conditions lead to fewer damage.

The documents identified for triangulation seldom included points on product safety inside the autonomous delivery vehicles. However, National Highway Traffic Safety Administration (NHTSA), which is part of the U.S. Department of Transportation (USDOT) highlighted in a report that AVs should have automated restraint systems which must protect the items in case of crashes (NHTSA, 2023).

### **5.2.3 Order Segmentation**

Some form of segregation of products was a common suggestion. The main reason for this is to prevent the customer from receiving the wrong product during the delivery process. Although there were different opinions on how segregation should be done, a few people suggested that beehive-like arrangements would be better than a regular van setting. A somewhat radical concept appears with mobile lockers Participant 4 envisioned. He stated that an AV delivery vehicle should be a “*driving locker*” and further explained that,

*“Beehive, if you cut it through, it should be like that with space. It's like a locker, a driving locker”.*

This metaphor highlights the conceptual shift from a vehicle as a transportation body to becoming a mobile intelligent storage space. The compartmentalization would aid in ensuring organized segregation of multiple customer orders, potentially along with real time updates with route and delivery sequence.

Participant 7 questioned if the vehicle would do single or multiple order deliveries. According to them, if there is a multiple order delivery setting, the absence of an order segregation process might

result in confusion if different orders are placed together and cause potential mismatch in delivery. He highlighted that single order deliveries would be much smoother stating,

*“If these are single order deliveries, then it is something else. So then you have a lot of small trucks that are moving in and on the road, and then each of those orders are for single customers.”*

However, this also raises the implicit issue of if doing a single delivery per vehicle is effective in terms of cost, operational complexity and sustainability.

The necessity of order segregation was also raised by several other participants as they emphasized the need to avoid cross customer delivery errors. Participant 4 also stated, *“if I have that in one of the compartments, it simply stays there”*, referring to the immobility of items once placed. Participant 2 further stressed the risk of misdelivery stating,

*“there would need to be some technology for that because right now it's based on the driver finding the right boxes and identifying them”*, describing the high dependency on the human personnel for identifying the deliveries based on orders, which would need a systemic alternative to in case of AVs. Participant 3 confirmed this concern as well, while pointing to a shared consensus that AV delivery systems may need to include smart verification technologies, along with real time tracking for drop off.

Participant 7 expressed concern about the handover and stacking of articles in various levels in a parcel locker like structure, as this can be limiting in terms of accessibility as well as not being ergonomically sound. This concern was potentially addressed from the discussion points of Participant 8 with the proposed principle of placing heavy items on the bottom and lighter ones higher. They stated,

*“The lower level lockers we can have really big orders in. The upper ones, we also have ergonomic convenience for the customer as they will be designed for smaller, and not too heavy orders.”*

The potential template of mobile locker conceptualized for bulky item delivery with weight based stratification with adjustable height features can not only appear to be a safety and damage prevention strategy but also a customer experience enhancer in unmanned and self service delivery.

US Postal Services explains that the mobile parcel locker would work well in postal deliveries. An app that notifies the customer when their package arrives is the idea they suggest. They go on to add that this system would increase convenience, eliminate package theft and reduce failed deliveries (US Postal Services, 2017). They also note that Google is working on this concept. However, our searches into whether the present efforts are ongoing or not did not yield any outcome.

#### **5.2.4 Vehicle Safety Features**

In many participants, there were concerns about the safety of autonomous vehicles as they are AI-powered. Participant 5 even stated that the vehicle should absolutely be “*perfect*” to be used for deliveries because once the vehicle gets into an accident, it would be hard for the company to recover from. However, other participants stated that accidents happen more frequently with human drivers, so it is not an issue. Participant 7 stated that “*safety is going to be very very important*”. The emphasis on safety would need to particularly peak in urban environments where vehicle behavior must be predictable and secure. Participant 2 echoed this assertion while optimistically cautioning that,

*“Accidents can turn people off. But as it gets better just like any technology change that we've experienced, as it gets better it gets safer”.*

According to a document published by the US Department of Transportation, safety will not be a concern in the future as AVs will have the potential of reducing human error (2020). Researchers from Harvard Kennedy School also back this claim, stating that if regulated right AVs will reduce accidents as they can better conform traffic rules (Fagan et al. 2022).

Participant 4, on the other hand, shared his views on how the public would perceive the vehicle in terms of safety, stating, “ (there would be) quite a lot of people who would be scared of that.”

This resonates with Participant 2, who also does not share the same optimism of development of technology.

Participant 7 elaborated on the notion that AVs should absolutely be perceived as safe,

*“It might be technically safe, but people have to feel safe.”*

The statement reflects the gap between actual and perceived risks, as they pointed out that technical safety is not enough. Trust is paramount when the user does not have communication with nor controls the vehicle.

Lastly, Participant 5 articulated how AV margin of error is held to a higher degree of standards as they conclude,

*“Meanwhile, human drivers are hitting people all the time. But the robot has to be perfect in order for people to accept it. And I think it's that high bar that makes it very difficult.”*

This higher level of standard places an alleviated need for assurance and perceived safety. KPMG’s AV Readiness Index supports this claim, stating that public tolerance of AV-caused accidents is very low (KPMG, 2020).

### **5.2.5 Handover Support Features**

There was a concern that autonomous vehicles would create further problems due to lack of help to the customers in the handover process. Participant 7 questioned the *handover process* stating,

*“How is the order handed over to the customer at the point of the customer's home or at the point of delivery?”*

Participants came up with different ideas to avoid this problem. Participant 6 imagined that a robotic hand or mechanism attached to the autonomous vehicle could help with product handover. He suggested,

*“something autonomous that really carries the weight, and it would be something robotic”.*

However, he also recognized that although robotic aid can carry the weight and help with the unloading process, it may prove to be quite challenging with current solutions and certain delivery types.

Other participants suggested that an automated ramp attached to the vehicle could do the task. Some participants suggested crowdsourcing as an option with the assumption that a fully autonomous setting is not yet possible. One participant working in the United States mentioned

that they are already in collaboration with a crowdsourcing app. After the IKEA delivery, customers can use the app to get their orders moved to the room of their choice or get them assembled. The participant came up with the idea that these processes could be made possible with the help of a crowdsourced worker in an autonomous setting. None of the documents used for triangulation address the handover process in AV deliveries, possibly due to the novelty of the concept. We recognize that this could be a research gap that might need addressing.

Many of those interviewed are concerned that the handover process will be a problem in a fully autonomous setting. They argue that autonomous vehicles will not be of use in this regard, as the main purpose of home deliveries is to move heavy items to the desired room or deliver them close to the customer's home. However, some suggested that as customers increasingly expect low-cost delivery, they may also need to engage more actively in the delivery process, an adjustment that autonomous vehicles could help support. Participants of that opinion are in favor of following IKEA's founding philosophy of "build your own furniture." Another frequently mentioned issue throughout the interviews is that since each product is different in terms of shape, size and weight, it is not wise to offer a single delivery method. Many people think that autonomous vehicles should be offered as an alternative to traditional delivery methods, not as the primary delivery method. According to this idea, customers should be free to choose the delivery method they want depending on the details of their order. Therefore, customers who strongly prefer to collect their products in person should be given the option to do so.

### **5.2.6 Optimized Routing**

According to participants, autonomous delivery vehicles should follow efficiently-planned routes. Some of them share the belief that future technologies will be better at managing and planning the delivery routes. Participant 3 foresees that optimized routing will be possible without the involvement of humans, stating:

*“But tomorrow, I think by deep learning, some AI things, this type of thing will be done by, you know, the system, not people.”*

Participant 9 believes that routing should be made more sustainable with the help of AI because the system will ensure that routes are planned in a way that minimizes energy consumption.

*“We'll be more efficient in reducing our energy consumption because we need only one vehicle, one trip to deliver the customer's needs.”*

Although participants mentioned routing in the discussion, none of them commented on if it should be the vehicle itself doing the routing during or before the journey or an external AI-powered software connected to the vehicle. However, some AVs available in the market already have features that allows them to route and reroute in real time. According to a report, Waymo vehicles can *“constantly calculate optimal, safe routes using 360° environmental data”* (AVIA, 2024).

### **5.2.7 Tracking and Visibility Features**

In the discussion about last mile deliveries, some participants mentioned that customers would like to track their orders in real-time. They also mentioned how software that can increase visibility would benefit the professionals themselves. Participant 8 mentions that they have been testing software that helps with tracking last mile deliveries and are able to track deliveries now. He highlights the benefits of the software by stating:

*“That gives us also a lot of information from how the last mile would look like and how many kilometers we are driving to do the deliveries and where we can optimize. So we are sitting on much more data than we had in the past.”*

When asked what kind of a feature would benefit deliveries, Participant 9 envisions an RFID solution that can help locate the goods inside the vehicle and make it easier for the items to be identified at the point of delivery.

*“So maybe, if we can find a solution to just cross the pallet with all the orders in a box or something like that, to be sure that all items in the right quantity are on the pallets. We will save time for the TSP (transport service provider), and then we can save on cost when we sign the contract, you*

*know, because the TSP needs less time to make their operations because they don't need to control (check) every order.”*

Many participants expect the goods to be easily identifiable inside the vehicle so that the delivery process is less time-consuming. They are also driven by the customers' expectation that the delivery should be trackable, on time and faster. Thus, an identification system on the vehicle and near the items seems to be a feature participants deem necessary.

The European Union's Automated Road Transport Report suggests that they plan to create urban mobility environments where autonomous vehicles will be able to communicate and give each other real-time traffic updates (The European Commission, 2020).

### **5.2.8 Sufficient Range**

Participants working in European countries expressed doubts about whether an autonomous vehicle capable of covering the entire range of deliveries could ever be available. Most participants work closely with electric vehicles and possess in-depth knowledge about the average range required for last mile deliveries. The required range varies from country to country, with countries like China and the USA requiring bigger range vehicles. Participants have divided opinions on whether the range of the existing fleet is sufficient or not. However, participants working in countries at the forefront of autonomous vehicle development, such as China and the US, confirmed that vehicles with this range already exist. China, especially, seems to be ahead in developing vehicles with bigger ranges according to the opinions of Participant 2 and 3. For instance, according to the State of AV report written on behalf of the AV manufacturer Nuro, it is mentioned that their vehicles already have the design for covering short and repeated urban deliveries (AVIA, 2024).

Two factors repeatedly were mentioned by participants on what affects range: weather conditions and battery life. When it comes to batteries, participants mention that most of the electric vehicles in operation are charged in certain zones operated by IKEA or public authorities. Participant 3 informs us that there are vehicles available on the market that use the battery-swapping solution where the battery is changed with a new one at a designated location. When asked which solution is better for an autonomous vehicle, she says it would depend on the size of the vehicle. She states,

*“A logistics vehicle, normally it's quite big, quite large. So it's not that convenient to do a quick exchange (of the battery). But if it's small, it is possible.”*

Thus, according to participants, an autonomous delivery should have sufficient range to be able to operate in harsh weather conditions and have sufficient battery power to cover the range of the deliveries. Some participants also showed concern about the environmental sustainability of delivery vehicles. Participant 4 wishes that they had a battery which *“can be recycled until forever.”*

### **5.2.9 Customer Interaction Features**

Many participants insisted that autonomous vehicles should absolutely be able to communicate with the customer. Reasons for this were cited as the need to be able to answer delivery questions in the absence of humans, to let customers know which product is theirs, and to build trust. The common concern is that the vehicle would be too confusing to figure out on the customer's end if it does not have any interactive features. Participant 7 envisions an interactive screen placed on the side of the vehicle.

*“You can have a window on the side of the truck. It sets (out to) the customer's home. The customer puts their code, and then it just, you know, brings the customer the order on a platter.”*

Two researchers on behalf of Drive Sweden published a report where they state that AVs for delivery purposes should be equipped with mobile apps, voice commands and interactive screens just like the participants suggested (Andlauer & Laurell, 2024).

Participant 8 brought up the point of safety and trust yet again stating,

*“It needs to be decent, lighted, safe for the customers (so) that they feel safe when collecting the items.”*

Another point discussed by Participant 7 was accessibility. He expects the vehicle to be accessible to everyone by asking,

*“So how will differently abled customers go in and pick it up? How will a young customer be able to pick up those orders by themselves?”*

### **5.2.10 Flexibility in Operations**

Participants discussed how flexibility is a key component for present and future modes of delivery, irrespective of the mode of delivery. This point does not only apply to AVs, rather extends to current forms of delivery as well. Recognizing the previous discussions on how customers prioritize convenience in delivery and other service expectations, Participant 8 points out how a wide delivery timeframe for collection would be beneficial as they added,

*“ What is important is that the customer has a pretty wide window of when he can collect.”*

They also advocate for AVs to be the future solutions for delivery as they go on to add,

*“I think as long as it's convenient, straightforward, simple to use, automation is the way to go.”*

Apart from the customer convenience perspective, according to some participants, AVs also have the potential to aid by providing limitless driving hours. This is brought forward from the concept that AVs would not require the downtime as with human drivers. However, the down time minimization is not the only key expectation from AVs. Participant 7 adds that it should be *“possible to drive that truck in the city”*.

Some participants hinted that the AVs should be suitable to be adjusted to match infrastructure. All participants confirm the prevalence of use of varied nature of vehicles to cater to different operational and regulation needs. This statement is by extension the expectation of various classes of AV vehicles that possess the ability to serve different necessities.

Lastly, current alternatives of AVs up to Level of Automation 4 require supervision from humans. Due to this, Participant 7 envisions a mixed setup for AV based deliveries as they stated *“I think, eventually, they will work together”*. Participant 10 echoes Participant 7 and adds that humans will always be present,

*“I think AI could be used quite widely so that it could be that human errors are not a factor, but, nevertheless, there will still be humans on the roads.”*

The last point that was raised a lot by the participants was that unlike humans, autonomous vehicles can remain in operation 24/7. For this reason, alternative delivery schedules such as late night deliveries were proposed. This idea is inspired by the autonomous trucks used in the long haul

trucking industry that run on certain highways at night. One of the companies that own autonomous fleets who run at night is Gatik. However, they only serve B2B customers and operate on designated roads (AVIA, 2024). It is unknown whether the same setting could be used for last mile deliveries due to lack of regulation on alternative schedules.

### **5.3 Findings From the Document Analysis**

In the 27 documents analyzed, many points supporting the interviews were identified. Most of the documents highlight the topic of autonomous vehicle regulations. Our analysis shows that AV regulations differ from region to region and that there is a mismatch between the pace of the innovation and policy-making. ASEAN's AV Landscape Report states that rather than following a coordinated framework, the member countries individualistic approaches (ASEAN, 2023). The report also highlights that apart from Singapore which has a well-defined strategy on AV adoption, the countries follow an exploratory approach that can lead to more fragmentation in policy among members (ASEAN, 2023). Similarly, the United States also suffers from the fragmentation problem where each state follows its own policies. The U.S. Department of Transportation emphasizes the need for harmonization but does not clarify how it is planning to implement changes (USDOT, 2021). Countries like UK aim to address these issues by introducing national-level policies (Department for Transport, 2015). The general consensus, however, is that while AVs are advancing rapidly, the lack of policy harmonization may hinder the development efforts. Some academic papers we have cited also highlight this need for regional and global harmonization (Hansson 2020; Punev, 2020).

Alongside the lack of policy coordination, the AV industry is also marked by fragmented manufacturing efforts across different producers. Manufacturers such as Nvidia and Nuro adhere to their own internal standards for autonomous vehicle (AV) development and voluntarily report on safety and liability (Steer, 2020; Nvidia 2025). However, there is currently no independent authority responsible for auditing or verifying their claims. This shows that there is a clear need for an independent regulatory body to oversee standardization and conduct external audits within the AV industry.

Another theme the documents highlight is the lack of infrastructure required to deploy AVs. AVs require a digital ecosystem where they can communicate with each other. In order to create such an ecosystem, high-bandwidth 5G, computing nodes and consistent signals are crucial (The European Commission, 2020). Implementing such technologies can be challenging even for developed countries. Hence, some reports highlight that developing countries and rural areas can lag behind in their efforts (AVIA, 2024). Moreover, in the context of last-mile delivery, the challenges are further exacerbated by the lack of adequate urban infrastructure to support designated pick-up and drop-off points for AVs (Fagan et al., 2022). Hence, until this issue is adequately addressed, AVs may be best suited for deployment in controlled or closed environments. Customer acceptance and trust is highest in closed environments as well (AVIA, 2024).

## **6. Discussion**

*This section integrates the findings from both research questions with the aim of providing a comprehensive understanding of how the identified features of autonomous vehicles (AVs) can address key challenges in last-mile delivery. By linking AV capabilities to specific pain points, we demonstrate their potential in enhancing deliveries. Theoretical implications and practical implications that emerge from the analysis are also presented in this section along with limitations and suggestions for future research.*

### **6.1 AV Features to Address Pain Points in LMD**

Based on our findings, the problem of balancing trade-offs will likely persist as it is one of the inherent and core problems of supply chain management. However, the findings of this study and all the papers on which it is based suggest that autonomous vehicles can become beneficial in terms of cost-savings once they enter widespread use (Lemardelé et al. 2021; Benallou et al. 2024). The main reasons for this are the expectation of complete savings on labor costs and enhanced routing with the support of artificial intelligence (Nvidia, 2025). Another point AVs can enhance is environmental sustainability. AVs might contribute to more sustainable delivery practices as most models are electric and rechargeable, making them more desirable than diesel vehicles in the near future (Wadud et al. 2016).

Autonomous vehicles are offering a major opportunity to compete with other companies in the market. While the use of autonomous vehicles in B2B is becoming widespread, their use for last mile deliveries is not yet extensive. For this reason, companies aiming to integrate this technology into their systems will become early adopters. Although being an early adopter is costly and brings with it the need to constantly update existing technologies, it is crucial in gaining an edge over other competitors. The majority of interviewees share this view. Leasing models can be used for autonomous vehicles to reduce the high implementation costs for early adopters.

According to the results of this research, it may not be possible to identify the needs of each country, company or delivery flow. For this reason, it would be better to aim to develop autonomous vehicles that are suitable for the nature of the products and can cover the full capacity of the flow. We believe that this can only be possible if autonomous vehicles are designed in such a way that either the capacity is adjustable, or the vehicle itself can be completely modified depending on the context. We have the opinion that autonomous vehicles with flexible and adjustable shelves can make significant contributions to fill rate utilization.

If a fully autonomous delivery setting is adopted, labor unavailability will largely cease to be a concern. However, our findings suggest that other innovative solutions should be developed alongside autonomous vehicles, as the transition to this level will be slow due to regulatory constraints. As several interviewees noted, crowdsourcing collaborations with third parties could address this issue for now.

Protecting fragile and large goods from damage in transit will remain a challenge for last mile delivery professionals. However, if the autonomous vehicle has sturdy walls, padding and other support features, potential damage will be minimized as much as possible. In addition, as the expectation that autonomous vehicles will be better drivers than humans is frequently found in the literature, we do not think that the issue of product damage will be as prevalent as before, as problems such as accidents, sudden braking or turns will be minimized (Nvidia, 2025).

One of the most frequently mentioned themes in the interviews was customer delivery problems. Consequently, if a system consisting of both autonomous vehicles and traditional delivery models is established at the beginning, failed deliveries may decrease as customers will obtain the flexibility they want. In addition, if autonomous vehicles with tracking systems are utilized for

the last mile, the same kind of positive impact can occur as the customer's visibility increases. In addition, it can be assumed that when the use of autonomous vehicles gradually increases and reaches public visibility, the infrastructure will be integrated accordingly.

According to our findings, the biggest barrier to the widespread adoption of autonomous vehicles is regulation. Many participants said the transition to autonomous settings would be slow if the necessary regulations were not in place. On the contrary, some emphasized that if more autonomous vehicles are produced and tested, supportive laws will be enacted. In addition, as the use of diesel vehicles will be minimized due to stricter sustainability laws, the acceleration of alternative solutions such as autonomous vehicles is likely to be inevitable. Nevertheless, the technology is still very new, therefore we will have to wait and see what the future will look like.

## **6.2 Theoretical Implications**

The results of the study offer several theoretical implications when examined from the perspective of the Diffusion of Innovations (DOI) Theory. DOI defines five attributes that influence the spread of an innovation as introduced in the Theoretical Framework section. The attributes are: Relative Advantage, Compatibility, Complexity, Trialability and Observability (Rogers, 2003). Based on the findings of this study, the DOI framework proves to be a valuable lens for understanding the potential adoption of autonomous delivery vehicles in last mile delivery.

The first attribute **Relative Advantage** was brought up often throughout the interviews. Participants have the belief that autonomous delivery vehicles would prove to be more useful compared to diesel vehicles in different ways. The biggest advantage they see is that autonomous deliveries will eliminate dependence on human labor and reduce costs. This finding is also in line with the literature as many researchers highlight the potential of AVs in eliminating labor-related costs (Lemardelé et al. 2021; Alverhed et al. 2024). One participant noted that autonomous vehicles will be expensive at first, but as they become more widely used they will become more affordable, just like other technologies. Another advantage identified by participants is the ability to operate at bigger time frames with AVs. The idea that autonomous vehicles can deliver for extended periods of time because they don't need drivers was raised many times. Some participants shared their doubts about efficiency. One participant suggested that there would be no increase in efficiency, arguing that deliveries would be made using the same routes and there would be no

change in kilometers traveled. Another participant pointed out that if the range is sufficient, autonomous vehicles could be a more sustainable option compared to diesel as they run on batteries. Overall, the majority perceive autonomous vehicles as relatively more advantageous than traditional delivery vehicles. Although costs and sustainability metrics may vary in real life applications, the results of our study are in line with Rogers' idea that innovations should be perceived as superior compared to their predecessors (2003).

**Compatibility** was brought up as a point of concern by many participants. The majority believe that autonomous delivery adoption will prove to be challenging due to lack of regulations, necessary infrastructure, and variance in customer expectations. Since current regulations hinder the deployment of Level 5 autonomous vehicles, the argument has often been made that humanless settings cannot yet be created. Reports and academic papers support participants' perceptions and state that Level 5 is hard to achieve given the current state of the regulations (Tran & Le, 2022; AVIA, 2024). Many participants argued that if regulations were changed and autonomous vehicles were allowed to be deployed, the use of the technology would become widespread. One participant also noted that if the manufacturing and testing of autonomous vehicles gains momentum, regulations to support them will also emerge over time. Due to the current lack of infrastructure, several participants suggested testing autonomous delivery scenarios between company-owned facilities first. The reason behind this was stated to be the availability of equipment that makes unloading and loading operations easier at company facilities. On the other hand, the issue of customer acceptance caused skepticism among many participants. There was a consensus that the adoption of autonomous delivery settings would accelerate if the handover process could also be automated. Our findings suggest that the infrastructure should be prepared for future AV adoption and that governments, decision-making bodies and international organizations should play a more active role in this process.

**Complexity** was one of the less talked about attributes. Participants emphasized that in order for autonomous vehicles to be accepted, it is essential that they have as simple an interface as possible. This point further affirms the founding idea of the Complexity dimension (Rogers, 2003). It was discussed that a simple interface would provide a sense of security for the customer. Building on this discussion point, some participants said that the acceptance of autonomous vehicles depends

on how safe they are perceived to be. This interpretation is closely linked to the theory, as it is about how the vehicle is perceived rather than its actual safety features (Rogers, 2003).

There were fewer comments related to the **Trialability** and **Observability** dimensions, as only half of the participants were able to see or experience autonomous vehicles personally. While a few respondents said they have come across brochures of autonomous vehicles designed for last mile delivery, the rest were not aware of the available technologies. This shows that autonomous technologies are not yet widespread. Participants' perceptions were therefore often based on assumptions rather than observable results. Nevertheless, participants argued that public acceptance of autonomous vehicles requires public exposure to the vehicles. The most popular idea was the gradual introduction of vehicles. Participants said that if people experienced the use of autonomous vehicles in everyday contexts, such as public transportation or food delivery, they would come to accept them for furniture deliveries as well.

Taking all these into consideration, it can be summarized that participants believe autonomous vehicles will be advantageous compared to past practices, but it will take time for them to spread due to challenges mentioned in the other 4 dimensions. According to the findings of this study, the concept of using autonomous deliveries for last mile deliveries is very new and companies like IKEA belong to the category of early adopters. We can also conclude that autonomous vehicles do not fully satisfy all five attributes of the DOI theory. While the Relative Advantage and Complexity dimensions are generally perceived positively and can be improved upon by simple interfaces and cost reduction efforts, the other dimensions remain underdeveloped. The infrastructure required for AVs varies from country to country and the potentialities of AVs are not visible to the public. The results of comparable studies support our conclusion that AVs do not fully meet all the key attributes outlined in the DOI theory (Yuen et al. 2020; Ganjipour & Edrisi, 2023). This suggests that several requirements should be satisfied before AVs can fully “diffuse” as an innovation.

While the Diffusion of Innovations Theory provides a good lens to interpret the findings of this study, it is necessary to underline that the theory has its limitations and cannot explain every point to be addressed. Moreover, since this dissertation does not follow a deductive approach, we do not seek to verify the theory itself. We recommend that the study be replicated using alternative theoretical frameworks to obtain a more reflexive stance.

### **6.3 Practical Implications**

While present day AV delivery vehicle alternatives possess the ability to operate and execute tasks in solitude, they are limited in applicability with the barriers of regulatory variance across nations as well as perception of safety (Schepis et al. 2023). AVs vary in levels of autonomy, which is a measure of ability and permissibility to operate without human supervision (SAE International, 2021). Real life applications based on interviews of industry professionals reaffirm the existing concern. However, the present day alternatives still hold promising applications which can be called a “helping hand” approach to current processes.

The platooning concept originally was spawned to alleviate the toll on drivers in long hauls in cross-country or continent deliveries (Lupi et al. 2025). This remains to be the most tested and viable application of autonomous vehicles, particularly on intercity highways (Lupi et al. 2025). However, platooning can also be mirrored in the last mile to use the existing regulatory necessity to supervise AVs, to an advantage. If an AV is configured to act as the “follow” vehicle with a human driven regular delivery van being the lead vehicle, a multiplied number of deliveries can be made without increasing the head count per delivery. Deliveries in urban areas are executed mostly with vehicles of limited load capacity and dimensions (Pahwa & Jaller, 2022). This is to conform to the regulations based on infrastructure in urban areas congestion and limited space. The interviews of industry professionals operating in last mile delivery with bulky items as IKEA expressed their interest in the possibility of operating a vehicle with a bigger capacity for operational ease and environmental concerns. Since volume and payload are key factors in bulky furniture delivery, having limited capacity is a challenge which often results in multiple deliveries in the same route. The elevated concern about the shortage of driver and delivery staff is an issue expressed by industry professionals and confirmed by reports (Mittal et al. 2018; AVIA, 2024). This approach can act as solutions to payload capacity requirements, handover issues and barriers posed by unevolved regulatory landscapes while not requiring an increase in head count.

The purpose of AVs adjusted and grouped with different delivery types can result in a varied range of solutions in last mile delivery. For instance, as mentioned earlier, the simplest use is platooning the AV with a human operated vehicle acting as the supervising entity. Secondly, the AV and driver van can be coupled so the driver van performs regular delivery tasks, while the AV vehicle is left

parked in a designated space to act as a click and collect solution. Click and collect solutions include manned vehicles parked in designated areas where customers collect from said location. Customers are notified when their parcel is ready, reducing failed delivery attempts due to a more flexible pickup window. However, it can prove to be a costly solution due to the man hours involved in this process. Using AV as click and collect point vehicle can allow the human driver to be assigned to a different process flow, alleviating the driver shortage or in avoiding man hour underutilization. This combination is suitable for curbside deliveries as well, that is the AV makes the curbside delivery while the regular human-operated vehicle completes deliveries requiring home drop-offs. While this model reduces the last mile challenges, it relies on customer compliance and accessibility, which may not be feasible in all residential contexts. It is best suited to planned communities or areas with high click and collect adoption.

Both in research and interview discussions a common concern is the handover to customers while ensuring safety. Present options in AVs do little to include in terms of mechanical handover or for in-home delivery; however, it would introduce an added weight to the vehicle affecting the vehicle payload. Mobile AV lockers are self-driving vehicles outfitted with secure compartmentalized storage units (Kötschau et al. 2023; Kötschau et al. 2024). Existing practices of static parcel locker design can be applied to these Mobile AV lockers by designing compartments, so heavier items are placed in lower levels and smaller lighter articles in the top compartments. However, to aid and ensure accessibility and operational ease in loading the vehicle, the vehicle should include adjustable height features. The mobile locker AVs drive predetermined or dynamically assigned routes, stopping at key points to allow customer pickup (Kötschau et al. 2024). This model can work well in suburban areas or planned communities with consistent delivery patterns and low theft risk. The effectiveness depends on predictable routes and timely notification systems. The solution's limitations include range constraints, vehicle vandalism risk, and the need for real time support systems in case of failure.

AVs can be used for internal logistics between facilities such as between warehouse buildings, production units, or storage sites operating within private domains, allowing for early and relatively unrestricted deployment. These vehicles can follow fixed or semi fixed routes and typically transport palletized or containerized goods over short distances. The limited variability in route and traffic conditions might mean lower technical demands compared to public road AVs.

These internal transfers can help reduce manual handling and optimize intra-organizational logistics. Nevertheless, human supervision might remain to address exceptions such as obstruction handling, gate access, or emergency interventions. Security and operational continuity might become key enablers in this setting.

#### **6.4 Limitations**

It is important to acknowledge some limits when looking at the results of the study. The outcomes of the research should not be overgeneralized, as it was drawn from ten interviews with professionals of IKEA. As a result, insights may not capture all the different views from the wider retail or other industries. Moreover, the location of participants may have biased the findings that were collected. Having biased information in the sample may make the results incomplete and less representative.

Additionally, the qualitative nature of the research inherently involves subjective interpretation of results. Due to the diversity of researchers' findings, alternate conclusions could be reached with different analyses of the data. This emphasizes the need for caution when generalizing the study's findings. Tracking down relevant documents was another challenge due to the novelty of the topic, which could limit the understanding we developed about the subject.

Additionally, some of the recommendations in the practical implications is derived from the discussion and the reviewed literature, as such in some cases might not be feasible in practice at the current landscape. In addition, Autonomous Vehicle (AV) technology is quickly advancing, so the findings from this study may not be as relevant in the future. The study was focused mainly on IKEA, even though logistics were not covered in detail. Logistics Service Providers' (LSPs) voices were left out of the conversation since attempts to get in contact with them through the participants remained unsuccessful. It is important for future studies to try to resolve these limitations so the findings have wider use and can last longer.

#### **6.5 Suggestions for Future Research**

Further work on this subject could greatly add to what is known about AVs and last mile delivery. A replication could be conducted that covers more regions besides dominantly featured European markets in the research. Doing comparative studies in Asia, Africa, or South America, regions

outside Europe, could highlight differences in how people accept new services, how laws work in the regions, and the availability of needed infrastructure. Studying consumer engagement with AV in different locations could uncover factors affecting the global interest in this technology. Surveys could be beneficial in collecting valuable feedback on customer expectations, whether they are willing to accept the technology, any risks they see, and their preferences. With this approach, different types of AV delivery situations could be explored (for example, for different places and times), to better see how attitudes change among consumers and to mark out thresholds for top acceptance and possible opposition.

Studying real and upcoming AV systems used for the last mile delivery process further help to understand the issue could prove beneficial. Investigative projects of such kind can aid in interpreting the challenges of implementation, how things work in practice, what issues arise, and how users respond. Moreover, a case study of such kind would show the situation and offer useful advice and guidelines from professionals in the field. Also, looking into the many ways AV technology can be applied for last mile deliveries can be a promising but difficult area to study. Undiscovered sectors like the logistics of healthcare, medicine, and vaccine distribution, precision agriculture, and the logistics of responding to disasters could be the focus of additional research. Recognizing useful, new ways to use AV might allow for a more comprehensive deployment and focus attention on what is needed to achieve success.

Lastly, investigating relevant laws, changes in policies, and expectations for future AV legislation can add important information to research. Gathering information from legal practitioners may help explain various legal concerns and the ability to be compliant. They would help with understanding ongoing changes in the rules and give a useful preview of the potential laws that would affect deploying AV systems. Since AV specific regulations are currently under development and uncertain, this would be helpful in finding areas of risk and openings for each stakeholder in the field.

## 7. Conclusion

*This section summarizes the main findings of this thesis in relation to the research questions and objectives. It presents points of considerations that emerge from the theoretical and practical implications. The results are analyzed through the lens of companies, logistics providers and decision-making bodies and the thesis is brought to a coherent close.*

AVs are transformative innovations with potential to alleviate a wide range of modern world transportation challenges. While AI and other technologies are rapidly improving AV capabilities, resistance and limitation in widespread use of the innovation affects its social perception greatly. The barriers for the adoption of autonomous delivery systems are mostly related to acceptance and regulation, rather than technology. Practical challenges in deployment emerge with how various regions address regulations and manufacturing standards. Since there is a lack of standardization in those aspects, fragmentation hinders the spread of the technology. To overcome this challenge, organizational and governmental partnership can help create uniform regulations and practices which will in turn help speed up the adoption process. Since regulations are yet to be fully developed, organizations should carry out temporary solutions such as operating vehicles in mixed setups and conducting supervised trials. Platooning solutions can help by creating more supervised autonomy on set routes, aid future regulations, and contribute to changes in perception through presence in customer vicinity. The successful use of AV technologies relies greatly on public exposure. Hence, projects of such nature should be encouraged. Short public appearances and experiences with AVs can greatly encourage acceptance and recognize the advantages due to increased observability. For organizations, R&D efforts and testing for AVs is vital to reap the benefits of the promising technology. It is also worth underlining that early adopters will likely face high costs due to the newness and rapid development of AVs. Nevertheless, we are of the opinion that AV initiatives should be undertaken to gain an edge over the competition in the market.

## References

- Al-Malki, A., Madandola, M., Thani, S. A., Bayram, G., Al-Kandari, A., & Furlan, R. (2024). Advancing urban mobility in the State of Qatar—Establishing a framework for autonomous vehicles in Doha. *Journal of Infrastructure Policy and Development*, 8(3). <https://doi.org/10.24294/jipd.v8i3.3051>
- Allen, J., Piecyk, M., Piotrowska, M., McLeod, F., Cherrett, T., Ghali, K., ... & Austwick, M. Z. (2018). Understanding the impact of e-commerce on last-mile light goods vehicle activity in urban areas: the case of london. *Transportation Research Part D: Transport and Environment*, 61, 325-338. <https://doi.org/10.1016/j.trd.2017.07.020>
- Alverhed, E., Hellgren, S., Isaksson, H., Olsson, L., Palmqvist, H., & Flodén, J. (2024). Autonomous last-mile delivery robots: A literature review. *European Transport Research Review*, 16(1). <https://doi.org/10.1186/s12544-023-00629-7>
- Amazon. (2025). *Amazon Prime*. <https://www.amazon.com/gp/help/customer/display.html?nodeId=G6LDPN7YJHYKH2J6>
- Andlauer, F., & Laurell, A. (2024, May 13). *Analysis of the delayed roll-out of fully autonomous vehicles*. Drive Sweden. <https://www.drivesweden.net/sites/default/files/2024-05/analysis-of-the-delayed-roll-out-of-fully-autonomous-vehicles.-ver.240513.pdf>
- Archetti, C., & Bertazzi, L. (2020). Recent challenges in routing and inventory routing: E-commerce and last-mile delivery. *Networks*, 77(2), 255-268. <https://doi.org/10.1002/net.21995>
- Autonomous Vehicle Industry Association. (2024). *State of AV 2024*. [https://theavindustry.org/resources/2024\\_StateOfAV.pdf](https://theavindustry.org/resources/2024_StateOfAV.pdf)
- Association of Southeast Asian Nations. (2023). *ASEAN autonomous vehicle landscape report on regulatory pilot space (RPS) to facilitate cross-border digital data flows to enabling self-driving car in ASEAN*. [https://asean.org/wp-content/uploads/2024/04/ID\\_RPS-Report\\_ASEAN-AV-Landscape-Report-Final.pdf](https://asean.org/wp-content/uploads/2024/04/ID_RPS-Report_ASEAN-AV-Landscape-Report-Final.pdf)

- Benallou, I., Azmani, A., & Azmani, M. (2024). Behind the wheel: Understanding the risks for truck drivers in the era of the Internet of things and advancements in autonomous vehicles. *Scientific Journal of Silesian University of Technology. Series Transport*, 124, 25-36. <https://doi.org/10.20858/sjsutst.2024.124.2>
- Boschetti, M. A., & Novellani, S. (2023). Last-mile delivery with drone and lockers. *Networks*, 83(2), 213–235. <https://doi.org/10.1002/net.22190>
- Boysen, N., Fedtke, S., & Schwerdfeger, S. (2020). Last-mile delivery concepts: A survey from an operational research perspective. *OR Spectrum*, 43(1), 1-58. <https://doi.org/10.1007/s00291-020-00607-8>
- Boysen, N., Schwerdfeger, S., & Weidinger, F. (2018). Scheduling last-mile deliveries with truck-based autonomous robots. *European Journal of Operational Research*, 271(3), 1085–1099. <https://doi.org/10.1016/j.ejor.2018.05.058>
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77-101. <https://doi.org/10.1191/1478088706qp063oa>
- Channon, M., McCormick, L., & Noussia, K. (2019). *The law and autonomous vehicles*. Taylor & Francis.
- Chen, C., Demir, E., Hu, X., & Huang, H. (2025). Transforming last mile delivery with heterogeneous assistants: drones and delivery robots. *Journal of Heuristics*, 31(1). <https://doi.org/10.1007/s10732-024-09543-0>
- Cheng, X., & Lin, J. (2024). Is electric truck a viable alternative to diesel truck in long-haul operation? *Transportation Research Part D: Transport and Environment*, 129, 104119. <https://doi.org/10.1016/j.trd.2024.104119>
- Ciobotaru, G. and Chankov, S. (2021). Towards a taxonomy of crowdsourced delivery business models. *International Journal of Physical Distribution & Logistics Management*, 51(5), 460-485. <https://doi.org/10.1108/ijpdlm-10-2019-0326>
- Clark, T., Foster, L., Bryman, A., & Sloan, L. (2021). *Bryman's social research methods*. Oxford University Press.

- Clean Motion (2022). *Challenges and potential business applications of automated delivery vehicles – A brief overview*. Clean Motion AB.  
[https://fudinfo.trafikverket.se/fudinfoexternwebb/Publikationer/Publikationer\\_006201\\_006300/Publikation\\_006270/Challenges%20and%20potential%20business%20applications%20of%20automated%20delivery%20vehicles,%20a%20brief%20overview.pdf](https://fudinfo.trafikverket.se/fudinfoexternwebb/Publikationer/Publikationer_006201_006300/Publikation_006270/Challenges%20and%20potential%20business%20applications%20of%20automated%20delivery%20vehicles,%20a%20brief%20overview.pdf)
- Corejova, T., Jucha, P., Padourova, A., Strenitzerova, M., Stalmachova, K., & Valicova, A. (2022). E-commerce and last mile delivery technologies in the European countries. *Production Engineering Archives*, 28(3), 217–224.  
<https://doi.org/10.30657/pea.2022.28.26>
- Crayton, T. J., & Meier, B. M. (2017). Autonomous vehicles: Developing a public health research agenda to frame the future of transportation policy. *Journal of Transport & Health*, 6, 245-252. <https://doi.org/10.1016/j.jth.2017.04.004>
- Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, 13(3), 319. <https://doi.org/10.2307/249008>
- De Maio, A., Ghiani, G., Laganà, D., & Manni, E. (2024). Sustainable last-mile distribution with autonomous delivery robots and public transportation. *Transportation Research Part C Emerging Technologies*, 163, 104615. <https://doi.org/10.1016/j.trc.2024.104615>
- Encarnación, T., & Amaya, J. (2024). Determinants of parcel locker adoption for last-mile deliveries in urban and suburban areas. *Transportation Journal*, 64(1).  
<https://doi.org/10.1002/tjo3.12031>
- The European Commission. (2021). *Automated road transport: On the way to connected and cooperative automated mobility*. [https://cinea.ec.europa.eu/system/files/2021-10/ART-brochure\\_2021-web\\_2.pdf](https://cinea.ec.europa.eu/system/files/2021-10/ART-brochure_2021-web_2.pdf)
- Fagan, M., Gillies, B., & Guo, E. (2022, April). *Autonomous delivery vehicles: Why you should care and what you should do*. Taubman Center for State and Local Government, Harvard Kennedy School.  
[https://www.hks.harvard.edu/sites/default/files/Taubman/AVPI/Taubman-AVPI\\_ADV%20Publication\\_05-2022.pdf](https://www.hks.harvard.edu/sites/default/files/Taubman/AVPI/Taubman-AVPI_ADV%20Publication_05-2022.pdf)

- Flick, U. (2014). *An introduction to qualitative research*. SAGE Publications.
- Fritschy, C., & Spinler, S. (2019). The impact of autonomous trucks on business models in the automotive and logistics industry—a Delphi-based scenario study. *Technological Forecasting and Social Change*, 148, 119736.  
<https://doi.org/10.1016/j.techfore.2019.119736>
- Ganjipour, H., & Edrisi, A. (2023). Consumers' intention to use delivery robots in Iran: An integration of NAM, DOI, and TAM. *Case Studies on Transport Policy*, 13, 101024.  
<https://doi.org/10.1016/j.cstp.2023.101024>
- Garg, V., Niranjana, S., Prybutok, V., Pohlen, T., & Gligor, D. (2023). Drones in last-mile delivery: A systematic review on efficiency, accessibility, and sustainability. *Transportation Research Part D: Transport and Environment*, 123, 103831.  
<https://doi.org/10.1016/j.trd.2023.103831>
- Garus, A., Christidis, P., Mourzouchou, A., Duboz, L., & Ciuffo, B. (2023). Unravelling the last-mile conundrum: A comparative study of autonomous delivery robots, delivery bicycles, and light commercial vehicles in 14 varied European landscapes.  
<https://doi.org/10.2139/ssrn.4662866>
- Greenhalgh, T., Robert, G., MacFarlane, F., Bate, P., & Kyriakidou, O. (2004). Diffusion of innovations in service organizations: Systematic review and recommendations. *The Milbank Quarterly*, 82(4), 581-629. <https://doi.org/10.1111/j.0887-378x.2004.00325.x>
- Hansson, L. (2020). Regulatory governance in emerging technologies: The case of autonomous vehicles in Sweden and Norway. *Research in Transportation Economics*, 83, 100967.  
<https://doi.org/10.1016/j.retrec.2020.100967>
- Helmers, E., & Weiss, M. (2017). Advances and critical aspects in the life-cycle assessment of battery electric cars. *Energy and Emission Control Technologies*, 5, 1-18.  
<https://doi.org/10.2147/eect.s60408>
- Hou, J., Chen, G., Huang, J., Qiao, Y., Xiong, L., Wen, F., Knoll, A., & Jiang, C. (2023). Large-scale vehicle Platooning: Advances and challenges in scheduling and planning techniques. *Engineering*, 28, 26-48. <https://doi.org/10.1016/j.eng.2023.01.012>
- IKEA. (2025). *Explore delivery service options and pricing*.  
<https://www.ikea.com/us/en/customer-service/services/delivery/>

- IKEA. (2025). *Our view on decarbonising transport and logistics – IKEA global*.  
<https://www.ikea.com/global/en/our-business/our-view-on/decarbonising-transport/>
- Ingka Group. (2024, June 18). *Ingka investments makes minority investment in Waabi to revolutionize autonomous trucking with generative AI*.  
<https://www.ingka.com/newsroom/ingka-investments-makes-minority-investment-in-waabi-to-revolutionize-autonomous-trucking-with-generative-ai/>
- Janinhoff, L., Klein, R., Sailer, D., & Schoppa, J. M. (2024). Out-of-home delivery in last-mile logistics: A review. *Computers & Operations Research*, 168, 106686.  
<https://doi.org/10.1016/j.cor.2024.106686>
- Katiyar, N., Shukla, A., Chawla, N., Singh, R., Singh, S. K., & Husain, M. F. (2024). AI in autonomous vehicles: Opportunities, challenges, and regulatory implications. *Educational Administration: Theory and Practice*, 30(4), 6255–6264.  
<https://doi.org/10.53555/kuey.v30i4.2373>
- Kötschau, R., Scherr, N., Tilk, C., & Ehmke, J. F. (2024). Mobile home delivery parcel lockers. *Transportation Research Part E Logistics and Transportation Review*, 193, 103867.  
<https://doi.org/10.1016/j.tre.2024.103867>
- Kötschau, R., Soeffker, N., & Ehmke, J. F. (2023b). Mobile parcel lockers with individual customer service. *Networks*, 82(4), 506–526. <https://doi.org/10.1002/net.22173>
- Koul, S., & Eydgahi, A. (2018). Utilizing technology acceptance model (TAM) for driverless car technology adoption. *Journal of technology management & innovation*, 13(4), 37-46.  
<https://doi.org/10.4067/s0718-27242018000400037>
- Kouroutakis, A. E. (2019). Autonomous vehicles; Regulatory challenges and the response from UK and Germany. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.3441264>
- KPMG International. (2022). *2022 Autonomous Vehicles Readiness Index*.  
<https://assets.kpmg.com/content/dam/kpmg/cl/pdf/2016-2022/2018-01-kpmg-chile-advisory-autonomous-vehicles.pdf>

- Kundu, T., Goh, M., & Choi, T. (2025). Home delivery vs. out-of-home delivery: Syncretic value-based strategies for urban last-mile e-commerce logistics. *Transportation Research Part a Policy and Practice*, 193, 104309. <https://doi.org/10.1016/j.tra.2024.104309>
- Lee, D., & Hess, D. J. (2020). Regulations for on-road testing of connected and automated vehicles: Assessing the potential for global safety harmonization. *Transportation Research Part a Policy and Practice*, 136, 85–98. <https://doi.org/10.1016/j.tra.2020.03.026>
- Lee, T., Han, S. R., & Song, B. D. (2023). Optimization of OmniChannel distribution network using micro fulfillment center under demand uncertainty. *IEEE Access*, 11, 107496-107510. <https://doi.org/10.1109/access.2023.3317690>
- Lemardelé, C., Estrada, M., Pagès, L., & Bachofner, M. (2021). Potentialities of drones and ground autonomous delivery devices for last-mile logistics. *Transportation Research Part E: Logistics and Transportation Review*, 149, 102325. <https://doi.org/10.1016/j.tre.2021.102325>
- Litman, T. (2024, October 23). *Autonomous vehicle implementation predictions: Implications for transport planning*. Victoria Transport Policy Institute. <https://www.vtpi.org/avip.pdf>
- Lu, M., Huang, C., Wang, R., & Li, H. (2023). Customer's Adoption Intentions toward Autonomous Delivery Vehicle Services: Extending DOI Theory with Social Awkwardness and Use Experience. *Journal of Advanced Transportation*, 2023, 1–17. <https://doi.org/10.1155/2023/3440691>
- Lupi, M., Conte, D., & Farina, A. (2025). Last mile urban freight delivery: A new system based on platoons of automated vehicles. *Transport Policy*, 164, 42-59. <https://doi.org/10.1016/j.tranpol.2025.01.023>
- Lyons, T., & McDonald, N. C. (2022). Last-mile strategies for urban freight delivery: A systematic review. *Transportation Research Record: Journal of the Transportation Research Board*, 2677(1), 1141-1156. <https://doi.org/10.1177/03611981221103596>
- Lyytinen, K., & Damsgaard, J. (2001). What's wrong with the diffusion of innovation theory? *IFIP Advances in Information and Communication Technology*, 173-190. [https://doi.org/10.1007/978-0-387-35404-0\\_11](https://doi.org/10.1007/978-0-387-35404-0_11)

- Madleňák, R., & Madleňáková, L. (2020). Multi-criteria evaluation of E-shop methods of delivery from the customer's perspective. *Transport Problems*, 15(1), 5-14.  
<https://doi.org/10.21307/tp-2020-001>
- Martínez-Díaz, M. (2021). Platooning of connected automated vehicles on freeways: A bird's eye view. *Datasets*. <https://doi.org/10.36443/10259/6899>
- Merkert, R., Bliemer, M. C., & Fayyaz, M. (2022). Consumer preferences for innovative and traditional last-mile parcel delivery. *International Journal of Physical Distribution & Logistics Management*, 52(3), 261-284. <https://doi.org/10.1108/ijpdlm-01-2021-0013>
- Milioti, C., Pramadari, K., & Kelepouri, I. (2020). Modelling consumers' acceptance for the click and collect service. *Journal of Retailing and Consumer Services*, 56, 102149.  
<https://doi.org/10.1016/j.jretconser.2020.102149>
- Mittal, N., Udayakumar, P. D., Raghuram, G., & Bajaj, N. (2018). The endemic issue of truck driver shortage - A comparative study between India and the United States. *Research in Transportation Economics*, 71, 76–84. <https://doi.org/10.1016/j.retrec.2018.06.005>
- Mohammad, W. A., Diab, Y. N., Elomri, A., & Triki, C. (2023). Innovative solutions in last mile delivery: concepts, practices, challenges, and future directions. *Supply Chain Forum an International Journal*, 24(2), 151–169. <https://doi.org/10.1080/16258312.2023.2173488>
- Molin, E., Kosicki, M., & Van Duin, R. (2022). Consumer preferences for parcel delivery methods. *European Journal of Transport and Infrastructure Research*, 22(2).  
<https://doi.org/10.18757/ejtir.2022.22.2.6427>
- Monios, J., & Bergqvist, R. (2019). Logistics and the networked society: A conceptual framework for smart network business models using electric autonomous vehicles (EAVs). *Technological Forecasting and Social Change*, 151, 119824.  
<https://doi.org/10.1016/j.techfore.2019.119824>
- National Highway Traffic Safety Administration. (2023, June 30). *Automated vehicles: Report to Congress*. U.S. Department of Transportation.  
<https://www.nhtsa.gov/sites/nhtsa.gov/files/2023-06/Automated-Vehicles-Report-to-Congress-06302023.pdf>

- NVIDIA (2025). *NVIDIA autonomous vehicles safety report*. <https://images.nvidia.com/aem-dam/en-zz/Solutions/auto-self-driving-safety-report.pdf>
- Ostermeier, M., Heimfarth, A., & Hübner, A. (2023). The multi-vehicle truck-and-robot routing problem for last-mile delivery. *European Journal of Operational Research*, 310(2), 680–697. <https://doi.org/10.1016/j.ejor.2023.03.031>
- Paddeu, D., & Denby, J. (2021). Decarbonising road freight: Is truck automation and platooning an opportunity? *Clean Technologies and Environmental Policy*, 24(4), 1021-1035. <https://doi.org/10.1007/s10098-020-02020-9>
- Pahwa, A., & Jaller, M. (2022). A cost-based comparative analysis of different last-mile strategies for e-Commerce delivery. *Transportation Research Part E: Logistics and Transportation Review*, 164, 102783. <https://doi.org/10.1016/j.tre.2022.102783>
- Pattinson, J., & Chen, H. (2019). A barrier to innovation: Europe's ad-hoc cross-border framework for testing prototype autonomous vehicles. *International Review of Law, Computers & Technology*, 34(1), 108-122. <https://doi.org/10.1080/13600869.2019.1696651>
- Peinkofer, S. T., Esper, T. L., Smith, R. J., & Williams, B. D. (2021). Retail "Save the sale" tactics: Consumer perceptions of in-store logistics service recovery. *Journal of Business Logistics*, 43(2), 238-264. <https://doi.org/10.1111/jbl.12294>
- Pourmohammadreza, N., Jokar, M. R. A., & Van Woensel, T. (2025). Last-Mile Logistics with Alternative Delivery Locations: A Systematic Literature Review. *Results in Engineering*, 104085. <https://doi.org/10.1016/j.rineng.2025.104085>
- Priscilia, S. A., Indra, Z., & Putri, F. P. (2024). Dynamic programming implementation for delivery route optimization in e-commerce logistics. *Jurnal Indonesia Sosial Teknologi*, 5(10). <https://doi.org/10.59141/jist.v5i10.6423>
- Punev, A. (2020). Autonomous vehicles: The need for a separate European legal framework. *European View*, 19(1), 95-102. <https://doi.org/10.1177/1781685820912043>

- Qiu, H., Wang, S., Yin, Y., Wang, D., & Wang, Y. (2021). A deep reinforcement learning-based approach for the home delivery and installation routing problem. *International Journal of Production Economics*, 244, 108362. <https://doi.org/10.1016/j.ijpe.2021.108362>
- Raghunatha, A., Lindkvist, E., Thollander, P., Hansson, E., & Jonsson, G. (2023). Critical assessment of emissions, costs, and time for last-mile goods delivery by drones versus trucks. *Scientific Reports*, 13(1). <https://doi.org/10.1038/s41598-023-38922-z>
- Raj, R., Singh, A., Kumar, V., De, T., & Singh, S. (2024). Assessing the e-Commerce last-mile logistics' hidden risk hurdles. *Cleaner Logistics and Supply Chain*, 10, 100131. <https://doi.org/10.1016/j.clscn.2023.100131>
- Ratchford, B., Soysal, G., Zentner, A., & Gauri, D. K. (2022). Online and offline retailing: What we know and directions for future research. *Journal of Retailing*, 98(1), 152–177. <https://doi.org/10.1016/j.jretai.2022.02.007>
- Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). Simon & Schuster.
- SAE International. (2021). *SAE levels of driving Automation™ refined for clarity and international audience*. The Mission of SAE International is to advance mobility knowledge and solutions. <https://www.sae.org/blog/sae-j3016-update>
- Schepis, D., Purchase, S., Oлару, D., Smith, B., & Ellis, N. (2023). How governments influence autonomous vehicle (AV) innovation. *Transportation Research Part a Policy and Practice*, 178, 103874. <https://doi.org/10.1016/j.tra.2023.103874>
- Schlenther, T., Martins-Turner, K., Bischoff, J. F., & Nagel, K. (2020). Potential of private autonomous vehicles for parcel delivery. *Transportation Research Record: Journal of the Transportation Research Board*, 2674(11), 520-531. <https://doi.org/10.1177/0361198120949878>
- Schuster, A. M., Agrawal, S., Britt, N., Sperry, D., Van Fossen, J. A., Wang, S., Mack, E. A., Liberman, J., & Cotten, S. R. (2023). Will automated vehicles solve the truck driver shortages? Perspectives from the trucking industry. *Technology in Society*, 74, 102313. <https://doi.org/10.1016/j.techsoc.2023.102313>

- Schwerdfeger, S., & Boysen, N. (2022). Who moves the locker? A benchmark study of alternative mobile parcel locker concepts. *SSRN Electronic Journal*.  
<https://doi.org/10.2139/ssrn.4063099>
- Sever, T., & Contissa, G. (2024). Automated driving regulations – where are we now? *Transportation Research Interdisciplinary Perspectives*, 24, 101033.  
<https://doi.org/10.1016/j.trip.2024.101033>
- Silva, Ó., Cordera, R., González-González, E., & Nogués, S. (2022). Environmental impacts of autonomous vehicles: A review of the scientific literature. *The Science of the Total Environment*, 830, 154615. <https://doi.org/10.1016/j.scitotenv.2022.154615>
- Siragusa, C., Tumino, A., Mangiaracina, R., & Perego, A. (2020). Electric vehicles performing last-mile delivery in B2C e-Commerce: An economic and environmental assessment. *International Journal of Sustainable Transportation*, 16(1), 22-33.  
<https://doi.org/10.1080/15568318.2020.1847367>
- Srinivas, S., Ramachandiran, S., & Rajendran, S. (2022). Autonomous robot-driven deliveries: A review of recent developments and future directions. *Transportation Research Part E: Logistics and Transportation Review*, 165, 102834.  
<https://doi.org/10.1016/j.tre.2022.102834>
- Statista. (2025). *Ecommerce - Worldwide | Statista market forecast*. <https://www.statista.com/outlook/emo/ecommerce/worldwide>
- Steer Group. (2020). *Economic impacts of autonomous delivery services in the US*.  
[https://steergroup.com/sites/default/files/2020-09/200910\\_%20Nuro\\_Final\\_Report\\_Public.pdf](https://steergroup.com/sites/default/files/2020-09/200910_%20Nuro_Final_Report_Public.pdf)
- Tadić, S., & Veljović, M. (2020). Logistics flows of household. *Tehnika*, 75(2), 225-237.  
<https://doi.org/10.5937/tehnika2002225t>
- U.S. Department of Transportation. (2021, January). *Automated vehicles comprehensive plan*.  
[https://www.transportation.gov/sites/dot.gov/files/2021-01/USDOT\\_AVCP.pdf](https://www.transportation.gov/sites/dot.gov/files/2021-01/USDOT_AVCP.pdf)

- U.S. Postal Service Office of Inspector General. (2017, October 2). *Autonomous vehicles for the Postal Service* (Report No. RARC-WP-18-001).  
<https://www.uspsoig.gov/sites/default/files/reports/2023-01/RARC-WP-18-001.pdf>
- Uvet, H., Dickens, J., Anderson, J., Glassburner, A., & Boone, C. A. (2023). A hybrid e-logistics service quality approach: modeling the evolution of B2C e-commerce. *The International Journal of Logistics Management*, 35(4), 1303–1331. <https://doi.org/10.1108/ijlm-06-2023-0238>
- Vakulenko, Y., Hellström, D., & Hjort, K. (2018). What's in the parcel locker? Exploring customer value in e-Commerce last mile delivery. *Journal of Business Research*, 88, 421-427. <https://doi.org/10.1016/j.jbusres.2017.11.033>
- Wadud, Z., MacKenzie, D., & Leiby, P. (2016). Help or hindrance? The travel, energy and carbon impacts of highly automated vehicles. *Transportation Research Part a Policy and Practice*, 86, 1–18. <https://doi.org/10.1016/j.tra.2015.12.001>
- Wang, M., Wood, L., & Wang, B. (2021). Transportation capacity shortage influence on logistics performance: Evidence from the Australian logistics service providers' driver shortage. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.3957222>
- Wang, Y., & Sarkis, J. (2021). Emerging digitalisation technologies in freight transport and logistics: Current trends and future directions. *Transportation Research Part E: Logistics and Transportation Review*, 148, 102291. <https://doi.org/10.1016/j.tre.2021.102291>
- Wejnert, B. (2002). Integrating models of diffusion of innovations: A conceptual framework. *Annual Review of Sociology*, 28(1), 297-326.  
<https://doi.org/10.1146/annurev.soc.28.110601.141051>
- Yu, S., & Puchinger, J. (2024). Collaborative truck–robot deliveries: challenges, models, and methods. *Annals of Operations Research*. <https://doi.org/10.1007/s10479-024-06127-w>
- Yuen, K. F., Cai, L., Qi, G., & Wang, X. (2020). Factors influencing autonomous vehicle adoption: An application of the technology acceptance model and innovation diffusion theory. *Technology Analysis & Strategic Management*, 33(5), 505-519.  
<https://doi.org/10.1080/09537325.2020.1826423>

*Zoom privacy statement.* (2025, April 15). Zoom.

[https://www.zoom.com/en/trust/privacy/privacy-statement/?cms\\_guid=false&lang=en-US](https://www.zoom.com/en/trust/privacy/privacy-statement/?cms_guid=false&lang=en-US)

# Appendices

## a. Interview Guide

| INTERVIEW GUIDE            |  |   |
|----------------------------|--|---|
| Pre-Interview Brief        | This interview will be recorded so that we can transcribe and use it in the data analysis part of our thesis. The information will be stored until May 18, the submission date. Afterwards, we will delete the data. Even though we have collected some personal information from you, you will remain anonymous in the text and will be referred to using a participant number. The questions are not aimed at collecting sensitive information, but you have the right to skip any question if you feel uncomfortable. And at any point you may withdraw from the interview. |   |
| Introductory Questions/Ice | Tell us about yourself and tell us about what you do.  |   |
|                            | How long have you worked for your organization?  |   |
| Main Questions             |  |   |
| Deliveries                 | If applicable, can you tell us about your experience working with last-mile deliveries?  | Connection to Literature and theory<br>Guiding Question   |
|                            | What are the biggest challenges you see or encounter with last-mile deliveries?  | Guiding Question  |
|                            | Which part of last mile delivery processes do you think can be inefficient?  | Archetti & Bertazzi, 2020; Silva et al. 2022; Ostermeier et al., 2023.  |
| Customers                  | What delivery type do the customers in your country mostly prefer? Why do you think so?  | Vakulenko et al. 2018; Tadić & Veljović, 2020.  |
|                            | Which types of deliveries is more challenging?   | Tadić & Veljović, 2020.   |
|                            | What do the customers expect in last mile deliveries? How did their expectations change over time?   | Boschetti & Novellani, 2023; Purmohammadreza et al., 2025.  |
|                            | Are there specific infrastructure or regulatory requirements in your country for deliveries?   | Monios & Bergqvist, 2019; Lee & Hess, 2020; Corejova et al., 2022; Tran & Le, 2022; Chen et al., 2025.                        |
|                            | What type of vehicles do you use for last mile deliveries? (we can add probing questions here)   | Mittal et al. 2018  |
|                            | In your opinion, how should the technical features be like for a delivery vehicle?   | Rogers 2003, related to the DOI attribute: Relative Advantage.  |
| Automation                 | What are the most resource-intensive or labor-intensive parts of the last mile deliveries that could benefit from more automation?   | Mittal et al. 2018  |
|                            | Are there any physical challenges for a fulfillment unit that affect operational efficiency?   | Peinkofer et al., 2020; Ray & Paul, 2023  |
|                            | Does your country face challenges regarding driver availability? In what way?  | Crayton & Meier, 2017   |
|                            | Do you see any areas in last mile delivery where rising costs are becoming unsustainable?  | Silva et al. 2022.  |
|                            | How do you see the role of human delivery personnel changing as automation increases?  | Rogers 2003, related to the DOI attribute: Relative Advantage   |
|                            | Do you think there could be roles or tasks in last mile logistics that could be automated? If yes, which ones?   | Guiding Question  |
|                            | What changes in your country is needed before your organization could integrate more automation in transport?  | Rogers 2003, related to the DOI attribute: Compatability  |
| Autonomous Vehicles        | How familiar are you with autonomous vehicles (self-driving vehicles)? What do you think about them?   | Rogers 2003, related to the DOI attribute: Complexity, Observability  |
|                            | Have you ever had any experiences with AVs? How do you think they could be applicable in your organization?  | Rogers 2003, related to the DOI attribute: Trialability   |
|                            | How do you think AVs could affect last mile delivery efficiency, from the fulfillment unit to the customer?  | Rogers 2003, related to the DOI attribute: Relative Advantage and Compatability; Lemardelé et al. 2021; Alverhed et al. 2024. |
|                            | How do you think customers in your country would react to deliveries using autonomous vehicles?  | Rogers 2003, related to the DOI attribute: Complexity, Compatability ;Yuen et al. 2020; Ganjipour & Edrisi, 2023.             |
|                            | Do you think there will be any delivery processes that will still need human involvement in the future? If yes, which parts?   | Future Expectations   |

## b. Survey to identify interviewees

### Autonomous Delivery Exploration

Hello,

We are Ceren Özel and Shadman Azad, students from Lund University, conducting our master's thesis in collaboration with IKEA. Our research, in supervision of Nynke Mensorides from IKEA, explores the operational feasibility of autonomous vehicles in IKEA's delivery operations, examining their potential impact on efficiency, labor, and sustainability.

To help us identify potential interviewees, we kindly ask you to complete this short preliminary survey. The survey will take approximately 3 minutes to complete.

For questions you can contact us through our emails: [ce2354oz-s@student.lu.se](mailto:ce2354oz-s@student.lu.se) ; [md4807az-s@student.lu.se](mailto:md4807az-s@student.lu.se) Or reach to our supervisor through [nynke.mensorides@ingka.ikea.com](mailto:nynke.mensorides@ingka.ikea.com).

Thank you in advance for your time and valuable input!

\* Required

What is your name? \*

Enter your answer

Which IKEA country are you employed in? \*

Enter your answer

Your company email address \*

Enter your answer

What is your job title? \*

Enter your answer

How long have you worked for IKEA (in years)? \*

Enter your answer

Please tick the topics that are of closest in relevancy to your job description. You may choose multiple. \*

Please select at most 3 options.

- Logistics & Supply Chain Operations
- Transport & Last-Mile Delivery
- E-commerce & Retail Logistics
- Automation, Robotics & Digital Transformation
- Innovation & Process Improvement
- Sustainability & Green Logistics
- Transport Compliance & Risk Management
- Regulatory & Government Affairs in AV Logistics

How familiar are you with autonomous vehicles (self-driving vehicles)? \*

1 - Not familiar at all to 5 - Very familiar

|                       |                       |                       |                       |                       |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| 1                     | 2                     | 3                     | 4                     | 5                     |
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

Do you or anyone in your team have experience in any way working with projects with autonomous vehicles (in and outside of IKEA)? \*

- Yes
- No

Would you like to participate in an interview with us? \*

Lasting maximum 1 hour, taking place March and early April

- Yes
- No

### c. Codes from the interviews

| Codes  | Themes                              |
|--|-------------------------------------|
| Capacity Vs Demand   | Balancing trade offs                |
| Capacity Vs Volume Forecast  |                                     |
| Cost Vs Customer Needs   |                                     |
| Cost Vs Sustainability   |                                     |
| Cost, Payload, Range   |                                     |
| Price Vs Speed   | Amazon effect                       |
| Amazon Impact On Customer Expectations   |                                     |
| Free Delivery  |                                     |
| Higher Degree Of Expectation From Urban Customers                                    |                                     |
| Market Competition   |                                     |
| Narrow Delivery Time Expectation   | Fill rate utilization               |
| Short Lead Time Expectation  |                                     |
| Compartmentalization Lowers The Fill Rate  |                                     |
| Fill Rate Utilization is Hard to Achieve   | Current and expected labor issues   |
| Inconsistent Loading Is A Barrier To Full Utilization Of Entire Space                |                                     |
| Inefficient Stacking Making Processes Inefficient                                    |                                     |
| Driver Shortage Exists   | EV challenges                       |
| Labor is Expensive   |                                     |
| Labor Shortage for Other Processes Exists  |                                     |
| Labor Shortage Forces Innovation   |                                     |
| Low Visibility in LMD due to Outsourcing Deliveries                                  |                                     |
| Loss Of Man Hours Due To Waiting Time  | Damage issues                       |
| Outsourced Workers   |                                     |
| Unavailability Of Labor  |                                     |
| Ev Range is Effected By Weather  | Weight and size challenges          |
| Ev Range is Insufficient   |                                     |
| Evs are Expensive  |                                     |
| Waiting For Vehicle Charging   |                                     |
| Damage Control   | Expected legislative changes        |
| Damage In Transport  |                                     |
| Damage Control Is Expensive  |                                     |
| IV2 Based on Weight  | Operational and Planning challenges |
| IV2 Delivery Based on Dimensions   |                                     |
| Home Delivery Is Painful   |                                     |
| Loading & Unloading Ergonomics   |                                     |
| No Elevators   |                                     |
| Non Uniformity Of Item Shapes  | Expected legislative changes        |
| Parcel Locker For Bigger Orders is Challenging                                       |                                     |
| Weight Of Articles   |                                     |
| Diesel Operability Will Change In Terms Of Area & Regulation                         | Operational and Planning challenges |
| Future Legislation for Europe  |                                     |
| Legislative Barriers   |                                     |
| Reality Vs Necessity Gap In Number Of Trucks Required                                |                                     |
| Vehicle Capacity   |                                     |
| Traffic Congestion   |                                     |
| Contrast In Efficiency Between Internal Movement And Customer Order Preparation      |                                     |
| Forecast Innacuracy About LMD  |                                     |
| Inefficient Routes   |                                     |
| Inefficient Stacking Inside the Vehicle  |                                     |
| Infrastructure and Lack Of Parking Spots   |                                     |
| Vehicle Maintenance Issues   |                                     |
| Process Difference Based on Delivery Area  |                                     |
| Vehicle Range Sufficiency Is Relative  |                                     |
| Scheduling Of Deliveries   |                                     |
| Split Deliveries - Multiple Drop Offs To Same Customer Due To Order Non-Accumulation |                                     |
| Tail Lift Adds To The Payload  |                                     |
| Time Loss In Standalone Order Preparation Of Same Items Due To Variance In Orders    |                                     |
| Time Management Issues In LMD  |                                     |
| Too Many Handover Points   | Issus stemming from customers       |
| Unable To Offer Some Delivery Options Due To System Limitations                      |                                     |
| Customer Misunderstanding Delivery Types - Curbside VS Room of Choice                |                                     |
| Failed Deliveries  | Handover                            |
| Handover   |                                     |

| Codes   | Themes                                     |
|---|--|
| Sustainability Concern Vehicle Size                       | Capacity to Cover the Entire Product Range |
| Fill Rate Utilization                                     |  |
| Weight Of Articles  |  |
| Suitable Area And Capacity                                |  |
| Big Payload   |  |
| Capacity  |  |
| Dimensions Suited To Cover Entire Product Range           |  |
| No Lifter, Deducts From Payload                           |  |
| Feature To Avoid Damages                                  | In Transit Product Safety Features         |
| Good Height   |  |
| Organize To Avoid Damage                                  |  |
| Padding In Cabin To Prevent Damages                       |  |
| Sturdy Walls  |  |
| Upright Positioning Is Safer For Delivery                 | Segregation of Items                       |
| Heavy Items On The Bottom And Lighter Ones Higher         |  |
| Order Segregation   |  |
| Mobile Lockers  |  |
| Single Order Or Multi Order - Separated                   | Vehicle Safety Features                    |
| Safety Concern  |  |
| Perceived As Safe   |  |
| Responsibility Non Ambiguity In Accidents                 |  |
| Av Margin Of Error Is Held To A Higher Degree Of Standard |  |
| Reduced Dependency On Humans                              | Handover Support Features                  |
| Handover Is Questionable                                  |  |
| Handover Process Support (Accessibility)                  |  |
| Handover Process Support (Mechanical Aid)                 |  |
| Handover Process Support (Robotic Aid)                    |  |
| Easy Handover   | Optimized Routing                          |
| Ai Powered Routing  |  |
| Routing And Delivery Optimization                         |  |
| Sustainable Routing For Vehicle                           | Tracking & Visibility Features             |
| Trackers To Identify Loaded Items                         |  |
| Visibility  | Sufficient Range                           |
| Range Sufficiency Is Relative                             |  |
| Big Range   |  |
| Sustainability Concern With Battery                       |  |
| Battery Recharge Or Battery Swap                          |  |
| Convenience And Comprehensibility                         | Customer Interaction Features              |
| Ability To Interact With The Customer                     |  |
| Accessibility   | Flexibility in Operations                  |
| Wide Delivery Timeframe For Collection                    |  |
| Limitless Driving Hours                                   |  |
| Adjusting To Match Infrastructure                         |  |
| Mixed Setup For Av Delivery                               |  |

## d. Consent form template



**LUNDS**  
UNIVERSITET

### Consent to participate in a Master Thesis at the Faculty of Social Sciences

I agree to participate in the thesis about the use of autonomous vehicles in last mile deliveries.  
*The dissertation is a student project and personal information will be collected to be processed.*

#### Information on the processing of personal data

The following personal data will be processed:

Name  
Job title and description  
E-mail address  
Company information  
Audio and transcription data

Personal data will be processed in the following ways:

The participants will be referred to as “participants” in the text and will remain fully anonymous.  
The interviews will be transcribed to be used in the data analysis process.  
The transcription process will be conducted solely by the authors and transcriptions will not be shared via cloud networks.  
Transcribed interviews will be deleted after the submission of the thesis (May 18, 2025).

We do not share your personal data with third parties.

Lund University, Box 117, 221 00 Lund, Sweden, with organisation number 202100-3211 is the controller. You can find Lund University's privacy policy at [www.lu.se/integritet](http://www.lu.se/integritet)

You have the right to receive information about the personal data we process about you. You also have the right to have inaccurate personal data about you corrected. If you have a complaint about our processing of your personal data, you can contact our Data Protection Officer at [dataskyddsbud@lu.se](mailto:dataskyddsbud@lu.se). You also have the right to lodge a complaint with the supervisory authority (the Data Protection Authority, IMY) if you believe that we are processing your personal data incorrectly.

I agree to participate in the thesis about the use of autonomous vehicles in last mile deliveries.

|          |                    |
|----------|--------------------|
| Location | Signature          |
| Date     | Name clarification |

## e. Reports used in document analysis

| Report Title   | Publishing Organization                          | Published Year |
|--|--|----------------|
| The Pathway To Driverless Cars: Summary Report And Action Plan   | Department for Transport (the UK)                | 2015           |
| Future Environment Net Assessment: Autonomous Vehicles   | U.S Department of Homeland Security              | 2017           |
| Autonomous Vehicles For The Postal Service   | United States Postal Service                     | 2017           |
| The Autonomous Car: A Consumer Perspective   | CapGemini Research Institute                     | 2019           |
| Autonomous Vehicle Feaibility Study  | Nevada Department of Transportation              | 2019           |
| Challenges And Potential Business Applications Of Automated Delivery Vehicles – A Brief Overview                 | Clean Motion                                     | 2020           |
| 2020 Autonomous Vehicles Readiness Index   | KPMG   | 2020           |
| Economic Impacts Of Autonomous Delivery Services In The Us   | Nuro   | 2020           |
| Automated Road Transport   | The European Commission                          | 2020           |
| Autonomous Trucks Lead The Way   | Deloitte   | 2021           |
| Issues In Autonomous Vehicles Testing And Deployment   | National Highway Traffic Safety Administration   | 2021           |
| Automated Vehicles: Comprehensive Plan   | U.S Department of Transportation                 | 2021           |
| Levelling Up: China’s race to an autonomous future   | KPMG   | 2022           |
| Autonomous Delivery Vehicles: Why You Should Care And What You Should Do   | TAUBMAN Center for State and Local Government    | 2022           |
| Autonomous Delivery Vehicle As A Disruptive Technology: How To Shape The Future With A Focus On Safety?          | U.S Department of Transportation                 | 2022           |
| Regulatory Pilot Space (Rps) To Facilitate Cross-Border Digital Data Flows To Enabling Self-Driving Car In Asean | ASEAN  | 2023           |
| More Autonomous Trucks Are Hitting The Road. How Should Insurers Be Changing Lanes On Coverage?                  | Deloitte   | 2023           |
| Autonomous driving’s future: Convenient and connected  | McKinsey & Company                               | 2023           |
| Automated Vehicles: Report To Congress   | National Highway Traffic Safety Administration   | 2023           |
| Preparing Infrastructure for Automated Vehicles  | OECD   | 2023           |
| How autonomous technology is revolutionizing mobility and manufacturing  | Shawn Kimmel, EY                                 | 2023           |
| State Of Av Report   | AVIA   | 2024           |
| Analysis Of The Delayed Roll-Out Of Fully Autonomous Vehicles  | Felix Andlauer & Adam Laurell, Drive Sweden      | 2024           |
| Autonomous Vehicle Implementation Predictions  | Todd Litman, Victoria Transport Policy Institute | 2024           |
| How China Is Shaping The Autonomous Driving Industry   | Business Sweden                                  | 2025           |
| The age of autonomous technologies in insurance: separating myth from reality                                    | Chris Raimondo, EY                               | 2025           |
| Nvidia Autonomous Vehicles Safety Report   | Nvidia   | 2025           |