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Automation in the transport sector: how the use of self-driving vehicles impacts the efficiency of urban delivery networks

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To my parents,

Without your love and advice,
so many of my achievements
would have been insurmountable
obstacles

ABSTRACT

Due to the prominent level of technology attained, companies try to stay one step ahead of change by offering the most technologically advanced products and services possible. These services include Last-Mile delivery, whose latest developments involve the inclusion of process automation, that is the area of research on which this study is based.

The aim of the research is therefore to understand whether these technologically advanced solutions actually lead to economic efficiency. In order to do so, a literature review was conducted on the topics of last-mile delivery, self-driving vehicles, and economic efficiency in this area. Subsequently, by conducting semi-structured interviews with companies in the Swedish territory, the study analyses the cost factors associated with such innovations and the companies' perceptions of efficiency. The results of the study help to understand how the use of self-driving vehicles impacts efficiency, in terms of costs, of urban last-mile delivery, and what the future developments of this technology will potentially be.

Keywords: “Last-Mile Delivery”, “Automation”, “Self-Driving Vehicles”, “Efficiency”, “Cost Factors”, “Urban Logistics”, “Freight Transportation”

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1. INTRODUCTION

In recent years, due to the phenomenon of growing urbanization and the consequent changes in logistics, we have seen a considerable growth in the movement of urban commodities worldwide.

This sector has been getting bigger and bigger thanks to the advent of e-commerce, which has been experiencing massive growth, so much so that its revenues reached approximately $4.9 trillion in 2021 and are expected to reach almost $5.5 trillion in 2022. According to Statista, this number will become about $7.4 trillion by 2025.[1]

The contributions of the pandemic, which impacted greatly to this increase as people suddenly started buying the things they needed online in a general fear at the time, were added to this already positive trend.[2] It was thanks to the development of the home delivery system that some of the constraints posed by Covid-19 were alleviated, such as the inability to leave the house to shop for groceries or buy food. Because of these constraints, people started ordering the items they needed at home to avoid leaving it. [3] Given this significant increase in deliveries, it became necessary to develop the supply chain to be able to provide a more reliable, faster, and smarter service so as to have a presence that can excel in the sector.[4]

Today, more and more operators deal with this type of delivery, and it has therefore become necessary to develop innovations concerning logistical hubs and means of delivery, which focus in particular on information systems that optimize the management of journeys, organizations within hubs, new and different forms of mobility in the city and the training of human resources.[5] Automation technology has advanced greatly in this regard over the last decade, which has aided in bringing innovation to the Last-Mile delivery market. According to Grolms (2019), it has been predicted that automation in this area will account for up to 80% of B2C (Business-to-Customers) deliveries.[6]

In addition, because this is the least efficient step in the logistics process, and because it is the most crucial step in the delivery process, organizations strive to make it as efficient and trouble-free as possible.[7] This inefficiency is due to the fact that orders are small and destinations are dispersed along

[1] Chevalier, 2022: *Retail e-commerce sales worldwide from 2014 to 2025*
[2] Suguna, Shah, Karthik Raj, & Suresh, 2021: *A study on the influential factors of the last mile delivery projects during Covid-19 era*
[3] Unnikrishnan & Figliozzi, 2020: *A Study of the Impact of COVID-19 on Home Delivery Purchases and Expenditures*
[4] Sarma, 2020: *Change is the only constant in last-mile delivery*
[5] ASviS, 2022: *LA CITY LOGISTIC*
[6] Grolms, 2019: *Autonomous Shuttles and Delivery Robots*.
[7] Vakulenko, Shamps, Hellström, & Hjort, 2019: *Service innovation in e-commerce last mile delivery: mapping the e-customer journey*

the way, which also makes it very expensive compared to the other elements of the delivery process. For a company, this can cost up to half of the total logistics costs. All this makes it important to understand how to reduce expenses.[8]

1.1 Problem Discussion

The logistics of the Last-Mile is a very in-depth topic in the literature in which one can find numerous definitions and regards. This is a fundamentally important part of the production process, and the last, so many authors agree that this should be the part of the supply chain that works best.[9] Despite this, it is repeatedly stated that this is the least efficient part of the production chain and that it is, therefore, necessary to try to find solutions that enable its implementation and optimisation.[10]

In order to address the challenges related to last mile delivery, the latest technologies can come to the rescue, such as self-driving vehicles, which are representing a real revolution in the field of urban logistics, thanks to which it is also possible to solve many problems that exist today, such as environmental and urban traffic problems.[11] At the same time, however, these vehicles can bring problems, such as those related to privacy.[12]

With this in mind, although much research can be found in academic publications on the characteristics of vehicles and their components, there are no publications accessible to this author that analyse the cost-efficiency of self-driving vehicles when applied to the last-mile delivery sector. Therefore, the research problem that it is proposed to solve is an existing gap in the literature due to the scarcity of existing academic works linking the use of self-driving vehicles to last-mile delivery and, even more so, the latter concept to that of efficiency.

[8] Mangiaracina, Perego, Seghezzi, & Tumino, 2019: *Innovative solutions to increase last-mile delivery efficiency in B2C e-commerce: a literature review*
[9] Olsson, Hellström, & Pålsson, 2019: *Framework of Last Mile Logistics Research: A Systematic Review of the Literature*
[10] Mangiaracina, Perego, Seghezzi, & Tumino, 2019: *Innovative solutions to increase last-mile delivery efficiency in B2C e-commerce: a literature review*
[11] Saeeda, Burris, Labi, & Sinha, 2020: *An empirical discourse on forecasting the use of autonomous vehicles using consumers' preferences*
[12] Suguna, Shah, Karthik Raj, & Suresh, 2021: *A study on the influential factors of the last mile delivery projects during Covid-19 era*

1.2Purpose and Research Question

The topic of this research is the efficiency of Last-Mile delivery via self-driving vehicles. The aim of this research is to analyse the impacts of this new automation technology on the transport of goods at an urban level, focusing on the costs this brings to businesses but also on other efficiency-related issues such as speed and sustainability, and to understand the opportunities and limitations of this technological choice.

In this thesis, the author, aims to fill the aforementioned academic gap by linking all these topics by analysing existing works on the vehicles that are used for this type of delivery today, autonomous vehicles, urban logistics, last-mile logistics, and cost-efficiency in logistics. The research question that encapsulates this aim is, therefore:

RQ1: *How does the use of self-driving vehicles impact the efficiency of the deliveries compared to the traditional delivery system?*

Sub-question 1: *Which are the main cost factors that impact last-mile delivery?*

1.3Delimitations

The first delimitation is geographical, as the study is based on a population of companies all from the same country, Sweden. This choice was made because of the variety of realities existing in this territory in this particular field and because it was easier for the author to come into contact with them. Another delimitation is that this research is predominantly based on cost factors, so the interview guide does not take into consideration other factors that relate to efficiency anyway.

1.4Disposition

For ease of reading, the way the search is organized is shown. This is divided into six sections as follows:

INTRODUCTION
- The first chapter introduces the research, the purpose and the research questions formulated. Subsequently, the delimitations are affirmed and the structure of the thesis is explained.

LITERATURE REVIEW
- The second chapter is an excursus of the literature review, touching on the topics of city logistics, self-driving vehicles and efficiency in the Last-Mile delivery sector.

METHODOLOGY
- The third chapter explores research strategy, research design, research methods and research quality.

EMPIRICAL FINIDNGS
- The fourth chapter presents the data collected through the semi-structured interviews, grouped by macro-themes.

DATA ANALYSIS
- In the fifth chapter the empirical results are also elaborated in the light of the previously conducted literature review.

CONCLUSIONS
- The sixth chapter contains answers to the research questions, research limitations, implications and recommendations for future research.

2. LITERATURE REVIEW

The literature review section investigates what has already been studied in earlier research in order to provide a theoretical basis for the study under review. In particular, this section is divided into three parts: in the first part, starting with the definition of the concept of "city logistics", we assess how the advent of digitalization has brought about changes in this regard, up to the most recent contributions made by the advent of the Covid-19 pandemic. The growing role of e-commerce to concerning the transport of goods is also further detailed at this point. The second part explains the arrival of the latest autonomous driving vehicles with an overview of the distinct kinds of solutions that are in use in this field. Finally, the third part covers earlier studies on efficiency in this sector and what variables need to be considered.

2.1City Logistics: a brief introduction

When we refer to city logistics, we refer to three main processes, or milestones, namely First-Mile logistics, Middle-Mile logistics, and Last-Mile logistics.

According to Sarma (2020), the definition of the exact path defined as the First-Mile may change depending on the nature of the industry. In general, we say that the First-Mile is the movement that goods make from the time they leave the plant where they were originally produced or the warehouse where they were stored to the time, they arrive at the place through which they are sold in the marketplace, such as retail stores or wholesalers. In the case of sales made online, for example, the First-Mile is the path that packages take from the seller's location until they reach the distribution centre found in the customer's city.

The Second-Mile or Middle-Mile logistics in the supply chain is not necessarily present in all industries. The concept refers to the transportation of goods, if necessary, from a warehouse to the retail or wholesale point where they are sold to the end consumer in the surrounding city or town. To ensure that stores have sufficient stock and are replenished at the right time, sales planning plays a crucial role in this phase of logistics.

Finally, the Last-Mile Logistics is the complete process formed by the planning, implementation, and control of transport and stock of goods, from the point of penetration of the order to the end customer. In line with a framework developed by Olsson, Hellstrom, and Palsson (2019), Last-Mile Logistic includes Last-Mile Distribution, which main factors and Last-Mile Fulfilment, Last-Mile Transport and, lastly, Last-Mile Delivery.[13]

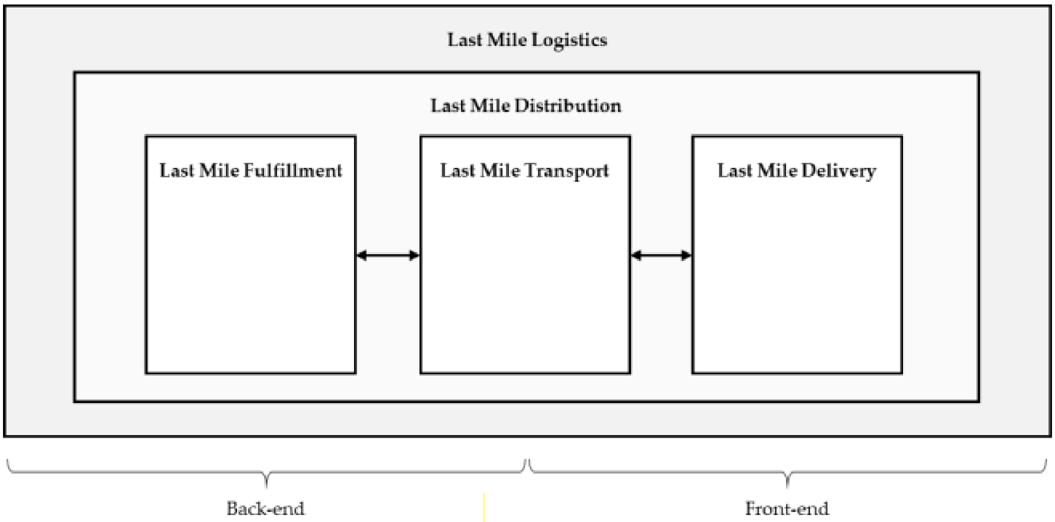

Figure 1:Overall framework, developed by Olsson, Hellstrom, and Palsson (2019), composed of five components

In particular, Last-Mile Distribution means the processing, movement, and storage capacity of goods to the point of final consumption through channels whose extent can vary and the attempts to improve this area affect all the other key areas. Last-Mile Fulfilment, on the other hand, is the process whereby an order is fulfilled and is then subsequently ready to be delivered. Last-Mile Transport occurs in the last part of the delivery process and the means that can be used for its realization are multiple, such as heavy, light vehicles, bicycles or drones, all either electric or ICE. This phase is located in the middle between Fulfilment and Delivery, which is the last step of the process, so it is a fundamental element of the chain.[14]

[13] Sarma, 2020: *Change is the only constant in last-mile delivery*
[14] Olsson, Hellström, & Pålsson, 2019: *Framework of Last Mile Logistics Research: A Systematic Review of the Literature*

2.1.1 Last-Mile Delivery

According to Lim et al. (2018), the concept of Last-Mile Logistics (LML) indicates the last step of a Business-to-Consumer package delivery service[15], thus a service that goes from a transportation hub to a final destination[16]. Actually, Last-Mile Delivery represents more than 50% of the share of global freight delivery.[17]

It can be said that urban freight distribution has a dual purpose: first, it has to limit the overall expense of transporting goods by taking advantage of the delivery of several goods at the same time and working over short distances; the second objective is to deliver goods correctly, without being too costly and providing good customer service that satisfies consumers.[18] Indeed, being Last-Mile Delivery the last step in the transportation system, it impacts both customer satisfaction and market share for logistics[19], so that the higher is the quality of the delivery, the higher is the satisfaction itself: for customers, having fast delivery represents added value and so they are willing to pay more for this benefit, and, for the companies, by charging a higher price, they can cover distribution costs, which, in turn, go up.[20] Moreover, this is the least efficient part of the transportation chain in terms of routing and the subsequent increase of costs that it takes[21], and therefore it is necessary to understand the barriers that are encountered during the internal process and mitigate them as this is the most important part of the process and it is also essential in order to ensure quality and customer satisfaction.[22]

When it comes to dense inner-city areas, parcel transportation experiences a challenge. This is because usually in these areas there are a lot of retailers and businesses and their demand for packages delivered is remarkably high due also to the variety of the goods they need. The challenge is also worsened by the fact that to reach the delivery requests of the recipients located in the urban territory the parcel must travel over long distances from the suburban hubs to the city centre.[23]

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[15] Lim, Jin, & Srai, 2018: *Consumer-driven e-commerce - A literature review, design framework, and research agenda on last-mile logistics models*
[16] Xia & Yang, 2018: *Is Last-Mile Delivery a "Killer App" for Self-Driving Vehicles?*
[17] Alfandari, Ljubic, & De Melo da Silva, 2021: *A tailored Benders decomposition approach for last-mile delivery with autonomous robots*
[18] Viu-Roig & Alvarez-Palau, 2020: *The impact of e-commerce related last-mile logistics on cities: a systematic literature review*
[19] Chen, Demir, Huang, & Qiu, 2021: *The adoption of self-driving delivery robots in last mile logistics*
[20] Jacobs, et al., 2019: *The last-mile delivery challenge*
[21] ASviS, 2022: *LA CITY LOGISTIC*
[22] Weber & Badenhorst-Weiss, 2018: *The last-mile logistical challenges of an omnichannel grocery retailer: a South African perspective*
[23] Aljohani & Thompson, 2020: *An Examination of Last Mile Delivery Practices of Freight Carriers Servicing Business Receivers in Inner-City Areas*

New expressions of Last-Mile delivery are speed-based services such as same-day delivery and instant delivery. These are also the fastest growing last-mile services with growth rates of 36% and 17% per year, respectively.[24] In particular, same-day delivery is a concept that became almost essential and no longer a luxury as it was in the last years. What customers expect is the speed of delivery which is essential to their satisfaction. Same-day delivery is growing along with other factors that have been gaining momentum in recent years such as urbanization and the accelerating use of e-commerce[25].

Joerss et al. (2016) state that the future of the last mile will be parcel delivery whose global costs, excluding pickup, inline transportation, and sorting, have an estimated 70 billion dollars.[26]

According to Sarma (2020) the main pillars of the Last-Mile Operations are the speed of the service, for which consumers are pleased to pay a premium price; efficiency in delivery; transparency in the communication with the clients, like the possibility to track an order and, lastly, the personalized experience made of shopping offers, discounts, and personalized delivery options.[27]

2.1.2 Digitalization in City Logistics

In recent years, we have witnessed a significant increase in urban freight movements worldwide, due to the phenomenon of rapid urbanization and subsequent changes in logistics.

As stated by ASviS (2022), urban logistics is a diverse sector, consisting of various kinds of supply chains: retail (that includes e-commerce), constructions, courier and postal services, waste management, logistics, and pharmaceuticals, which are all extremely relevant economic sectors to the activities of cities. Since the size of the population in cities is estimated to grow rapidly in the upcoming years, it is thought that the work carried out by city logistics will have to increase dramatically, as this is where demand is concentrated.

Predominantly, the first and last kilometres of the supply chain are served by commercial vehicles, which are also one of the greatest causes of road traffic and air pollution, if we compare their emissions with the other types of vehicles. Indeed, also the European Commission has estimated that urban logistics produces negative externalities of €100 billion a year, with a production of 20% of

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[24] Deloison, et al., 2020: *The future of the last-mile ecosystem*
[25] Narashimman, 2021: *Same-day delivery: the true game changer*
[26] Joerss, Schröder, Neuhaus, Klink, & Mann, 2016: *Parcel delivery: the future of last-mile*
[27] Sarma, 2020: *Change is the only constant in last-mile delivery*

traffic and 30% of CO2 emissions. It is also estimated that, of the kilometres covered by the vehicles dedicated to goods urban distribution, the 20%-25% is committed to the transport of outgoing goods, the 40%-50% is for incoming goods, while the rest is used for transporting the goods within the urban border.[28]

2.1.3 The impact of the Covid-19 pandemic on the LMD sector

During the Covid-19 pandemic, it has been noticed significant growth in the Last-Mile delivery industry. This happened mainly because at that time consumers suddenly began purchasing needed goods online in the caught of a general panic.[29] Indeed, it was due to the development of the home delivery system that some of the constraints posed by Covid-19 were alleviated, such as not being able to leave the house to shop or buy groceries. Because of these constraints, people began ordering the items they needed at home to avoid leaving the house. In addition, a search relationship was noted between household income and the frequency with which online purchases are made: households that had a higher percentage of home orders before the pandemic ordered even more during this event.[30]

The Covid-19 pandemic has contributed significantly to the increase in deliveries and therefore a supply chain development was needed so that a more reliable, faster, and smarter service could be provided. It is now common knowledge among companies that having a multi-channel presence with customers is very important in the industry, especially during a time of pandemics.[31] But this exponential growth due to covid is estimated to last beyond the pandemic and is thought to be able to replace traditional item sales by revolutionizing the entire supply chain. To this end, relying on human work is riskier and more labour intensive than relying on automation, as the former can lead to costly mistakes for the parent company, while automation would allow for optimized delivery times and route organization while increasing service levels and costs.[32]

The efficiency of Last-Mile delivery has the greatest effect on companies that use e-commerce because it represents a set of important customer touchpoints[33]. Additionally, during the Covid-19

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28 ASviS, 2022: *LA CITY LOGISTIC*
29 Suguna, Shah, Karthik Raj, & Suresh, 2021: *A study on the influential factors of the last mile delivery projects during Covid-19 era*
30 Unnikrishnan & Figliozzi, 2020: *A Study of the Impact of COVID-19 on Home Delivery Purchases and Expenditures*
31 Sarma, 2020: *Change is the only constant in last-mile delivery*
32 Suguna, Shah, Karthik Raj, & Suresh, 2021: *A study on the influential factors of the last mile delivery projects during Covid-19 era*
33 Suguna, Shah, Karthik Raj, & Suresh, 2021: *A study on the influential factors of the last mile delivery projects during Covid-19 era*

pandemic, this concept intensified due to the massive use of electronic means of buying and selling due to isolation.

During this phase, therefore, there was an opportunity to begin to modernize the delivery system already, as previously shown with the advent of services such as same-day delivery[34], which was born in this period. Other types of modernization concern the means by which these deliveries are made, indeed already during the pandemic, automation of item delivery has been used, when drones were used to transport surgical masks to hospitals to avoid human touch. Building on this, it is now expected that automation will increasingly become a reality in the delivery of goods.[35]

2.1.4 E-commerce in freight transportation

This concept is strictly connected to the e-commerce market, whose growth directly involves an increased volume of parcels that are globally delivered.[36] Indeed, globally, in the last years the e-commerce sector is experiencing a massive growth so that its revenues have reached approximately 4,9 trillion US dollars in 2021 and they are forecast to reach almost 5,5 trillion US dollars in 2022, according to Statista (Accessed in March 2022), this number will become about 7,4 trillion US dollars by 2025, reaching a growth of about 50 per cent.[37]

This is in some way due to the emerging needs of e-shopping, crowd shipping and omnichannel retailing arising in the last years[38], whose emergence was accentuated by the Covid-19 pandemic.

[34] Narashimman, 2021: *Same-day delivery : the true game changer*
[35] Suguna, Shah, Karthik Raj, & Suresh, 2021: *A study on the influential factors of the last mile delivery projects during Covid-19 era*
[36] Chen, Demir, Huang, & Qiu, 2021: *The adoption of self-driving delivery robots in last mile logistics*
[37] Chevalier, 2022: *Retail e-commerce sales worldwide from 2014 to 2025*
[38] Aljohani & Thompson, 2020: *An Examination of Last Mile Delivery Practices of Freight Carriers Servicing Business Receivers in Inner-City Areas*

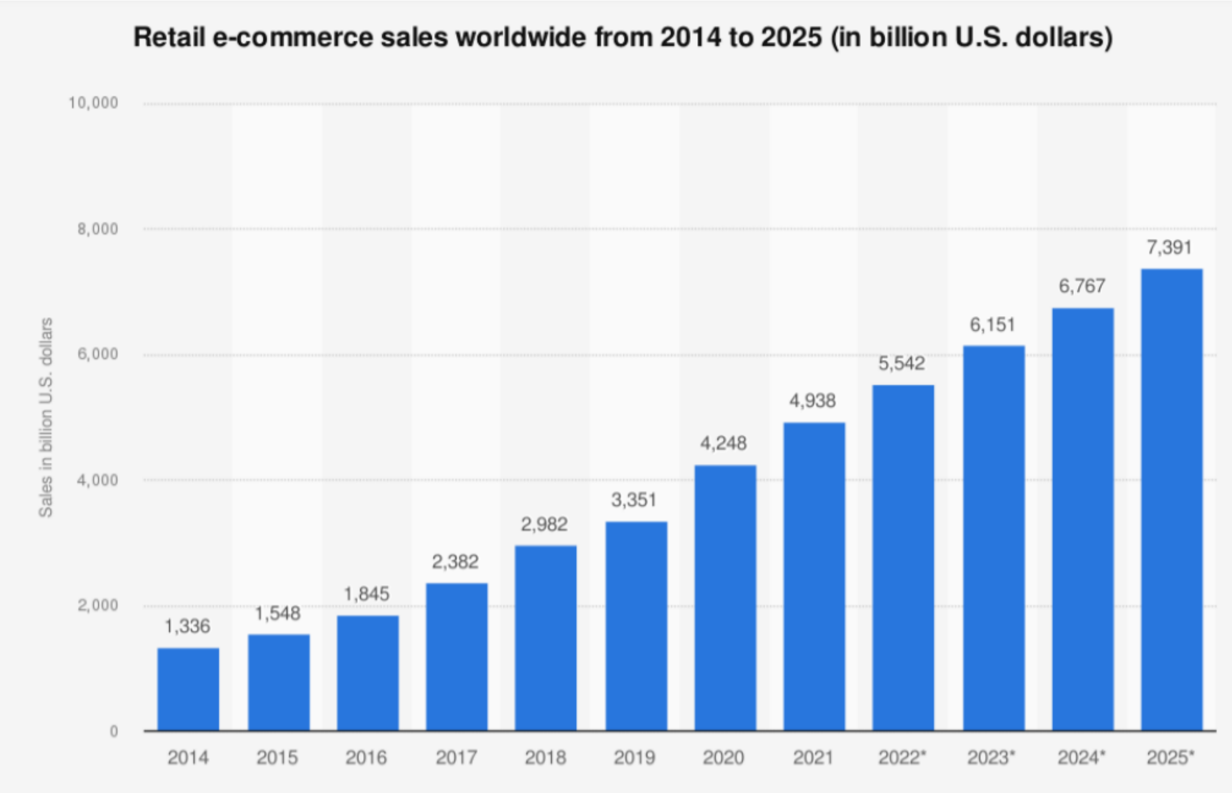

Figure 2:Retail e-commerce sales worldwide from 2014 to 2025 (in billion U.S. dollars). From Statista: https://www.statista.com/statistics/379046/worldwide-retail-e-commerce-sales/

In addition, according to ASviS (2022), due to the immense growth of e-commerce, which will account for 22% of total sales by 2024, as estimated by Netcomm, the efficiency of delivery times and the new, more technologically advanced delivery methods are driving the changes in urban logistics. In addition, other studies show that due to the increase in e-commerce, traffic within cities will also increase significantly. According to World Bank and McKinsey, the increase in online shopping leads to a decrease in the number of trips made by individuals and in total there would be an increase of around 69% in vehicle/km travelled. More and more operators are making direct home deliveries, which presupposes a smaller load, and sometimes delivery does not happen on the first attempt, which implies a return shipment, which is complex and expensive. All this makes the delivery system inefficient. Last-Mile delivery is therefore central, and these inefficiencies imply the need to have an improvement on this part of city logistics through innovations concerning new logistics hubs and delivery means. Specific new technological solutions focus in particular on information systems that optimise travel management, organisations within hubs, the new and different forms of mobility in the city and the training of human resources.

To conclude, the increase in online shopping has caused urban transport to undergo a major revolution, namely the creation of service innovations that grant the consumer greater relevance and precision in delivery, through more precise slots and the possibility of choosing the place of delivery.[39]

2.2Self-driving vehicles

The most difficult challenge for logistics is to move objects from one place to another, and that is what the Last-Mile delivery is all about.[40] In recent years, thanks to the technological transformation of vehicles we are witnessing the emergence of new modes of transportation such as self-driving vehicles and new services based on these recent technologies.[41] These AGV (Autonomous Guided Vehicle) can deliver packages without the need for human intervention in the delivery process customers are alerted via a notification of the date and time their package will be delivered, and they will be instructed on how to pick up their package from the vehicle via an application embedded within it.[42]

The main concern when it comes to autonomous vehicles lies in safety, especially in urban areas and areas where traffic is heavier and therefore it is important to continue to innovate the technology. Autonomous driving is a good mode of delivery but can cover limited areas. It is a type of delivery that before Covid-19 would have been judged futuristic while now it is reality.[43] This new way of delivering helps to increase satisfaction and fall within the expressed needs of customers and Last-Mile delivery is concerted on them.[44]

Automation technology has evolved significantly over the past decade, and this has helped in bringing innovation to the Last-Mile delivery industry. According to Grolms (2019), it has been predicted that automation in this area will account for up to 80% of B2C (Business-to-Customers) deliveries.[45]

One reason for delivery automation is the increase in road deliveries, which, according to Bauer et al. (2020) would lead to the emission of about six million tons of CO_2, which is in contrast to efforts

[39] ASviS, 2022: *LA CITY LOGISTIC*
[40] Suguna, Shah, Karthik Raj, & Suresh, 2021: *A study on the influential factors of the last mile delivery projects during Covid-19 era*
[41] Saeeda, Burris, Labi, & Sinha, 2020: *An empirical discourse on forecasting the use of autonomous vehicles using consumers' preferences*
[42] Bouton, et al., 2017: *An integrated perspective on the future of mobility, Part 2: transforming urban delivery*
[43] Chen, Demir, Huang, & Qiu, 2021: *The adoption of self-driving delivery robots in last mile logistics*
[44] Bogatzki & Hinzmann, 2020: *Acceptance of Autonomous Delivery Vehicles for Last Mile Delivery in Germany*
[45] Grolms, 2019: *Autonomous Shuttles and Delivery Robots*.

that have been underway for years to try to reduce carbon emissions.[46] In addition, the presence of autonomous vehicles helps reduce the risk of labour shortages in logistics services.[47]

The features of autonomous vehicles, when they share the road with normal vehicles, can help solve problems such as congestion, parking, pollution and reckless driving, but it can also leave room for deprivation and thus having to deprive ourselves of being able to use the vehicle anytime, anywhere and any occasion we need it. Other concerns raised by the use of self-driving vehicles are due to privacy, autonomy, and freedom of choice and mobility. According to many studies, the predominant mode of use of autonomous vehicles will be sharing.[48] Challenges have emerged in the Last-Mile delivery field in recent times mainly due to environmental regulations and parking restrictions[49], this has resulted in new and increasingly innovative solutions being developed.

Self-driving vehicles are also an excellent solution to reduce the delivery cost of logistics services. These, thanks to automation technologies can remain operational 24 hours a day 7 days a week. This ensures service flexibility in terms of time as it expands the time window over which deliveries can be made compared to the time in which these can be made by employees, and then by deliveries through human intervention.[50]

2.2.1 AVs solutions for Last Mile Delivery

Starting from the study of various initiatives that have taken place in the latter years about self-driving vehicles used for the purpose of delivery, there is a different kind of vehicles used for this purpose whose evidence can be found in the literature.

The first kind of vehicles, developed by companies such as E-Novia, Starship and Twinsheel and also Amazon, are sidewalks robots, thus being robots that can only make one delivery at a time and then return to the base from which they departed.[51]

[46] Suguna, Shah, Karthik Raj, & Suresh, 2021: *A study on the influential factors of the last mile delivery projects during Covid-19 era*
[47] Twinn, et al., 2020: *The impact of COVID-19 on logistics*
[48] Saeeda, Burris, Labi, & Sinha, 2020: *An empirical discourse on forecasting the use of autonomous vehicles using consumers' preferences*
[49] Akeb, Moncef, & Durand, 2018: *Building a collaborative solution in dense urban city settings to enhance parcel delivery: An effective crowd model in Paris*
[50] Wu, Ding, Ding, & Savaria, 2021: *Autonomous Last-Mile Delivery Based on the Cooperation of Multiple Heterogeneous Unmanned Ground Vehicles*
[51] Alfandari, Ljubic, & De Melo da Silva, 2021: *A tailored Benders decomposition approach for last-mile delivery with autonomous robots*

Starship Technologies is a company that in 2014, the year of its foundation produced its prototype robot. These robots are characterised by a weight of 27 kg and a speed of 6 km/h[52] which allows them to smoothly make one delivery at a time, i.e., make a delivery and then return to the starting point[53] where the processes of loading, recharging and cleaning take place at the end of each delivery.[54] In order to use this vehicle for deliveries, users must place an order via an app, which also allows the vehicle to be tracked during delivery. The concept is that of truck-based delivery whereby a truck is loaded with items ordered by users and, in conjunction, autonomous robots in a central warehouse. Once the truck has reached its destination, such as a city centre, the robots are loaded with the parcels they need to take to their destination and then released to make deliveries to customers. After the robot arrives at its destination, the user receives a notification on the app itself so that he can go and pick up his order from the robot at the point indicated in the order. Once all the deliveries that need to be made in that area have been made, the truck proceeds to a new destination. When all customer deliveries to all destinations have been made, the truck returns to the central depot to organise the next round of shipments.[55] Regarding the efficiency of this method, it has been estimated that, for the companies, it can cost about 15 times less than a traditional courier.[56][57]The price set for this service is about 0.99 GPB per delivery, but this price changed during the pandemic when the pricing became dynamic and therefore rose when there was a lot of demand, or the delivery had to be made to a distant point[58] and fell when there was less demand or the distance to be covered, was less.

[52] Valdez, Cook, & Potter, 2021: *Humans and robots coping with crisis – Starship, Covid-19 and urban robotics in an unpredictable world*
[53] Alfandari, Ljubic, & De Melo da Silva, 2021: *A tailored Benders decomposition approach for last-mile delivery with autonomous robots*
[54] Valdez, Cook, & Potter, 2021: *Humans and robots coping with crisis – Starship, Covid-19 and urban robotics in an unpredictable world*
[55] Boysen, Schwerdfeger, & Weidinger, 2018: *Scheduling last-mile deliveries with truck-based autonomous robots*
[56] Ackerman, 2015: *Startup Developing Autonomous Delivery Robots That Travel on Sidewalks*
[57] London Assembly, 2017: *Transport Committee – Transcript of Agenda Item 6 – Future Transport*
[58] Starship, 2021: *MK community: updates to our pricing & NHS discounts*

Figure 3:Truck used by Mercedes-Benz in collaboration with Starship and the starship automated vehicle. Source: Boysen et al. (2018) and https://www.engineeringforchange.org/solutions/product/starship-robot/

Another type of autonomous vehicle that is used in the Last-Mile delivery is the drone, and its adoption to date has been made increasingly difficult due to the many stringent regulations that are imposed as they take hold, particularly concerning safety in urban areas and operation. Being that self-driving robots touch low speeds; it is not dangerous to think that they can share the streets with people and cyclists.[59]

This type of delivery also relies on a base, usually a truck that is used to carry the drones and cargo between stations, from which vehicles leave and are directed directly to customers and then return directly to the base. According to Wang et. al (2021), the use of this means saves 10% of the delivery cost just by combining this type of transport with traditional transport. In addition, these vehicles are faster and have lower costs, do not require manual intervention, are not subject to terrain-related conditions such as traffic and have high environmental benefits.[60]

While the first two solutions listed above both refer to vehicles that have the capacity and autonomy to carry one delivery at a time, self-driving vehicles capable of transporting several items at once and over much longer distances are in the pipeline. One of these is the vehicle developed by CabiBUS. This type of vehicle can transport various goods: when the customer books a shipment, he rents a cabin in which he will place the package he wishes to ship, and this cabin will only open once he has reached his final destination.[61]

[59] Alfandari, Ljubic, & De Melo da Silva, 2021: *A tailored Benders decomposition approach for last-mile delivery with autonomous robots*
[60] Wang, Lan, Saldanha-da-Gama, & Chen, 2021: *On Optimizing a Multi-Mode Last-Mile Parcel Delivery System with Vans, Truck and Drone*
[61] CabiBUS, 2022: *Sustainable mobility*

2.3 Efficiency in the last mile delivery industry

Last-Mile delivery is the least efficient because orders are small and destinations are dispersed along the way, this also makes it expensive compared to the other elements of the delivery process. For a company, this can come to cost as much as half of their overall logistics costs, so it's important to figure out how to reduce expenses.[62]As this is evaluated to be the most crucial step in the delivery process, companies care about it being as efficient and trouble-free as possible.[63]

This kind of delivery is executed egregiously when several things, one after the other, are performed efficiently. These things are inventory management, order dispatch, route planning, runner assignment, and finally, on-time delivery of orders to the customer's door. If there is a lack of efficiency in any of these points, the whole delivery can suffer negative consequences such as delayed deliveries or the risk of not meeting the minimum quality limit that the customer expects in their delivery. It is also particularly important to understand how to best manage other services such as order returns and on-demand deliveries to increase the efficiency of the whole service. Thus, improving the efficiency of this part of the delivery process ensures the excellence of the customer experience.[64]

In order to increase last mile delivery efficiency, lots of new and innovative solutions have been found to help companies overcome the limits that this industry has experienced until now, like for example the high probability of failing the deliveries. According to Mangiaracina et. al (2019), the efficiency of the last mile delivery sector is based on the components that affect the costs of the service and on the innovative solutions that companies are trying to elaborate on to increase the value of the cost-efficiency. They elaborated a relationship scheme between the factors and the cost components.

The main elements that affect costs are transport mean costs, driver costs and opportunity costs. In particular, the transport mean cost is defined as the multiplication between two main elements: the transport mean travel cost per km, which includes the resources as fuel and the allocation of fixed and semi-fixed costs as maintenance per km[65], and the travelled distance of the transport means, that is how many kilometres does the mean employ to perform one delivery tour.[66]

[62] Mangiaracina, Perego, Seghezzi, & Tumino, 2019: *Innovative solutions to increase last-mile delivery efficiency in B2C e-commerce: a literature review*
[63] Vakulenko, Shamps, Hellström, & Hjort, 2019: *Service innovation in e-commerce last mile delivery: mapping the e-customer journey*
[64] Sarma, 2020: *Change is the only constant in last-mile delivery*
[65] Reyes, Savelsbergh, & Toriello, 2017: *Vehicle routing with roaming delivery locations.*
[66] Asdemir, Jacob, & Krishnan, 2009: *Dynamic pricing of multiple home delivery options*

The second cost component is the driver cost which depends on variables such as the driver hourly fee, that increases with the increase of the workers' specialization[67]; the delivery time, i.e. time spent to deliver the parcel to the customer including the time spent waiting for the customer retiring his parcel[68]; the problem solving time, thus the one used to face possible problems that can arise during the delivery as traffic conditions[69] and, finally, the travel time, that is used to deliver the parcel to the final destination.[70]

Lastly, the opportunity cost includes costs that aim to quantify which influence does customer dissatisfaction have on the delivery services that are affecting the company[71] and it depends on the cost of failed deliveries, which can imply the loss of the customer, and the cost for customer effort for collecting the parcels, thus when the customers have to do some efforts to take the parcel as a move to collect it or other situations that can bother them.[72] The main factors that affect this last variable are the customer travelled distance opportunity cost and the distance travelled by the customer that, if long, can generate a high sense of discontent between them and cause the need to change the delivery choice.[73]

There is a particular relation between the aforementioned cost factors and cost components that can be positive, if the cost factor makes the cost component increase or negative, if the cost factor makes the cost component decrease. To give an example, as said before, the cost factor "resources consumption" makes the cost component "transport mean travel cost" increase, so there is a positive relation between them.

Mangiaracina et. al summed up this concept in a table illustrated here in Figure 4, where 9 cost factors are analysed in light of 12 cost components.

[67] Kafle, Zou, & Lin, 2017: *Design and modeling of a crowdsource-enabled system for urban parcel relay and delivery*
[68] Wen & Li, 2016: *Vehicle routing optimization of urban distribution with self-pick-up lockers*
[69] Dorling, Heinrichs, Messier, & Magierowski, 2017: *Vehicle routing problems for drone delivery*
[70] Giuffrida, 2012: *Home delivery vs parcel lockers: an economic and environmental assessment*
[71] Klein, Mackert, Neugebauer, & Steinhardt, 2017: *A model-based approximation of opportunity cost for dynamic pricing in attended home delivery*
[72] Reyes, Savelsbergh, & Toriello, 2017: *Vehicle routing with roaming delivery locations.*
[73] Chen, Yu, Yang, & Wei, 2018: *Consumer's intention to use self-service parcel delivery service in online retailing: an empirical study*

Cost factors	Cost components: Transport mean travel cost	Travelled distance	Driver hourly fee	Delivery time	Problem solving time	Travel time	Parcels delivered in a tour	% Failed deliveries	Failed delivery opportunity cost	Failed delivery probability	Customer travelled distance opportunity cost	Distance travelled by customer
Resources consumption	+											
Share of (semi)fixed transport cost	+											
Driver specialisation			+									
Delivery automation				–								
Traffic/ obstacles					+							
Transport automation						–						
Customer density		+				+	+					
Failed delivery probability					+			+		+		
Delivery–home distance												+

Figure 4: Relationships among cost factors and cost components. Source Mangiaracina et al. (2019)

In order to increase the delivery efficiency in the last years a lot of innovative solutions are arising. In particular those identified are: reception boxes, a special space outside of an house where it is possible to deliver packages ordered by the customers[74] even if he is not at home or sign anything during this delivery process;[75] parcel locker, when packages are placed in a box owned by a third party, usually located in easily accessible public places such as a supermarket[76] that customers access via a password or QR code;[77] pick-up points that are partner locations of the delivery company where customers can go to pick up their parcels;[78] crowdsourcing logistics in which case, parcels are delivered by non-professional people who have to make that same route for personal reasons and decide to make the delivery along the route paid or even free of charge;[79] drones that are autonomous aerial vehicles that deliver packages by traveling via GPS and, once the delivery is made, return to base which can be a warehouse[80] or a vehicle that continues to move to make other deliveries;[81] trunk, where customers can find the packages they ordered directly in the trunks of their cars, which unlock with a digital key and are intercepted via GPS[82]. Moreover, there is dynamic pricing, in which case

[74] Wang, Zhan, Ruan, & Zhang, 2014: *How to choose 'last mile' delivery modes for E-fulfillment*
[75] (Punakivi, Yrjölä, & Holmström, 2001)
[76] Wang, Zhan, Ruan, & Zhang, 2014: *How to choose 'last mile' delivery modes for E-fulfillment*
[77] Mangiaracina, Perego, Seghezzi, & Tumino, 2019: *Innovative solutions to increase last-mile delivery efficiency in B2C e-commerce: a literature review*
[78] Wang, Zhan, Ruan, & Zhang, 2014: *How to choose 'last mile' delivery modes for E-fulfillment*
[79] Carbone, Rouquet, & Roussat, 2017: *The rise of crowd logistics: a new way to co-create logistics value*
[80] Dorling, Heinrichs, Messier, & Magierowski, 2017: *Vehicle routing problems for drone delivery*
[81] Murray & Chu, 2015: *The flying sidekick traveling salesman problem: optimization of drone-assisted parcel delivery*
[82] Reyes, Savelsbergh, & Toriello, 2017: *Vehicle routing with roaming delivery locations.*

different prices are set according to the time window in which the customer wants their packages delivered, based on how well they optimize truck delivery routes;[83] mapping customer behaviour which is done through a data mining process to calculate when the customer is at home,[84] underground delivery in which parcels move underground through specially created pipelines[85] and robots i.e. autonomous vehicles on the ground that carry packages from the point of departure to the customer via pre-determined routes.[86]

Each of these solutions has a particular relation (either positive or negative) with the cost factors that were previously found. The relations are highlighted in the following table:

	Cost factors								
Innovative solutions	Resources consumption	Share of (semi-)fixed transport cost	Driver specialisation	Delivery automation	Traffic/ obstacles	Transport automation	Customer density	Failed delivery probability	Delivery–home distance
Reception boxes				+				–	
Parcel lockers				+			+	–	+
Pick-up points							+	–	+
Crowdsourcing logistics		–	–						
Drones	–			+	–	+	–		
Trunk				+			+	–	
Dynamic pricing							–	–	
Mapping customer behaviour								–	
Underground delivery	–			+	–	+	–		
Robots	–			+		+	–		

Figure 5: Relationships among innovative solutions and cost factors. Source: Mangiaracina et al. (2019)

The authors also identify a relation between cost components, cost factors and innovative solutions that sums up the shreds of evidence of the study. In particular, the upper part shows the cost components that are added together and grouped to form a more streamlined formula. In the part of the cost factors, all those previously found are shown and in particular, the connections between these cost factors and the cost components are highlighted. An arrow starts from each one and ends with the indication of the cost component related to it. In the lower part, the innovative solutions are written down and in the same way, these are linked to the cost factors. Since the latter is in turn linked to the cost components, a relationship is generated between all three of these categories. Continuous arrows show a positive relationship, while discontinuous arrows show a negative relationship. This is represented in the figure below.

[83] Asdemir, Jacob, & Krishnan, 2009: *Dynamic pricing of multiple home delivery options*
[84] Pan, Giannikas, Y.Han, Grover-Silva, & Qiao, 2017: *Using customer-related data to enhance e-grocery home delivery*
[85] Slabinac, 2015: *Innovative solutions for a last-mile delivery*
[86] Slabinac, 2015: *Innovative solutions for a last-mile delivery*

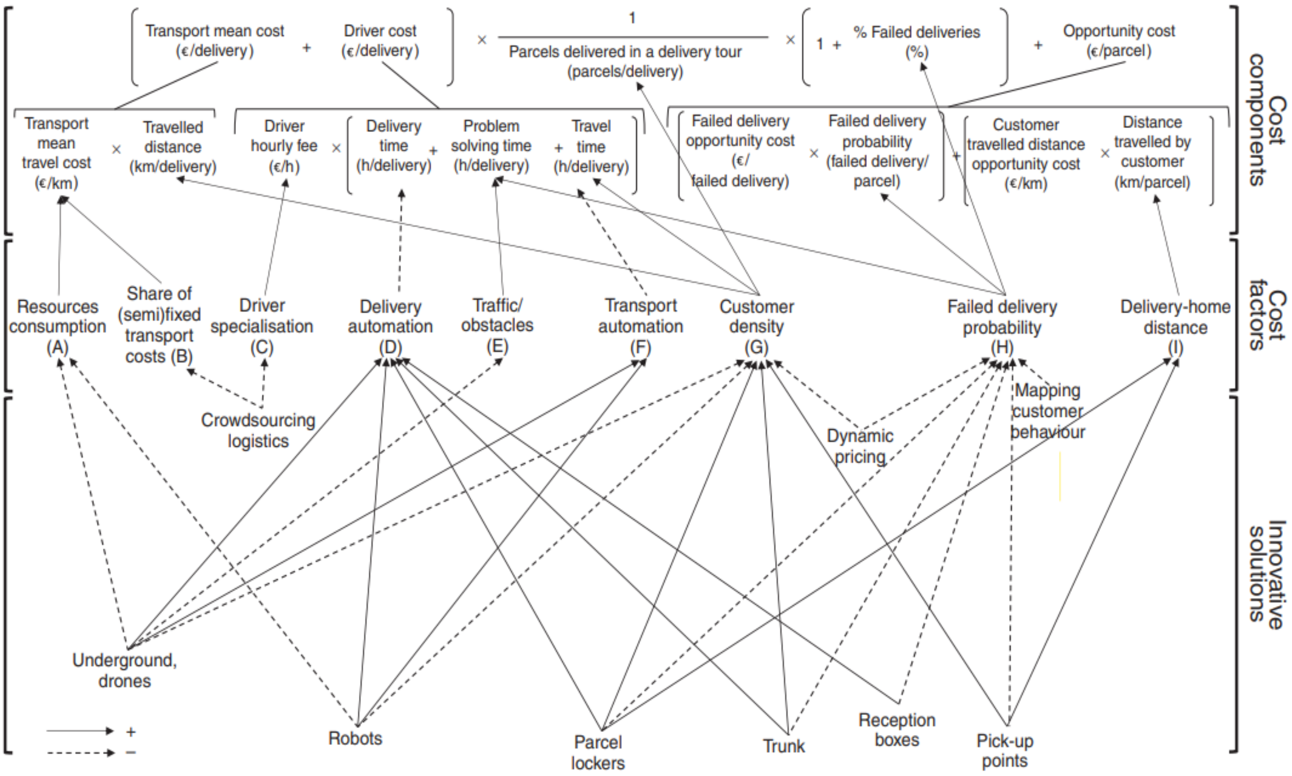

Figure 6: Relationships among innovative solutions and cost factors. Source: Mangiaracina et al. (2019)

3. METHODOLOGY

The methodology section aims to illustrate which methods were used in the research. In particular, it discusses research strategy and design and goes into more detail about both primary and secondary data collection methods, including the conduction of interviews, the interview guide and more details about the sampling carried out. Finally, there is a focus on research quality concerning trustworthiness and authenticity.

3.1Research Strategy

A research strategy is generally an orientation towards conducting business research. According to Bell et. al (2019), two main categories can be distinguished: qualitative and quantitative research. Specifically, quantitative research is based on an approach that links theory and deductive research and therefore an method dedicated to testing theories. In addition, this is based on a view of reality that sees social relations as external and objective. On the other hand, the other type of research, the qualitative one, is based on the emphasis on words, thus neglecting the collection and analysis of data. In addition, this type of analysis assumes that the world is an ever-changing reality and that it is up to individuals to interpret it.

There are different logics of inquiry that can be used in research. The first one is the inductive approach, i.e., a type of approach according to which research gives rise to a theory. Induction is found in the one-sided connection whereby inferences are drawn from observations which are then generalised into theory. Although this is the basic idea, it is not possible to have a purely inductive process; in fact, this will always be accompanied by a small part involving deduction, i.e. an iterative process between data and theory in which the author wants to collect further data in order to be able to establish whether the grounded theory holds up or not. Inductive research, therefore, involves the use of existing theory in the analysis of data and also in the generation of new theory.

The second is the deductive approach, which is also the most widely used in research. According to this approach, the researcher, based on what is known in a given field of research, deduces one or more hypotheses and subjects them to subsequent empirical examination. In this case, it is necessary to explain how the data will then be collected and thus how the hypothesis formulated is translated into operational terms. In this case, the theory stands for the starting point, and the hypotheses guide the data collection process. From this latter, findings are drawn, which will then be used to approve or reject the hypotheses and, finally, this process is followed by the revision of the theory. This last step implies, in turn, a process of induction, that is, here the research gives birth to the theory.

The approach used in this research has become quite common in recent years, namely the abductive approach. This method is seen as overcoming the limitations of the processes of induction and deduction. In particular, it goes beyond the dependence of deductive reasoning on the hard logic of theory testing, and the excessive need for empirical data required for theory building arising from the process of induction. Based on the pragmatist perspective, the abductive process consists in posing a hypothesis, that the existing theory cannot explain, and then trying to explain it. Through this type of reasoning, the researcher tries to reason back and forth between the social world and theoretical ideas. Among all, the researcher has to select the best interpretation of the collected data. This underlines the rational thinking ability of the researcher and highlights the importance of cognitive reasoning when constructing a theory.

Qualitative research is a method that is now increasingly established in business, and it usually emphasises words instead of the data characteristic as the quantitative analysis does. Furthermore, it allows to drill down to people's beliefs, focusing on people and what causes them to engage in certain behaviours rather than others.[87]

3.2 Research Design

Research design is useful to get a picture of how data are collected and analysed. The choice of the type of research design to be used, encapsulates, according to Bell et al. (2019), the importance the researcher attaches to the causal connections between variables, the generalisation of findings to larger groups than are part of the study, the understanding of behaviour and its meaning in a specific context, and the temporal appreciation of social phenomena and the connections between them.

The research design must therefore be a structure that makes it possible to generate data that are suitable for the quality criteria and also for the research question that has been set.

This research aims to understand how the use of self-driving vehicles affects the efficiency of the urban logistic network. In order to pursue this aim, among the different possible kinds of research designs, the one chosen by the author is a comparative one, a method that, according to Bell et al.

[87] Bell, Bryman, & Harley, 2019: *Business Research Method*

(2019), involves studying several cases by comparing them. The underlying logic is that by comparing several contrasting and significant cases, social phenomena can be better understood and explained.

In this research, the comparative design will be applied to a qualitative strategy through the use of a multiple case study. This essentially means a comparative study of more than one case and the cases can be either companies or organisations or individuals. The main advantage of this approach is that it helps to produce concepts that help to build emerging theory because by comparing multiple cases it will be easier for the researcher to determine whether or not the theory will materialise.[88] Indeed, this design relies on the constant evaluation of data and theory taken from different case studies to explain the phenomenon being analysed. The choice of different case studies, therefore, helps to figure out a more complex and deeper view of the phenomenon than the more limited view provided by a single case. Moreover, this comparison between cases itself suggests which contents are relevant, improves theory building and helps to achieve more generalizable results.[89]

This research design is particularly suitable for the research because within the field there is little empirical evidence given also that a lot of the projects being considered have not yet been fully implemented. Through this study, therefore, there will be an opportunity to delve into where we are with respect to reality implementation. [90]

3.3 Research Method

The research method has followed the subsequent path. First of all, the general research question has been chosen. After that, the collection of secondary and then primary data began. The data collection was followed by the analysis and interpretation of these data. Finally, the conclusions of the paper were drawn.

[88] Yin, 1984: *Case Study Research: Design and Methods*
[89] Bell, Bryman, & Harley, 2019: *Business Research Method*
[90] Eisenhardt, 2021: *What is the Eisenhardt Method, really?*

3.3.1 Primary Data Collection

According to Rabianski (2003), primary data are those that the researcher manages to collect by himself with the aim of using them in the research in question. There are two ways of obtaining primary data and these are observation and questioning. In particular, observation is based on the collection of data through the researcher's observation of the behaviour of individuals. Questioning on the other hand can give demographic, economic, psychographic and other data on the characteristics of a population in a specific market. In this research, primary data is collected through the questioning method.[91]

In particular, the instrument used to collect data in this research was the semi-structured interview. This process involves the interviewer having a ready guide to the questions she wants to ask the respondent, but the respondent itself has a wide margin over the answer. Since the process is quite flexible, there is no need for the conduct of the questions to follow strictly what is written in the Interview Guide: it is possible to ask different things or to vary the questions slightly by taking inspiration from what the interviewee says, although in general very similar questions should be asked to everyone so that the answers can be compared. Moreover, it is known that this formulation is suitable to go in-depth, understand what the respondents think, making them express themselves on the topic while still being guided by the interview guidelines and, if necessary, modify or add questions to understand the response in every part.[92]

Potential interviewees were contacted via a message on their companies' email and personally via LinkedIn and the message sent to them is reported in Appendix C. The sample analysed is 6 persons and all the interviews have been audio-recorded by the author.

Two distinct types of analysis can be used for data analysis in qualitative research: content analysis and thematic analysis.

According to Turunen (2013), content analysis is a useful coding approach if one wants to analyse a large amount of textual data in order to understand what the trends in the terms are used, the relationships between them, the frequency of words, and the structure of the communication. The purpose of this technique is therefore to understand the characteristics of the content of a document. The thematic analysis, on the other hand, is not a method of analysis but a descriptive approach that succeeds in identifying, analysing and understanding the patterns, or recurring themes, within the

[91] Rabianski, 2003: *Primary and secondary data: concepts, concerns, errors, and issues*
[92] Bell, Bryman, & Harley, 2019: *Business Research Method*

collected data. This result is particularly suited to qualitative analysis, which is why the type of analysis chosen to process the data for this research is thematic analysis. [93]

This kind of analysis has been used to set up the presence of possible patterns within the collected interviews. The interviews have first been fully transcribed and then carefully reviewed by the interviewer who has then went ahead to schematize the information collected by coding the information. These codes have then been grouped into broader categories, named “themes”, that allowed for the identification of the most frequent responses among respondents. After that, the relationships between the various themes, which may be positive, negative, or non-existent, have been sought and through them, a critical analysis of the quantitative results was conducted.[94]

3.3.2 Secondary Data Collection

Secondary data are defined by Rabianski (2003) as data from secondary sources, i.e., not collected directly by the researcher but taken from journals, articles, and reports previously published by other authors. Thus, information that has been collected for another research and has been generated as primary data for that research is part of this type of data.[95]
Secondary data were collected by researching papers previously written by the authors concerning the concept of 'delivery' in general and then more in-depth for 'Last-Mile Delivery', efficiency in the delivery sector and the diverse types of existing self-driving vehicles used, or planned to be used, in deliveries. The papers were searched on various search engines: Google Scholar, ScienceDirect and Scopus, using the keywords: “Last-Mile Delivery”, “Efficiency”, “B2C E-Commerce”, “Digitalization”, “Delivery and Covid-19”, “City Logistics”, “Sustainability of urban freight”, “ “Efficiency and Delivery”, “Autonomous Robots”, “Drone Delivery”. Approximately 80 sources including journal articles, books and websites were analysed, of which 60 were chosen for the purpose of theory writing using secondary data. These data were then analysed to produce a literature review useful for this research.

[93] (Turunen, 2013): *Content analysis and thematic analysis: Implication for conducting a qualitative descriptive study*
[94] Bell, Bryman, & Harley, 2019: *Business Research Method*
[95] Bell, Bryman, & Harley, 2019: *Business Research Method*

3.3.3 Sampling

Sampling indicates the choice of interview respondents from which the data used in the analysis will be collected. According to Bell et al. (2019), there are two types of sampling, probability sampling and non-probability sampling. The first term refers to a sample that has been randomly selected from the population. This type of sampling tries to keep errors to a minimum.

The second type of sampling refers to a sample that is not randomly selected, so in this case, some subjects are more likely to be selected than others. Non-probability sampling is more useful when selecting people to be interviewed and is, therefore, better suited to qualitative research.

A non-probability sample will therefore be used in this research. Within this category, we find three possibilities: convenience sampling, quota sampling and snowball sampling. Convenience sampling is a type of sampling in which the researcher uses for observations a sample that is easy for him to reach based on its accessibility. Quota sampling is a type of sampling used for studies of exceptionally large populations in which the population is divided into categories with certain characteristics such as gender, age or ethnicity. Finally, snowball sampling is a type of sampling in which the researcher chooses a small circle of samples to observe and then asks them to recruit other subjects to be observed in turn.[96]

The sampling type used in this is a mix between convenience sampling and snowball sampling. In fact, the respondents were chosen on a voluntary basis, through the network of the researcher and not, and it was they who made themselves available for the interview. In addition, other respondents were reached by asking people already taking part in the survey to recruit others.[97] In particular, the sample observed in this research consists of companies whose aim is to operate in the field of last-mile delivery by self-driving vehicles. All the companies interviewed are based in Sweden and this choice was made because there are many realities in this country that are already working on this type of delivery. For what concerns the size of the companies, the sample is composed by three start-ups, one medium and two big firms.

The following table shows the main characteristics of the companies interviewed such as name, the vehicle used with the photo, categorisation between air and ground vehicles, company purpose, company size and location:

[96] Bell, Bryman, & Harley, 2019: *Business Research Method*
[97] Bell, Bryman, & Harley, 2019: *Business Research Method*

	Company Name	Vehicle	Cathegory	Purpose	Size	Site
Repondent 1	**CABIBUS Sustainable Mobility**		Grounded Vehicle	The goal for the company is to develop and use autonomous vehicles for share public transit and deliveries globally	Start-up	Sweden
Repondent 2	**RI.SE (GLAD project)**		Grounded Vehicle	The aim is to develop an initial knowledge base on the efficiency, safety and experience of small autonomous electric delivery vehicles during the first and last mile in Sweden.	Big	Sweden
Repondent 3	**HUGO Delivery**		Grounded Vehicle	Enabling autonomous robots to help us humans in daily life, right now.	Start-up	Sweden
Repondent 4	**LogTrade Technology**	Applicable to all kind of vehicles	Grounded Vehicle and Drones	The mission is to give people with what they need, when and where they need it. Their product is the key to circular logistics.	Medium	Sweden
Repondent 5	**AERIT**		Air Vehicle	The aim is to be the best option for last-mile delivery in the future.	Start-up	Sweden
Repondent 6	**RI.SE (AWARD project)**		Air Vehicle	Develop a logistic platform leveraging on AI techniques to coordinate a fleet of autonomous vehicles for moving goods within a warehouse and for last mile delivery.	Big	Sweden

Table 1: Characteristics of the interviewed companies. Source: Produced by the author.

3.3.4 Interview conduction and guide

Before the interview, information about the topic was gathered from journal articles and earlier studies. Based on this, the interviewer developed questions suitable for conducting a semi-structured interview. Next, the selection of respondents took place, as previously stated. These were contacted via social networks (LinkedIn) and e-mails and asked for their willingness to take part in the interview. Following confirmation of adherence, interviews were conducted, online, via the Google Meet or Zoom platforms.

At the beginning of the interview, the interviewer informed the interviewees about the purpose of the study and then proceeded with the actual interview, asking one question at a time and leaving space for the interviewee to fully express their answers. In some cases, it has been necessary to make slight changes to the questions as they progressed. During the interview, it was the interviewer's responsibility to take numerous and detailed notes, as well as to record the interview with the consent of the interviewee, so as to be able to report results as close to reality as possible. The following table illustrates the details of the conducted interviews:

	Company Name	Interviewee	Date	Place	Length
Repondent 1	**CABIBUS Sustainable Mobility**	Founder	07/04/2022	Zoom	30 min
Repondent 2	**AERIT**	Co-founder and CTO	19/04/2022	Zoom	10 min
Repondent 3	**LogTrade Technology**	CEO	20/04/2022	Microsoft Teams	15 min
Repondent 4	**RI.SE (GLAD project)**	Senior Researcher and Acting Unit Manager	25/04/2022	Microsoft Teams	20 min
Repondent 5	**RI.SE (AWARD project)**	Research Engineer	26/04/2022	Microsoft Teams	15 min
Repondent 6	**HUGO Delievery**	CEO	27/04/2022	Phone Call	10 min

Table 2: Details of the interviews conducted. Source: produced by the author

Before the interview, an interview guide, which is reported in Appendix A, was set. This is composed of seven bigger questions to which contextualized questions were added based on the needs of the individual interviews. The first part focuses on finding out more information about the company such as its size, purpose and geographical location, as well as understanding the role of the interviewee within the company. This information is considered important in order to understand whether companies are, in certain respects, comparable. Next questions are needed to try to better understand the characteristics of the type of vehicle that each company uses and the reasons that led to the choice of a certain type of vehicle and whether the decision to use it was taken at once or whether it is the result of innovation within the company. Respondents are then asked to compare the innovative vehicle they have chosen to use with the most common methods used today to carry out this type of action. The next questions move on to the concept of efficiency and more specifically ask respondents whether they think their product is efficient, then moving on, in more detail, to what they believe are the costs that affect this, or, in the case of a negative response, what they believe are the reasons why efficiency is not achieved. Finally, we talk about future trends in the project and how respondents think efficiency can be improved in the future.

3.4Research Quality

This section aims to report on the characteristics of research quality. The concept of Research Quality refers to the process of reviewing a research study that analyses all elements of a study and judges whether the methods, research questions, measurement and outcomes match and are consistent with each other. This is therefore particularly important for understanding whether a study has a high scientific value. [98]

Fundamentally, research quality indicates the coherence, credibility and applicability of research results. The present study is based on qualitative research and as reported by Bell et. al (2019), some authors believe that the criteria on which the quality of research should be based are different from the classical criteria of quantitative research. In particular, according to Guba and Lincoln (1994), the alternative criteria to reliability and validity for qualitative research are trustworthiness and authenticity.[99]

3.4.1 Trustworthiness

According to Guba and Lincoln (1994), trustworthiness is divided into four criteria which are credibility, transferability, dependability and confirmability. These four criteria are the quantitative research equivalent of validity, external validity, reliability and objectivity respectively. This change in the criteria of reliability and validity is due to the fact that in qualitative research it is not possible, according to them, to have an unambiguous account of social phenomena.

The **credibility** criterion is based on the criteria that figure out the acceptability by other researchers of the research in question. This cannot be taken for granted precisely because various scenarios can be drawn from qualitative research. In order to establish whether the results of a research are credible, it is necessary to use a technique called 'respondent validation' or 'member validation' that the results themselves are submitted to experts in the field to ensure that the researcher has correctly understood and processed the data at his disposal by fully understanding the context. To do this, during and at the end of the interview, the author asked for confirmation of what he had written down to make sure

[98] International Network for Natural Science, 2022: *Standards of a Quality Research*
[99] Guba & Lincoln, 1994: *Competing Paradigms in Qualitative Research*

he had reported the information correctly. Furthermore, as agreed with them, at the end of the work, the conclusions of the research will be shared with the interviewees.

The criterion of **transferability** of results is based on whether the results obtained through the research are in some way transferable to other contexts. Although this end is more difficult to achieve through qualitative research, the researcher ensured that as much detail and observation as possible are included in the study so that other researchers in the future can fully assess whether or not the research is transferable to other contexts.

The **dependability** criterion is based on setting up the research method through the approach of 'auditing'. This approach requires the researcher to ensure that the entire research process, in all its stages from the formulation of a research question to the analysis of the data, is fully recorded so as to be accessible. The entire process followed to make this thesis was recorded and constantly reviewed to ensure that what was reported was consistent with what happened.

The last of the criteria for trustworthiness is **confirmability**. According to this criterion, it is necessary to prove the good faith of the researcher in line with the fact that it is well known how impossible it is to have completely objective results in qualitative research. It is, therefore, necessary to show that neither the theoretical inclinations nor the personal values of the researcher have influenced the impartiality that the research and its results require. This criterion has been confirmed by the fact that this thesis work has been approved and reviewed by two supervisors from two different universities and a co-supervisor.[100]

3.4.2 Authenticity

The criterion of authenticity is based, according to Guba and Lincoln (1994), on five pivotal points. These are fairness, ontological authenticity, educational authenticity, catalytic authenticity, and tactical authenticity. These criteria are based on a vision of the political impact of the research.

In particular, the principle of **fairness** presupposes that the different points of view between members within the same social context are represented fairly. This principle applies to research carried out within the same company context, so it will not be taken into account as a criterion here, as this research is based on data from different companies. The principle of **ontological authenticity** is based on the fact that it will be possible to gain a better insight into the relevant social context through the

[100] Bell, Bryman, & Harley, 2019: *Business Research Method*

research in question. This principle is not in accordance with this thesis as it does not deal with a purely social issue. **Educational authenticity** presupposes that members of a social environment are, through research, helped to appreciate that environment. In order to fulfil the criterion of **catalytic authenticity,** the researcher has to ask whether members have been stimulated to act and engage in actions that involve changing their current situation. Finally, about the criterion of **tactical authenticity**, this is based on whether the research ensured that members of the social context were empowered to engage in action.

The latter four criteria , therefore, focus on a more practical than the theoretical outcome of the results obtained. However, as this research has no social or political aims, it is not considered necessary to meet all the authenticity requirements indicated by the authors.

4. EMPIRICAL FINDINGS

The chapter on empirical findings encapsulates the salient parts of the previously conducted semi-structured interviews, organised by macro topics and without any interference from the author about personal judgements or arguments. The purpose of this section is to report the observations made by the researcher in order to complete answering the research questions.

In particular, this section is organized as follows: the first paragraph is dedicated to the findings of the self-driving vehicles used by the company interviewed, where data is collected on the type of vehicle used and whether this choice of using it represented an innovation for the company. In addition, this section supplies data on what respondents see as the differences between delivery by self-driving vehicles and traditional delivery methods. In the second section, there is a specific focus on the data taken on the efficiency of the use of this delivery method for companies using it. In particular, there are two focuses: one on costs and one on the potential future development of the technology.

It was decided to organise the section in the way described above, following a thematic analysis of the interview texts. Within them, codes were first identified, which were then grouped into sub-topics, which in turn were divided into the two topics that are judged to be the main ones: the discussion on self-driving vehicles and the discussion on the efficiency of the delivery process using this type of vehicle. The table produced by the analysis just explained can be found in Appendix B.

4.1Self-Driving Vehicles

Grounded Vehicles

About self-driving vehicles travelling on land, several types of vehicles are used. The vehicle proposed by Respondent 1 is a van consisting of six cabs and is therefore equipped with three doors on each side. Each cabin can hold eight compartments for parcels to be delivered, so the van can carry up to forty-eight parcels at a time. For this respondent, the decision to start with autonomous vehicles stems from a need to cut down on driver costs and optimise delivery routes, in fact, according to this respondent, having a driver make deliveries on days and times set by the customer would imply a large commitment of resources that would turn into a large cost for the customer with consequent abandonment of the service. In this case, the decision to use self-driving vehicles was therefore taken from the outset and was born together with the project.

Respondent 2's project was born to understand what impact the use of self-driving vehicles will have on society. The vehicle used in this case is specially made for this project and is a small, autonomous and electric tricycle that can be either driven by human intervention or can walk autonomously. Concerning whether the project included the use of self-driving vehicles from the outset, the respondent answered in the affirmative.

As far as Respondent 3 is concerned, the vehicle used in this case is a self-made and modular vehicle, i.e., it is possible to change the size of the vehicle according to the customer's needs. The initial decision to use self-driving vehicles came from the desire to solve the problem of emissions resulting from last-mile delivery by using a vehicle that had an impact on CO2 emissions. In this sense, the strategy was to work on an area that could be developed early in the market and therefore the choice fell on a small vehicle, which is also safer.

> *"We have developed our own legion. So we developed a platform through which we can adjust the vehicle size depending on their own user needs"*
> (Respondent 3)

As for Respondent 4, when asked about the type of vehicle used, he specified that their company supplies software that can be used on the most diverse types of vehicles, from trucks to drones. The use of their mean is very wide. The Respondent explained how the idea came from the need to create an autonomous robotic defence system for the military. While working on this project, they asked themselves how four different robots could hit a boat at sea at the same time, despite being sent from different areas. From here it was realised that if mathematics can do this, then it will be possible to build an autonomous society, and last mile delivery is part of this kind of society that they plan to build.

> *"If with mathematics this is possible, then we could have a house that builds itself, a tomato that decides when to start growing and who should eat it. And that should build an autonomous society. [...] So we are really designing a*

complete autonomous society where the food decides who eats it and when to start growing it. And the buildings build themselves and rent themselves and maintain themselves and tear themselves down. We're going to have a society where human beings are subscribers to services and give us services to products and the products will actually be the third person as a type in the world." (Respondent 4)

Air Vehicles

What emerges from the interviews about aerial vehicles is that the most commonly used are drones. In particular, according to Respondent 5, this type of vehicle is chosen because of its flexibility in terms of delivery routes, which are easier to plan and modify. Another point in favour of this type of vehicle for last-mile delivery is the absence of traffic and obstacles in the sky. According to this respondent, the idea of using self-driving vehicles stems from the need to drop human input into the delivery process. In addition, the decision to use self-driving vehicles for the project originated with the project and was not the result of technological innovation within the company.

> *"We use drones for their flexibility with delivery routes and lack of obstacles in the sky."* (Respondent 5)

According to Respondent 6, the vehicle used in this project is a purpose-built hexacopter. The vehicle is one metre in size between the width of the propellers and can carry a few kilograms of weight. Also about this project, the decision to use self-driving vehicles originated together with the project itself.

4.1.1 Differences with the traditional way of delivery

Grounded Vehicles

According to Respondent 1, the main difference between this type of delivery and traditional methods is that, as the vehicle is a level four autonomous vehicle, it does not need any human intervention, not even through pedals. These vehicles can handle delivery within the limits of a predefined area within a city, and these vehicles are fully programmed to drive on the roads in that area, they know all the roads in that area. In contrast, traditional vehicles are not automated and do not have this route efficiency. In addition, another difference is in the type of resources these types of vehicles use: while traditional vehicles use petrol, Respondent1's vans use energy. There is also a difference in the avoidance of hazards, as in traditional vehicles, the driver can take control and easily get around the obstacle, whereas with the self-driving vehicle, there is a need for additional help, the human one, to get around demanding situations. In fact, control centres can detect critical situations and send operators to manually guide the vehicle until the obstacle is overcome. Another difference is in safety, as the self-driving vehicle is more precise and safer in making exact deliveries, as the error is reduced by the use of technology, which also benefits route planning, which is faster, more efficient and more precise.

> *"Our vehicles, intended for this use are level 4, so they don't need wheels or pedals, and they don't need any kind of control from the driver. These vehicles can handle driving within the predefined area, around 100 kilometres around each city, they have their own maps programmed into the vehicles that know all the roads in that area. So this is fully autonomous at level 4. Autonomous driving can also be used for lower levels, like level 2 or level 3, where drivers can relax a little bit, but they have to be aware that they have to be in control of the vehicle immediately in some situations. It is not possible to read or relax too much, but it is necessary to hold the steering wheel all the time."*
> (Respondent 1)

According to Respondent 2's project, the differences lie in the speed of delivery: self-driving vehicles are much slower than normal vehicles. Furthermore, according to this respondent, the construction of the self-driving vehicle is much less expensive.

> *"I mean, it's not a car but it's not a robot driving on the pavement, it's on the road, so it has to handle that kind of complexity. It's not a car and it's not the same price, it's a much cheaper vehicle. The cost is increased by the advanced technology behind it."* (Respondent 2)

According to the Responding 3's answers, this difference between self-driving vehicles and traditional vehicles when it comes to delivery is mainly in the costs, as this service will be fifty times cheaper (this figure is an estimate of cost reduction based on studies and internal data of the respondent's company) and if we take into consideration the delivery time of the products, the difference is that by using autonomous vehicles these are considerably reduced. Another difference is that this method will not, at least not immediately, be used for all areas of the city, but will be used in more modern neighbourhoods with large spaces where the roads make this type of service easier. Therefore, historical centres that can lead to complex and uncomfortable situations will be avoided.

Respondent 4 thinks that the differences between the two types of delivery are both legal and technical. Furthermore, as far as last mile delivery is concerned, the difference is that the robots can operate in an area of 500 metres, which would be struggling with a human driver because it would be excruciating to drive back and forth for a radius of 500 metres every day, while these kinds of vehicles can facilitate operations in recurring and limited situations such as this one.

Air vehicles

As regards the differences found between the use of self-driving vehicles in last-mile delivery and the use of traditional vehicles, according to Respondent 5, the main is the absence of a human driver, although currently, for airborne vehicles, according to EASA (that is, the European Union Aviation Safety Agency), the presence on the ground of a pilot who coordinates movements is necessary to ensure safety. Nowadays, a pilot can drive several drones at the same time.

According to Respondent 6, differences with the traditional method of delivery include the fact that with this method of transport it is not possible to travel far, which differs from traditional methods of delivery that can travel thousands of kilometres. Next, a difference was found in the cost of the driver. In the case of drones, the drivers, who in this case are pilots, will have a much higher salary than a truck driver. A third difference is found in the number of parcels that can potentially be delivered. A drone basically delivers a single parcel at a time, whereas a truck can contain many.

> *"Drone pilots can get more pay than a truck driver. Moreover, the drones basically deliver single packets. While a truck driver contains as many as needed."* (Respondent 6)

4.2 Efficiency in the last-mile delivery industry

Grounded Vehicles

For what concerns the efficiency of the project, according to Respondent 1, this service would be a very efficient and cost effective system. Also, the electric drive contributes to economic efficiency and this is because of the costs. This type of service would be too expensive both for parcel delivery and passenger transportation if there is a driver in each vehicle. In fact, having a driver for many goods helps to spread the costs over each one, so when transporting fewer goods, the cost of the driver weighs heavily on the total costs for each delivery. Also, the route planning is contributing to the efficiency, indeed some companies are developing this road planning and booking systems so it's optimised rope for each vehicle, thus, you say where to pick up the where to drop off.

According to Respondent 2, delivery efficiency depends on several factors. One of these is the subtraction of the cost of the driver. Alongside this, however, there is the issue of remote operators who will be useful in the event of unpredictable situations requiring human input. This requires a remote ability to run, monitor and problem solve. In addition, the fact of having to maintain and service the vehicles is a cost that needs to be made more efficient. Efficiency is also affected by a factor of perceived brand value, thus, public relations. In particular, a company will be seen in a better light if it does not pollute traffic with traditional vehicles, and this is an important aspect to take into account. In general, a shortcoming of the service in terms of efficiency is the slowness of the system.

Respondent 2's vehicle is halfway between other existing vehicles dedicated to this service and traditional vehicle in terms of speed.

> *"The efficiency of the project depends on many factors. There is the fact that we can subtract the drivers' costs from the costs, but that is not the only thing. You have to take into account the aspect of remote operators because I don't think we can just rely on deploying these vehicles in traffic and then hope that everything will work out well. It won't work. I mean, they will still need some kind of remote operation, remote monitoring and also troubleshooting. And then you need to have an organisation to support the vehicles in the field if something happens and there is no driver to take care of it."* (Respondent 2)

According to Respondent 3, data on cost efficiency is already known and available. In particular, the service is not overly expensive but still a cost for companies. So, it is necessary to use this tool when the delivery item is a valuable one. The fact that it is not too expensive means that it is still cheaper to use a robot than a delivery man . So, if the delivery man cannot deliver and the area is small, the robot is already more cost-efficient.

> *"If it's still not expensive, but it cost quite some money the monthly fee. So the company needs a use case where each delivery is valuable. But it's not very expensive, so it it's already cheaper to use a robot than using a Foodora person to do delivery, for example. So anywhere where Foodora can deliver and it's a small area, the robot is more efficient already."* (Respondent 3)

According to Respondent 4, the company claims that in terms of efficiency, automated solutions raise the bar in that they will not deliver the wrong parcels, to the wrong place at the wrong time. Then at the same time, it will not choose the wrong parcel because it is data-driven. It is also very reliable in terms of the level of security, and this allows deliveries to be made at off-peak times, such as at night. So, it's a solution that allows to raise quality and reduce costs, and what's more, it allows to work at times when people, usually, don't want to work.

Air vehicles

Regarding the efficiency of the last mile delivery service, Respondent 5 stated that the level of efficiency of the service depends on the parameters that are considered. In particular, if the efficiency of CO_2 emissions per delivery is assessed, drone delivery is very cost-effective, even compared to what is currently available to consumers. If, on the other hand, cost efficiency is assessed, the system is not so efficient because it is not possible to deliver the same number of parcels per hour as a truck can deliver.

> *"Depends on what your definition of efficiency is. Is it more efficient in regard to co2 per delivery than what's currently available for consumers? Yes. Can the system deliver more packages per hour compared to a van? Probably not."* (Respondent 5)

According to Respondent 6, when it comes to cost efficiency, the project is not efficient. This is because there is a big problem that is often underestimated, which is that of regulation. In fact, until now, according to the regulation of drones, it is necessary to have a pilot of the aerial vehicle, which must be a pilot, i.e., someone who handles the flight. According to most interpretations of this law so far, each pilot can only fly one drone at a time. This means that even if the drones can fly autonomously, there is still a need for a pilot per drone, which is a huge cost for delivery, and eliminates the benefit of removing the human component from delivery and, in addition, increases costs as a pilot costs much more than a truck driver. Plus, again in terms of efficiency, there is the fact that drones deliver one parcel at a time, whereas a truck can deliver many.

4.2.1 Costs in using self-driving vehicles

Grounded Vehicles

When dealing with the questions about the costs, Respondent 1 exponent said that a cost-saving will occur on the resources used as the vehicle is fully electric and is powered by a hub which in turn is powered by solar panels. The cost related to traffic arises mainly from the problem that if the vehicle is in an unmanageable traffic situation, human intervention by staff will be required. This staff is linked to an office through which the staff can manually drive the vehicle remotely to overcome the obstacle. This service can also be outsourced, in fact there are companies that offer this control service for remote operations.

According to Respondent 2, the use of this vehicle leads to great savings in money. This is due to features such as not using truck drivers. However, there are some noticeably big costs to consider which are the development costs of the initiative.

As far as the costs of Respondent 4 are concerned, the ones that are subtracted due to automation are the labour costs, which are greatly reduced. This is the most common aspect but other costs that are missed are the costs of using resources when they are already used by others. For example, if there are peak times in cities, this vehicle, thanks to the use of data, can decide not to work at that time, but at other times. So, the autonomous vehicle will work when the streets are not crowded, in this sense they do not use the resources already used by others. And these calculations can be made from the data in a very precise way, even they can be calculated to the millisecond.

> *"You don't have any labour cost. Of course, that's the most common, but you also don't have the cost of using resources when they are used by others."*
> (Respondent 4)

Air vehicles

According to Respondent 5, the cost of resources is extremely low and the cost of transport itself is estimated at one euro per delivery. As far as traffic or obstacles are concerned, it is possible to find other UAMs generating traffic or ambulance or police helicopters along the route.

The cost discussion for Respondent 6 centred on the fact that for each drone flying behind there is a lot of human work involved. This is because a pilot is needed, and a pilot costs a lot of money. This aspect is usually not noticed when dealing with an autonomous drone, because it flies for itself, but, according to the regulations, it is necessary to have a piloting guard that will monitor the flight and can act and control of the drone at all times. So, is labour connected to any drone flight and today a pilot can only control one drone at a time.

> *"One must have in mind that for every drone flight there is human labour. You need a pilot and the pilot will cost money. You don't think of that when you think of an autonomous drone, because it flies for itself"* (Respondent 6)

4.2.2 Future trends to improve efficiency

Grounded Vehicles

According to Respondent 1, the important thing for the future is to be able to build a vehicle that consumes less and less energy, regardless of how much this may increase the price of the vehicle itself. To do this, it is necessary to reduce the weight of the vehicles. In addition, the organisational structure must be reviewed, as the most efficient combination of transport will be the simultaneous transport of people and goods.

> *"The total cost depends on how much the vehicle cost to produce but that is not the main part of it. So, it's better to build a vehicle with a high quality that will last many years maybe 30 years with a minimum service cost then it doesn't matter if the vehicle cost three million or four million. Elevation costs*

> *will not be so important it's better to make it low weight to reduce energy consumption."* (Respondent 1)

According to Respondent 2, the first development for the future is to develop a vehicle that is truly autonomous in every respect, something that is lacking in this sector to date. Existing vehicles still require human intervention in certain situations. In addition, the first improvement factor is to have a completely reliable vehicle. This will involve the use of materials that are currently expensive, but which will be reduced over time.

Respondent 3 believes that the data shows that the costs of sensors and computers are getting lower and lower and also the efficiency, as more robots are used, will get lower and lower. So, the cost of operations will drop dramatically and it is believed that production costs will also follow this path. In addition, when autonomous vehicles are so autonomous that they require less human intervention, they will be very cost-effective. Costs will probably be reduced by more than ten times in the future compared to today.

The future improvements of Respondent 4 are that first of all, the entire process will be made more efficient but differently than we see it now. What we are aiming for in the future is to build a completely autonomous company. As far as last-mile delivery is concerned, what will happen in the future is the automation of all delivery processes, and traditional vehicles will no longer have any reason to exist in this sense. And, in addition there will be new methods of exchanging parcels between vehicles.

> *"By addressing this new type of quality we will change the usage of this type of drones or autonomous vehicles or whatever we call it. That's the huge thing to have in mind when you start planning this. So I think trucks in the future will not go a long way we will have very effective ways of exchanging goods between trucks and trucks will go in shorten areas, exchanging."* (Respondent 4)

Air vehicles

About the development of the work and therefore the future trends in the efficiency of this delivery service, using drones, Respondent 5 replies that they are increasingly trying to lower the weight of the UAS and that they will try to increase the efficiency of propulsion but that, despite the various efforts, there are still major gaps to be filled in terms of the infrastructure on which the service is based. Another point of development is the batteries, particularly as regards their replacement and charging. Other points where improvements can be made are the way in which packages are collected and routed.

> *"We're constantly working towards lowering UAS weight and increasing propulsion efficiency but there are big gains to be made in the infrastructure surrounding the ops. Battery swapping and charging, parcel pick up operations, routing [...]"* (Respondent 5)

According to Respondent 6, regarding future trends, one important thing is to test and evaluate these regulations and figure out safe solutions. Prove to the authorities that these solutions are safe where one pilot can control several drones at a time. If there is a drone pilot that controls several drones, then it is possible to start to split the labour cost between different lengths. Another solution or the other possibility is to find applications where the fast delivery is really worth about. Because it is going to cost quite much, but in some cases, it can be worth identical. This, for example, happens if you think of lifesaving equipment. Indeed, if it is possible the special applications where the customer is willing to pay quite a lot to have the delivery quick, this system can be much quicker because doesn't have to think about traffic. The situations where customers are willing to pay are more towards healthcare applications where time can save lives or at least give patients a better prognosis or better chance of surviving and remove suffering or where time is critical for real.

> *"We just need to find those applications where there is willing to pay. I think that the situations where customers are willing to pay is more towards healthcare applications where time can save life or at least give patients a better prognosis or better chance of surviving remove suffering or where time*

is critical for real. I'm not talking about sending football shoes here. We're talking about sending what it's important for real, and it's not important to pay." (Respondent 6)

5. DATA ANALYSIS

In this section, the empirical results are also elaborated in the light of the previously conducted literature review. The focus is indeed on the analysis of primary and secondary data, both those collected through the literature review and those collected through the semi-structured interviews. The object is to put the data together in a logical manner and to derive a single view of the cost-efficiency situation of the transport of parcels at the urban level through self-driving vehicles.

The section presents the same division as the chapter on empirical findings, that is, the one elaborated after the thematic analysis presented in Appendix B. In each section, the data collected by the different companies are compared and merged, and the data from the literature are then integrated to support these.

5.1Self-driving vehicles

The type of vehicles used by the interviewees in this research is autonomous vehicles, and in particular, when analysing the type of vehicles used by the six companies responding to the interviewer's questions, the first thing to point out is that the vehicles they use fall into two broad categories: ground vehicles and aerial vehicles. Three out of six respondents use ground vehicles, two use drones, and one applies its software to both types of vehicles. Moreover, the ground vehicles are all quite different from each other: one company uses a van with six cabs that can carry up to 48 parcels at a time; then we have a vehicle that can be likened to a tricycle. Both vehicles can also be driven manually and are not just automatic. The third ground vehicle, on the other hand, has a unique feature in that it is a modular vehicle, thus, it can change as customers' needs change, and this vehicle is smaller than the others and can only deliver one parcel at a time. As far as aerial vehicles are concerned, both companies interviewed use drones.

Indeed, also according to Mangiaracina et. al (2019), when talking about innovative solutions found in the last-mile delivery sector, reference is made to solutions such as reception boxes, parcel lockers, pick-up points, crowdsourcing logistics, drones, trunks, dynamic pricing, customer behaviour mapping, underground delivery and robots. The two categories that arose from this research, fall into the one individuated by the authors of the paper. Furthermore, according to Grolms (2019), in the last decade, the great innovation in this sector has been brought about by the evolution of automation technologies, and in fact, it is this very phenomenon that will account for approximately 80 per cent of B2C deliveries: is a type of delivery that before Covid would have been judged futuristic while now it is reality.[101]

When it comes to the motivations behind the decision to use a self-driving vehicle can vary depending on the category we are considering. In more detail, the motivation chosen by those who decided to implement ground vehicles was to cut driver-related costs, optimise routes and use a vehicle that would have an impact on CO2 emissions. According to findings in the literature, one reason for the automation of deliveries is the increase in road deliveries, which, according to Bauer et al. (2020) would lead to the emission of around six million tonnes of CO2[102] and, furthermore, according to Twinn et. al (2020) the presence of autonomous vehicles helps to reduce the risk of labour shortages in logistics services.[103] Regarding aerial vehicles, according to the respondents, the motivation for this was the flexibility of drones about delivery routes, which are easier to plan and change, other reasons being the absence of traffic and obstacles in the trajectory.

Already in the literature, it was found that a motivation for the implementation of drones in deliveries had arisen during the pandemic, where this has been identified in the transport of surgical masks to hospitals in order to avoid human contact,[104] as also Respondent 6 reported.

In general, according to Wu et. al, self-driving vehicles are also an excellent solution to reduce the cost of delivery of logistics services. In fact, these, thanks to automation technologies are able to remain operational 24 hours a day 7 days a week. This supplies service flexibility in terms of time as it expands the time window in which deliveries can be made compared to the time in which they can be made by employees, and thus deliveries through human intervention[105]. This latter concept has also been stressed by Respondent 1.

In addition, according to ASviS (2022), it is stated by World Bank and McKinsey how the increase in e-commerce, boosts traffic within cities due to the increase of e-commerce transportation trucks. In fact, the increase in online shopping leads to a decrease in the number of journeys made by people

[101] Chen, Demir, Huang, & Qiu, 2021: *The adoption of self-driving delivery robots in last mile logistics*
[102] Suguna, Shah, Karthik Raj, & Suresh, 2021: *A study on the influential factors of the last mile delivery projects during Covid-19 era*
[103] Twinn, et al., 2020: *The impact of COVID-19 on logistics*
[104] Suguna, Shah, Karthik Raj, & Suresh, 2021: *A study on the influential factors of the last mile delivery projects during Covid-19 era*
[105] Wu, Ding, Ding, & Savaria, 2021: *Autonomous Last-Mile Delivery Based on the Cooperation of Multiple Heterogeneous Unmanned Ground Vehicles*

for purchasing, and in total there would be an increase of about 69% of vehicles per km travelled. This estimate already considers the reduction due to fewer people leaving home for shopping.[106]

Regarding the decision to use self-driving vehicles as early as the company's or product's start, all companies confirm that the decision was made from the beginning and was therefore not a later innovation.

Factors	Robots (EF)	Robots (LR)	Drones (EF)	Drones (LR)
Drivers Costs	x			
Route Planning	x		x	
CO2 Emissions	x	x		
N. of deliveries		x		
Labour Shortage		x		
Obstacles/Traffic			x	x
Human Contact			x	x
Delivery Costs				x
Time Flexibility	x			x

Table 3: Factors contributing to the choice of automated vehicles according to literature (LR) and findings (EF). Source: produced by the author

The motivations for companies to use this type of vehicle are therefore shown in the table above, divided by category and whether the information was found through Empirical Findings or Literature Review. With this table we also want to highlight how new factors emerged from the interviews compared to those reported in the literature reviewed by this research, which are for robots the cost of drivers and flexibility in terms of time, and for both categories of route planning. Furthermore, some factors highlighted in the literature review were also confirmed by the findings, such as CO_2 emissions, the avoidance of human contact (this being a need born in the pandemic period) and the obstacle or traffic factor; the other factors present in the literature, such as the number of deliveries, labour shortage and the cost of delivery, were not reflected in the empirical findings as to the motivation of using self-driving vehicles.

[106] ASviS, 2022: *LA CITY LOGISTIC*

5.1.1 Differences with the traditional way of delivery

In both literature and empirical findings, it has been found that there are fundamental differences between vehicles traditionally used for deliveries and autonomous vehicles. It has also been found that the decision to use autonomous vehicles is made by companies at the beginning of their business. Probably these differences, explained by those who have studied this issue before starting a business, help to understand why companies decide to start their business using autonomous vehicles. This decision is certainly accentuated by the growth of e-commerce and thus home delivery services, which Netcomm estimates will account for 22% of total sales by 2024.[107] According to Suguna et. al (2021), this exponential growth due to the advent of the Covid-19 pandemic is estimated to grow and will last well beyond the end of the pandemic, even expected to replace sales of traditional items by revolutionising the entire supply chain.[108]

The main differences that have been found both in the literature and in the empirical findings can be best summarised in three categories identified by the author: the first, termed 'absence of labour', encapsulates the discourses of risk, labour, delivery time, route planning, speed of delivery and overcoming obstacles. The second category, called 'costs and resources', encapsulates the differences in cost, quality, and resources, where the latter concept is linked to that of sustainability. The third category, called 'vehicle characteristics' encompasses those differences related to speed, areas of possible deployment and vehicle capacity. These categories will be analysed in more detail below.

[107] ASviS, 2022: *LA CITY LOGISTIC*
[108] Suguna, Shah, Karthik Raj, & Suresh, 2021: *A study on the influential factors of the last mile delivery projects during Covid-19 era*

Absence of labour

When dealing with last-mile deliveries, and according to Suguna et. al (2021), when relying on human labour, there is a risk of mistakes being made that, through automation, could be avoided. This can lead to the parent company having to manage costs that, in some situations, can be massive.[109] Respondent 1 agrees with this statement. In fact, according to him, the main difference between the two types of delivery lies precisely in the fact that the autonomous vehicle, unlike the traditional one, does not need human intervention. This is not true only when it is taken into consideration the possibility for the vehicle to find obstacles. In this case, according to respondent 1, there would be a need for human intervention, linked to a kind of control tower for ground vehicles, which could manually assist the vehicle in a critical situation. This view is also supported by Respondent 2, who agrees with the view that nowadays there are still no fully autonomous vehicles, but existing vehicles still need human intervention in certain situations. In this regard, however, Wang et. al (2021) state that one of the strengths of these vehicles is the absence of the need for manual intervention, along with other factors such as reduced costs and, in the case of aerial vehicles, the absence of dependence on traffic conditions and large environmental impacts.[110] These latter statements on air vehicles are also confirmed by Respondent 5, who states that he chooses this type of vehicle precisely because of the usual absence of obstacles in the sky and the flexibility of its routes.

Turning then to the topic of routing, according to Respondent 1, another key difference is that these vehicles can handle deliveries within the limits of a predefined area within a city, and are fully programmed, to drive on the roads of that area, to travel in which they are perfectly programmed. Conventional vehicles, on the other hand, not being automated, again according to Respondent 1, cannot boast this efficiency in routing, which is, therefore, comparatively, faster, more efficient, and more accurate. This is supported by both Suguna et. al (2021), according to whom automation optimises route organisation[111], and by Respondent 6. The latter, however, introduces a further difference that may be an obstacle in the implementation of this type of delivery, namely the fact that with autonomous vehicles it is not possible to travel long distances, while with conventional vehicles it is possible to travel hundreds of kilometres.

[109] Suguna, Shah, Karthik Raj, & Suresh, 2021: *A study on the influential factors of the last mile delivery projects during Covid-19 era*
[110] Wang, Lan, Saldanha-da-Gama, & Chen, 2021: *On Optimizing a Multi-Mode Last-Mile Parcel Delivery System with Vans, Truck and Drone*
[111] Suguna, Shah, Karthik Raj, & Suresh, 2021: *A study on the influential factors of the last mile delivery projects during Covid-19 era*

As far as delivery times are concerned, according to Suguna et. al (2021), these are completely optimised with automation[112], as confirmed by Respondent 3, according to whom, if we consider product delivery times, the difference is that by using autonomous vehicles, these are significantly reduced. This fact is, as stressed before, even in accordance with Wu et. al (2021).[113] Finally, according to the ASviS report (2022), delivery time efficiency and new technologically more advanced delivery methods are driving changes in urban logistics. Therefore, the rise of online shopping has led urban transport to undergo a major revolution, namely the creation of service innovations that guarantee consumers greater relevance and accuracy in delivery through more precise slots and the possibility to choose the delivery location.[114]

Costs and resources

The differences between conventional and self-driving vehicles in terms of cost lie mainly, according to Wang et. al (2021), in the fact that costs are lower. Suguna et. al (2021) agree, according to whom, in addition to lower costs, there is also an increase in service quality.

Also, according to Respondent 2, there is a difference in terms of cost with regard to the construction of the vehicle itself: in fact, the construction of the autonomous vehicle would be cheaper for them. This view is also supported by the interview of Respondent 3 according to whom, the difference between self-driving vehicles and conventional vehicles concerning deliveries is mainly in cost, as this service will be fifty times cheaper (this figure is an estimate of cost reduction based on studies and internal data of the respondent's company). This is truly consistent with Wu et. al (2021), according which self-driving vehicles are also an excellent solution for reducing the delivery costs of logistics services.[115] More specifically, but only in the case of drones, another thing that affects costs as a difference is the variation in the cost of the driver. In fact, in the case of drones, the drivers are pilots who, as stated in the legislation, guide the vehicle from the ground. The cost of these drivers is, according to Respondent 6, certainly much higher than the cost of drivers of normal vehicles. Therefore, this difference in the cost of the vehicle driver would affect the cost of the service.

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[112] Suguna, Shah, Karthik Raj, & Suresh, 2021: *A study on the influential factors of the last mile delivery projects during Covid-19 era*

[113] Wu, Ding, Ding, & Savaria, 2021: *Autonomous Last-Mile Delivery Based on the Cooperation of Multiple Heterogeneous Unmanned Ground Vehicles*

[114] ASviS, 2022: *LA CITY LOGISTIC*

As far as resources are concerned, the difference between the two types of delivery is, according to respondent 1, attributable to the fact that while traditional vehicles use petrol, self-driving vehicles are electric and therefore use petrol. This makes them, according to Wu et. al (2021), highly environmentally beneficial vehicles.[116] Furthermore, again about drones, according to Respondent 5, the main difference is the absence of a human pilot inside the vehicle. Indeed, according to EASA (the European Union Aviation Safety Agency), the presence of a pilot on the ground to coordinate movements is still necessary to ensure safety. The difference with grounded vehicles is that, according to this respondent, one pilot can fly several drones at the same time. According to Respondent 6, however, this is not yet possible and will have to wait for further implementation of the legislation for this to happen.

Vehicle characteristics

The main differences between the two vehicle categories mentioned so far, according to Wang et. al (2021), lie in the speed and safety of autonomous vehicles. In fact, according to these authors, which is also supported by the interview of Respondent 2, the difference in terms of speed is that autonomous vehicles are slower than normal vehicles.[117] This translates, according to Wang et. al (2021) and according to Respondent 1, into greater safety. In fact, according to the former, as the speed is reduced, it is not dangerous to think that they can share the roads with people and cyclists,[118] while the latter understands safety also in terms of delivery accuracy and states that the self-driving vehicle is more accurate and safer in making exact deliveries, as the error is reduced by the use of technology and data.

Another difference that, for Respondents 3 and 6, is central for these two means of transport is certainly the difference in the areas of implementation. In fact, according to Respondent 3, this method will not be used, at least not in the immediate future, for all areas of the city, but will be used in more modern neighbourhoods with large spaces where roads make this type of service easier. Thus, historical city centres will be avoided, which can lead to complex and uncomfortable situations, while

[115] Wu, Ding, Ding, & Savaria, 2021: *Autonomous Last-Mile Delivery Based on the Cooperation of Multiple Heterogeneous Unmanned Ground Vehicles*
[116] Wang, Lan, Saldanha-da-Gama, & Chen, 2021: *On Optimizing a Multi-Mode Last-Mile Parcel Delivery System with Vans, Truck and Drone*
[117] Alfandari, Ljubic, & De Melo da Silva, 2021: *A tailored Benders decomposition approach for last-mile delivery with autonomous robots*
[118] Alfandari, Ljubic, & De Melo da Silva, 2021: *A tailored Benders decomposition approach for last-mile delivery with autonomous robots*

traditional transport methods are used everywhere, in old and modern city centres and also in suburban areas. According to Respondent 4, however, the difference is that robots can operate in an area of five hundred metres, which would be excruciating for a human driver because it would imply driving back and forth for a radius of five hundred metres every day.

A final key difference in delivery characteristics can be found, according to Respondent 6, in the number of parcels that can be delivered at a time. Indeed, both drones and smaller autonomous ground vehicles can carry, one or a few parcels, while traditional vehicles can potentially carry hundreds.

The table below shows the differences between autonomous and conventional vehicles based on the factors highlighted by both, the literature review and empirical findings. In the rows, there are the factors divided by the categories identified in this paragraph, while the columns specify the vehicles to which they apply and the source from which the information comes, so as to highlight the contribution of research in this area. The table is completed with the available data as follows:

			Differences with traditional vehicles (Source)				
			Robots (LR)	**Robots (EF)**	**Drones (LR)**	**Drones (EF)**	**Traditional Vehicles**
Factors	**Absence of labour**	Human Intervention	Not needed	Necessary, for contingecies	Not needed	Necessary, from the ground	Needed
		Traffic Dependency	Low	Low	None	None	High
		CO2 Impact	Low	Low	Low	Low	High
		Routing	Optimised	Optimised	Flexible	Flexible	Not optimised
		Distances		Short		Short	Long
		Delivery Time	Low	Low	Fast	Fast	Fast
		Accuracy	High	High			Low
	Costs and resources	Construction Costs		Low		Low	High
		Quality	High		High		Low
		Delivery Costs	Low	Low	Low	Low	High
		Driver Costs		Low		High	Medium
		Resources	Energy	Energy	Energy	Energy	Petrol
	V. Characteristics	Speed	Low	Low	Fast	Fast	Fast
		Safety	High	High	High	High	Low
		Implementation areas		Small		Small	Big
		Number of parcels	Few	Few	One	One	Many

Table 4: Differences between self-driving vehicles and traditional vehicles, a comparison between literature review (LR) and empirical findings (EF). Source: produced by the author

To conclude, as the table above shows, the factors on which the difference between normal and self-driving vehicles emerged from this study are sixteen, which can be grouped into three categories.

In particular, differences between the primary data (LR) and the secondary data (EF) are noted with regard to:

- **Human intervention:** in this case, according to the literature, human intervention is not necessary, whereas according to the interviewees, there are situations where it is still necessary nowadays, as far as robots are concerned, while, with regard to drones, it was found that human intervention is always necessary due to regulation.

- **Distances:** The distances that can be covered by these vehicles are not analysed in the literature. However, empirical findings have shown that the distances that these new vehicles can cover are relatively low and certainly shorter than those of conventional vehicles.

- **Construction costs:** empirical evidence showed that the cost of building the vehicles is low. This information was not present in the literature and applies to all types of autonomous vehicles.

- **Quality:** the quality of delivery by autonomous vehicles appears to be exceedingly high according to the literature. However, this information was not found in the empirical findings, where no respondents focused on this aspect.

- **Driver costs:** this information was taken from the empirical findings and is not found in the literature. What has been found is that, for robots, the cost of a driver, only needed on specific occasions, is low, whereas for drones it is a much higher cost than for conventional vehicles.

- **Implementation areas:** this data, missing from the literature, states that the deployment area of autonomous vehicles is relatively minor compared to the range of traditional delivery.

5.2Efficiency in the last mile delivery industry

Efficiency in last-mile delivery is, according to Sarma (2020) one of the pillars of last-mile operations, along with the speed of service, for which consumers are willing to pay a premium price, transparency in communication with customers, such as the ability to track an order, and, finally, the personalised experience made up of purchase offers, discounts and customised delivery options.[119]

This point is particularly important to the research because, due to the big and fast growth that this sector has experienced in the last period due to the pandemic, as reported in the literature review, it became necessary to develop the supply chain to be able to supply a more reliable, faster, and smarter service in order to have a presence to excel in the industry.[120]

Sustainability

One of the main problems lies in the fact that, according to ASviS (2022), commercial vehicles, which are those mainly used for the first and last kilometres of the logistics chain, are a major cause of road traffic and air pollution, if one compares their emissions with those of other types of vehicles. In addition, it is estimated that around 35-40% of such vehicles are used for transporting goods within urban boundaries. In this regard, the European Commission has estimated that urban logistics generate negative externalities of 100 billion euros per year, accounting for 20% of traffic and 30% of CO2 emissions.[121] According to the empirical findings, the new solutions found by the respondents for last-mile delivery overcome this efficiency problem in terms of sustainability. Both Respondent 1 and Respondent 5, touch on the topic of CO2 emissions when talking about how efficient these vehicles are in last-mile delivery. In fact, both state that these vehicles are powered by electricity, which drops the emissions associated with this type of activity, based on what is available to consumers today. Respondent 2 also points out that efficiency is also influenced by a perceived brand value factor, and a company will be seen in a better light if it does not pollute traffic with traditional vehicles, and this is an especially important aspect to consider.

[119] Sarma, 2020: *Change is the only constant in last-mile delivery*
[120] Sarma, 2020: *Change is the only constant in last-mile delivery*
[121] ASviS, 2022: *LA CITY LOGISTIC*

Failure to deliver

According to Mangiaracina et al. (2019), among the limitations that the last-mile delivery sector has experienced so far, and which need to be improved in order to increase efficiency, is the high probability of failed deliveries.[122] This theory is also supported in the literature by ASviS (2022), according to which, delivery does not always happen on the first attempt, which implies a complex and expensive return shipment. This makes the delivery system inefficient.[123] According to Respondent 4, however, automated last-mile delivery solutions overcome this problem as it is not possible for them to deliver the wrong parcels, in the wrong place and at the wrong time. And, at the same time, it is not possible that they will pick the wrong parcel because they are data-driven.

This concept of delivery failure is linked to the implementation of route planning, that is, an internal map system that allows the vehicle to move autonomously through the city streets. Indeed, this is a feature that, according to Mangiaracina et al. (2019), makes the industry inefficient because orders are small and destinations are dispersed along the route, which also makes delivery expensive compared to other elements of the delivery process.[124] In this regard, Respondent 1 also states that route planning is a key element when it comes to the efficiency of the process, and in fact, some companies are developing route planning systems in order to optimise the trips for each vehicle, telling where to pick up and where to drop off the parcels.

Costs

As far as cost efficiency is concerned, a significant difference emerges from the secondary data collected regarding the two macro categories of vehicles analysed. In fact, with regard to ground vehicles, all respondents agreed that the use of these vehicles is cost-efficient. In fact, according to Respondent 1, the service is very efficient and economical due to the reduction in costs resulting from the absence of a driver in each vehicle, because this cost is an important part of the total cost of transport. Also, Respondent 2, states that the efficiency of deliveries depends on the factor of subtracting the cost of the driver. However, he emphasises that there is a cost in the issue of remote

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[122] Mangiaracina, Perego, Seghezzi, & Tumino, 2019: *Innovative solutions to increase last-mile delivery efficiency in B2C e-commerce: a literature review*
[123] ASviS, 2022: *LA CITY LOGISTIC*
[124] Mangiaracina, Perego, Seghezzi, & Tumino, 2019: *Innovative solutions to increase last-mile delivery efficiency in B2C e-commerce: a literature review*

operators, which are useful in unpredictable situations that require human intervention, and also in the maintenance and servicing of vehicles, which is a cost that needs to be made more efficient. According to Respondent 3, the service is certainly cost-efficient, as according to him using a robot in a small area is more cost-effective than using a delivery driver. Also, according to Ackerman (2015) and London Assembly (2017), on the cost-efficiency of this method, it has been estimated that it can cost about 15 times less for companies than a traditional courier.[125] [126]

About the drone category, however, the results are different. According to both respondents, using a drone for home deliveries is not cost-efficient. In fact, according to Respondent 5, when it comes to the efficiency of the last mile delivery service, he stated that the level of efficiency of the service depends on the parameters that are taken into consideration: if cost-efficiency is evaluated, the system is not so efficient because it is not possible to deliver the same number of parcels per hour that a truck can deliver. Also, according to Respondent 6, when it comes to cost efficiency, the project is not efficient. The reasons this respondent sees behind this statement are to be found in regulation, which is reflected in increased costs, as well as in the same reason given by Respondent 5. In fact, until now, according to drone regulation, it is necessary to have a pilot of the aerial vehicle, who must be a pilot, thus, someone who handles the flight. According to most interpretations of this law so far, each pilot can only fly one drone at a time. This means that even if drones can fly autonomously, a pilot is still required for each drone, which represents a huge cost for deliveries, removes the benefit of eliminating the human component from deliveries and, in addition, increases costs as a pilot cost much more than a truck driver. Also, in terms of efficiency, there is the fact that drones deliver one parcel at a time, whereas a truck can deliver many.

Other Factors

In general, according to Respondent 2, a shortcoming of the service in terms of efficiency is the slowness of the system, because the vehicle used is, in terms of speed, somewhere between other autonomous vehicles dedicated to these services and traditional vehicles. Furthermore, according to Respondent 4, efficiency is high in terms of safety and in terms of time flexibility, as it allows deliveries to be made at off-peak times, such as at night. It is therefore a solution that allows for increased quality and reduced costs and, in addition, for working at times when people do not want

[125] Ackerman, 2015: *Startup Developing Autonomous Delivery Robots That Travel on Sidewalks*
[126] London Assembly, 2017: *Transport Committee – Transcript of Agenda Item 6 – Future Transport*

to work. According to Sarma (2020), efficiency in last-mile delivery occurs when there is efficiency in several tasks, which are inventory management, dispatch of orders, route planning, allocation of runners and, finally, prompt delivery of orders to the customer's door. If there is a lack of efficiency at any one of these points, the entire delivery can suffer negative consequences, such as delivery delays or the risk of not meeting the minimum quality limit that the customer expects in the delivery. It is also especially important to understand how best to handle other services, such as order returns and on-demand deliveries, to increase the efficiency of the entire service. Improving the efficiency of this part of the delivery process ensures the excellence of the customer experience.[127]

The categories that, according to the literature review and according to the respondents, define the efficiency of the last mile delivery sector are shown in the table below together with the solutions that autonomous vehicles provide, increasing and thus how they contribute to increasing efficiency:

Category of inefficiency	Type of inefficiency	AVs Solution	Source
Sustainability	Traffic and air pollution	Vehicles powered by electricity	LR, EF
Failure of Delivery	Failed delivery	Data-driven organization	EF
Failure of Delivery	Inefficient Route Planning	Data-driven and GPS optimization	LR, EF
Costs	The drivers cost impact on the total cost	For robots only: absence of driver	EF
Other Aspects	Slowness	Improved in drones delivery	LR, EF
Other Aspects	Flexibility	Route and time management data-	EF
Other Aspects	Quality	Increased by precision	LR, EF
Other Aspects	Time Waste	Possibility of working in peak-off	EF

Table 5: Illustration of inefficiencies in last mile delivery and ways in which the use of autonomous driving vehicles overcome them. Source: produced by the author

The inefficiencies shown in the table emerged from the analysis of primary data, while the solutions appeared from the analysis of secondary data and are not present in the literature analysed in this research. Inefficiencies in the use of self-driving vehicles, on the other hand, include the inability of drones to cut costs on the driver and the presence of ancillary services, which, according to the literature, contributes to the definition of efficiency in this sector.

[127] Sarma, 2020: *Change is the only constant in last-mile delivery*

5.2.1 Costs in using self-driving vehicles

According to Mangiaracina et al (2019), the efficiency of the last-mile delivery industry is based on the components that impact the cost of the service and the innovative solutions that companies try to produce to increase the value of cost efficiency. [128] When respondents were asked what they thought were the costs that affected most on the efficiency of last-mile delivery compared to traditional vehicle delivery, there were different answers. These differences are particularly noticeable when comparing the two categories, i.e., there is a substantial gap between respondents from companies operating with robots and those operating with drones. This is due to the differences between the two types of vehicles and also to the fact that they are subject to different regulations.

According to Respondent 1, the costs that affect the most are those of the resources used, which are significantly decreased since the vehicle is fully electric and is powered by a hub that in turn is powered by solar panels. Also, according to Respondent 4, costs are lost in the use of resources when these are already being used by others, as is the case at peak times. Respondent 5 is also of the same opinion; according to him, the drone also contributes to lower resource costs. This is also found in the literature, where in the framework of Mangiaracina et. al (2019), both drones and autonomous vehicles decrease resource consumption.

Another cost highlighted by the respondents is that of traffic, which, according to Respondent 1, stems mainly from the problem that if the vehicle is in an unmanageable traffic situation, human intervention of personnel will be required, which although it is possible to outsource, still represents a cost. Also, according to Respondent 5, with regard to drones, it might be possible to have to change routes when traffic is not completely absent, but it is possible to find other UAMs generating traffic or ambulance or police helicopters along the route. This aspect is missing in the literature, where this component for robots is not considered, while for drones, according to Mangiaracina et. al (2019) the relationship between their use and the cost factor "traffic/obstacles" is negative.

The third cost that many respondents dwell on is the cost of drivers. As far as robots are concerned, according to Respondent 1, cutting down on drivers leads to a large saving of money, an idea that is also confirmed by Respondent 4 according to whom labour costs decrease considerably, but are not eliminated. In fact, as already seen, labour is still needed in emergencies where the vehicle is unable to proceed alone. According to Respondent 6, on the other hand, the cost of drivers has a significant impact on the total costs for delivery. Indeed, drones still require a driver on the ground and this costs

[128] Mangiaracina, Perego, Seghezzi, & Tumino, 2019: *Innovative solutions to increase last-mile delivery efficiency in B2C e-commerce: a literature review*

a lot of money. This is because of regulations, according to which it is necessary to have a pilot guard who can monitor the flight and can intervene and take control of the drone at any time. Thus, the workforce is attached to any drone flight. In the theoretical framework analysed in the literature, this aspect related to drivers is missing, which is positively related to robots and negatively related to drones.

With regard to the other costs, according to the respondents, the cost of failure to deliver does not exist, and this evidence is also consistently found in the literature. In addition, it was indicated by Respondent 2, large initiative development costs that affect the total costs negatively and in addition, according to Respondent 5, there is also a small cost related to transport.

These factors influencing costs are shown in the following table, which aims to update the framework in Table 1 with the results obtained from this research.

	Cost Factors						
Innovative Solutions	Resource Consumption	Driver Cost	Delivery Automation	Traffic/ Obstacle	Transport Automation	Customer Density	Development Cost
Drones	–	–*	+	–	+	–	–*
Robots	–	+*	+	–*	+	–	–*

Table 6: Mangiaracina et al. (2019) framework updated with evidence. Source: produced by the author

In the diagram, relationships that have been added are showed with an asterisk next to the symbol showing the type of relationship between the vehicle implementation and the cost factors involved. The cost factors added are the cost of drivers and the cost of development, while the traffic/obstacles category has been updated by adding the relationship with robots which, from empirical evidence, was found to exist and to be negative.

5.2.2 Future trends to improve efficiency

Regarding the possible long-term solutions that the respondents see for increasing the efficiency of this new home delivery system that is being developed, some answers touch on several topics. According to what was gathered in this research, many things can be improved in the future. One type of efficiency analysed is resource efficiency, which can be increased by building vehicles that consume less and less energy, so the ones, built, according to Respondent 1, from lighter materials. The organisational structure is also to be improved, as according to this respondent the most efficient transport combination will be the simultaneous transport of people and goods. The latter was also found in the literature, where according to Saeeda et. al (2020), the predominant mode of use of autonomous vehicles will be sharing.[129] Technologically, according to Respondent 2, there is a need for improvement and the future development will be the implementation of a vehicle that is fully autonomous in all respects, something that is currently lacking in this sector. Existing vehicles still require human intervention in certain situations.

Another factor for improvement is to have a completely reliable vehicle. In terms of costs, one thing that will change in the future according to Respondent 3 is that the costs of computers and sensors will decrease and therefore vehicle construction costs will decrease by about ten times compared to today. In addition, due to the increased use of these vehicles, there will also be an increase in efficiency compared to the initial costs. According to Respondent 4, the future improvement will be in terms of the automation of the whole society, and as far as last mile delivery is concerned, what will happen in the future is the automation of all delivery processes, and traditional vehicles will no longer have any reason to exist in this respect. According to this respondent, there will be new ways of collecting and exchanging parcels between vehicles. And this is also confirmed by the answer of Respondent 5, who emphasises that there will also be improved ways of collecting and sorting parcels using drones.

In addition to this, future improvements will be seen in the areas of infrastructure, battery replacement and recharging, and increasing vehicle propulsion efficiency. Finally, again in the area of aerial vehicles, according to Respondent 6, as far as future trends are concerned, work will be done on vehicle regulation, to find more efficient but at the same time safe solutions. There will be a need for tests to prove to the authorities that these solutions are safe by having each pilot check several drones at a time. If one drone pilot is controlling several drones, then it is possible to start dividing the cost

[129] Saeeda, Burris, Labi, & Sinha, 2020: *An empirical discourse on forecasting the use of autonomous vehicles using consumers' preferences*

of the work between different lengths. Another solution to be implemented in the future is to find applications where fast delivery is really important. If special applications are possible where the customer is willing to pay a lot to have fast delivery, this system can be much faster because it does not have to think about traffic. The situations where customers are willing to pay are more oriented towards healthcare applications where time can save lives or at least give patients a better prognosis or a better chance of survival by ending suffering or where time is critical for real. This is also confirmed by Respondent 3, according to whom it is necessary to use this tool when the object of delivery is valuable.

6. CONCLUSIONS

This section will report on the conclusions of the entire research. To this end, the answers to the main research question and the sub-question will be reported in the first paragraph. These will be answered by taking the data reported in the analysis, integrating them and uniting them under the formulation of an answer consistent with the paper. Subsequently, the implications and limitations of this research, due to situations that the author could not have addressed differently, will be indicated. Finally, there is a paragraph dedicated to recommendations for future research, in which the author indicates what, in his opinion, are the possible developments of research in this field, starting from the present work.

6.1 Answering the Research Questions

What has emerged from the entire analysis is that there are two types of vehicle categories to be taken into consideration, namely "drones" and "robots", which in some cases can be treated in the same way, while in other cases this is not possible and different contributions for the two categories will be highlighted. As described in the introduction to this thesis, the project is based on the main research question and a sub-question. In order to fully answer the main question, we will first analyse the answer to sub-question 1, which was previously formulated as follows:

Sub-question 1: *"Which are the main cost factors that impact on last-mile delivery?"*

Given the data analysed in Chapter 5, it can be said that the cost factors that must be taken into account when analysing last-mile delivery are to be found, for both types of vehicles, in the resources used, driver costs, delivery automation, traffic and obstacle costs, transport automation, consumer density and development costs.

In fact, both types of vehicles require upstream investment in research and development on the part of the company in order to develop the necessary infrastructure for implementing automation and also the research so as to develop the vehicle that best suits its needs and those of the customer. In addition, successful delivery implies costs related to drivers, which in the case of robots, having to intervene in a targeted and occasional manner, represent a gain compared to the initial situation. In the case of drones, on the other hand, this reasoning is more complex, and the cost is higher as it is necessary to hire a pilot, and therefore face a much higher cost. The gain perceived in both cases is the automation of delivery and transport, which, according to the analysis, brings precision, security, reliability and flexibility. Another factor to consider with regard to both types of vehicles is the cost related to traffic, which is certainly more present in robots than it is in drones and can cause difficulties in terms of management. Customer density certainly affects the cost of both types of vehicles and in particular robots, which are better suited for deliveries in small, concentrated areas rather than in large areas, while drones are certainly suitable over long distances but cannot make a large number of deliveries.

With the information also gathered by answering sub-question 1, the main research question can be answered. It was stated as follows:

Research Question 1: *"How does the use of self-driving vehicles impact the efficiency of the deliveries compared to the traditional system?"*

According to the data analysis, the main differences between robots and conventional vehicles were found, in terms of cost, the need for human intervention, route optimisation, delivery accuracy, delivery costs, and the number of parcels that can be delivered at a time. The conclusion that the respondents also drew from the data was that despite the differences in terms of speed, where robots are slower than conventional vehicles, and in terms of capacity, where robots can transport far fewer parcels than conventional vehicles, it is still cost-effective to use these vehicles. This is because, compared to traditional vehicles, drivers intervene sporadically, which helps to reduce driver costs. Other costs that are lowered are those of the delivery itself, which is also less expensive in terms of the type of resources used, i.e., energy instead of petrol. Also important is the impact of routing, which helps optimise delivery times thanks to data-driven solutions.

As far as drones are concerned, the main differences between autonomous vehicles and robots are that in this case the driver required to complete the deliveries is much more expensive than the drivers of normal trucks, and this factor weighs heavily on the overall cost. Furthermore, in terms of capacity, drones can only deliver one parcel at a time. The distances over which they can move are short, but they have the advantage of being extremely fast. The characteristics that negatively affect costs mean that delivery by drones is, according to research and the respondents, not cost-efficient. Nevertheless, this type of delivery is very efficient when looking at efficiency from the point of view of speed and accuracy. However, as the cost of delivery remains high, to make this efficient it is necessary to find products that are of such value that using a drone makes sense, and because this way the consumer will be satisfied to pay this extra price. This is the case with medical devices, because if you think that the items that need to be transported serve to save a life, the content of the delivery becomes invaluable, and speed of delivery becomes important.

In short, it can be said that Last-Mile delivery is cost-efficient if done by robots, while it is not cost-efficient if done by drones, but in the latter case, it is speed-efficient.

In general, for both categories, there is also a cost gain in terms of increased brand value, increased in particular by the sustainability of the initiative and the punctuality, and flexibility in terms of space and time that self-driving vehicles can guarantee, in addition to the high quality standards.

6.2 Implications

For what concerns the practical implications, this study can be important for companies that are in this industry or want to join it, on what cost factors they need to improve in order to make their business sustainable. Understanding which cost factors work against efficiency can help them think through which changes or technological advances are most appropriate to ensure that they can offer an actually efficient service. The theoretical implication regards the fact that this study is part of a literature context in which a gap existed regarding the link between the concept of efficiency and the concept of last-mile delivery by autonomous vehicles. Here, the cost factors that make up this type of business are analysed, and this gap is filled in, arriving at a definition of the costs through which this activity leads a company to achieve economic efficiency or not, through the study of existing literature and empirical evidence gathered in the field.

6.3Limitations

The first limitation is that there is a paucity of studies, published online, on the subject of the efficiency of autonomous vehicles in logistics and, even more so, in last-mile delivery. Another limitation lies in the fact that as all interviewees were Swedish and the interviewer Italian, the interviews were conducted in English, which is not the native language of either party, which is a shortcoming in the study. A constraint was also the time available for the writing of the paper, which took about three months, which did not allow for a more in-depth study of the phenomenon, e.g., in a more in-depth study of costs, which leaves room for future research.

Finally, a final limitation is the fact that the paper is written by an author who is not an expert in the field of research, so the conduct of the interviews and the depth of the results are compromised by the author's inexperience.

6.4 Recommendations for future research

From this section, it is possible to suggest new insights for future research. First of all, it is possible to address the fact that all the companies interviewed in this research are based in Sweden by conducting the study in another country. If the researchers conduct this study in a country whose language, they find fluent, it will be possible to overcome the language limitation considered in section 6.2.

A further way of developing the research could be to conduct a more in-depth study of the cost items, taking into consideration the numerical values and also analysing the possible revenues in order to be able to calculate the efficiency in terms of profits.

Finally, it would be interesting to conduct a study on the implementations of this service in the technological sphere, analysing from a technical point of view, the innovative technologies that are flourishing in the sector and seeing how they can be applied to the context to ensure greater efficiency, including the technical ones.

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APPENDIX

A. Interview Guide

The following is the outline of questions used as an Interview Guide:

Question 1*:* Can you please introduce your company and your role in it?

Sub-question 1: Which is the dimension of the company?

Sub-question 2: Which is the scope of the company?

Sub-question 3: Where is your company located?

Question 2**:** Can you please tell me about your company project for self-driving vehicles in delivery and introduce your involvement in the project?

Sub-question 1: What kind of vehicle do you currently use? Why?

Sub-question 2: Did the company start with the decision to use self-driving vehicles, or did you first use another type of vehicle and then decide to convert it?

Question 3**:** Which is the difference between the traditional way of operating last-mile deliveries and the use of self-driving vehicles when it comes to efficiency?

Question 4**:** Do you think that this project reaches efficiency? In which terms?

IF YES: ***Question 5:*** Can you please tell me which are the main cost factor that influence your business?

IF NOT: ***Question 5:*** What do you think are the reasons why the project did not achieve efficiency?

Question 6**:** How do you think that the efficiency of the project could be improved?

Question 7**:** How does the kind of vehicle you use affect the answers given?

B. Thematic Analysis Coding Table

Aggregate	Second Order	First Order	Exemplary Quotes	Respondant
Self -Driving Vehicles	Vehicles informations	Aspect	*"The vehicle is small, three wheeled and self-driving"*	4
		Modularity	*"We have developed our own region. So we developed a platform so we can adjust the vehicle size depending on their own user needs"*	6
	Differences with the traditional way of delivery	Pilots	*"Currently it is mandated by EASA to have one operator watching the drone conducting the delivery operations but there is no hard limit on how many operations she can watch at once"*	2
		Drivers	*"These vehicles for this use are level 4, so they don't need wheel or pedals any controls for the driver they don't need to have it."*	1
		Areas of implementation	*"But it's also going to be deployed where it's easy, so modern neighbourhoods with lots of space and it's easy to deploy. We're not going to do old city centres with very complicated situations in in the beginning"*	6
	Decision of using self-driving vehicles	Idea	*"The idea actually came from an autonomous robot defence system for the military."*	3
		Timing	*"So it was already in the project proposal that we were out to fly some packages with drones."*	5
		Purpose	*"The purpose at the beginning was to solve the last mile problem to make an impact on CO2 emissions and the strategy has been to work where it can be deployed early in the market and therefore we have chosen a smaller vehicle that is safe."*	6
Efficiency in the last-mile delivery industry	Costs in using self-driving vehicles	Resources	*"You don't have the cost of using resources when they are used by others."*	3
		Labour	*"One must have in mind that for every drone flight there is human labour. You need a pilot and the pilot will cost money"*	5
		Development	*"A big cost is to get this vehicles to work in practise. I mean, the development costs are really large"*	4
	Efficiency of the delivery	Sustainability	*"Is it more efficient in regards to co2 per delivery than what's currently available for consumers"*	1
		Capacity	*" I don't think that this kind of delivery is efficient in terms of cost: the drones basically deliver single packets. While a truck driver contains as many as needed"*	2
		Economy	*"the service when it's in operation it would be a very efficient and cost effective system. Also the electric drive contributes to the economic efficiency."*	3
	Future trends to improve efficiency	Fully automated	*"The improvement factor number one is to start with the completely self-driving vehicles, the one we have today still need some human assitance*	4
		Value	*"Other solution or the other possibility is to find applications where the fast delivery is really worth about."*	5
		Combined Solutions	*" I think that, for the future, the combination between parcel and people is the most cost efficient solution"*	1

C. Message to the Respondents

Dear Doctor X,

I am Francesca Ciliberti, a Double Degree student in Innovation and Industrial Management at the University of Gothenburg and in Management at the LUISS University of Rome in Italy.

I am conducting a research project about self-driving vehicles in last mile delivery and I have seen your involvement in the Y project by Z. For this reason I would like to ask you a short interview to help me with my research

Do you think you could help me?

I look forward to hearing from you and wish you a good day,

Francesca Ciliberti

THESIS SUMMARY

1. INTRODUCTION

In recent years, we have witnessed a significant increase in the movement of urban goods worldwide, due to the phenomenon of rapid urbanization and the resulting changes in logistics.

This sector has been getting bigger and bigger thanks to the advent of e-commerce, which has been experiencing massive growth in recent years, so much so that its revenues reached approximately $4.9 trillion in 2021 and are expected to reach almost $5.5 trillion in 2022. According to Statista, this number will become about $7.4 trillion by 2025, reaching a growth of about 50%.[130]

To this trend, which was already positive, were added the contributions of the pandemic, which contributed exponentially to this growth as consumers suddenly started buying the goods they needed online in a general panic at that time.[131] It was thanks to the development of the home delivery system that some of the constraints posed by Covid-19 were alleviated, such as the inability to leave the house to shop for groceries or buy food. Because of these constraints, people started ordering the items they needed at home to avoid leaving the house. [132] Given this significant increase in deliveries, it became necessary to develop the supply chain in order to be able to provide a more reliable, faster, and smarter service so as to have a presence that can excel in the sector.[133]

Today, more and more operators are making this type of delivery and it has therefore become necessary to develop innovations concerning logistical hubs and means of delivery, which focus in particular on information systems that optimize the management of journeys, organization within hubs, new and different forms of mobility in the city and the training of human resources. [134] For this purpose, automation technology has evolved significantly over the past decade and this has helped in bringing innovation to the Last-Mile delivery industry. According to Grolms (2019), it has been predicted that automation in this area will account for up to 80% of B2C (Business-to-Customers) deliveries.[135]

[130] Chevalier, 2022: *Retail e-commerce sales worldwide from 2014 to 2025*
[131] Suguna, Shah, Karthik Raj, & Suresh, 2021: *A study on the influential factors of the last mile delivery projects during Covid-19 era*
[132] Unnikrishnan & Figliozzi, 2020: *A Study of the Impact of COVID-19 on Home Delivery Purchases and Expenditures*
[133] Sarma, 2020: *Change is the only constant in last-mile delivery*
[134] ASviS, 2022: *LA CITY LOGISTIC*
[135] Grolms, 2019: *Autonomous Shuttles and Delivery Robots*.

As this step in the logistics process is the least efficient in the production chain, and as it is considered the most important step in the delivery process, companies take care that it becomes as efficient and trouble-free as possible.[136] This inefficiency is due to the fact that orders are small and destinations are dispersed along the way, which also makes it very expensive compared to the other elements of the delivery process. For a company, this can cost up to half of the total logistics costs. All this makes it important to understand how to reduce expenses.[137]

Problem Discussion

The logistics of the Last-Mile is a very in-depth topic in the literature in which one can find numerous definitions and regards. This is a fundamentally important part of the production process, and the last, so many authors agree that this should be the part of the supply chain that works best.[138] Despite this, it is repeatedly stated that this is the least efficient part of the production chain and that it is, therefore, necessary to try to find solutions that enable its implementation and optimisation.[139]

In order to address the challenges related to last mile delivery, the latest technologies can come to the rescue, such as self-driving vehicles, which are representing a real revolution in the field of urban logistics, thanks to which it is also possible to solve many problems that exist today, such as environmental and urban traffic problems.[140] At the same time, however, these vehicles can bring problems, such as those related to privacy.[141]

With this in mind, although much research can be found in academic publications on the characteristics of vehicles and their components, there are no publications accessible to this author that analyse the cost-efficiency of self-driving vehicles when applied to the last-mile delivery sector. Therefore, the research problem that it is proposed to solve is an existing gap in the literature due to the scarcity of existing academic works linking the use of self-driving vehicles to last-mile delivery and, even more so, the latter concept to that of efficiency.

[136] Vakulenko, Shamps, Hellström, & Hjort, 2019: *Service innovation in e-commerce last mile delivery: mapping the e-customer journey*
[137] Mangiaracina, Perego, Seghezzi, & Tumino, 2019: *Innovative solutions to increase last-mile delivery efficiency in B2C e-commerce: a literature review*
[138] Olsson, Hellström, & Pålsson, 2019: *Framework of Last Mile Logistics Research: A Systematic Review of the Literature*
[139] Mangiaracina, Perego, Seghezzi, & Tumino, 2019: *Innovative solutions to increase last-mile delivery efficiency in B2C e-commerce: a literature review*
[140] Saeeda, Burris, Labi, & Sinha, 2020: *An empirical discourse on forecasting the use of autonomous vehicles using consumers' preferences*
[141] Suguna, Shah, Karthik Raj, & Suresh, 2021: *A study on the influential factors of the last mile delivery projects during Covid-19 era*

Purpose and Research Question

The topic of this research is the efficiency of Last-Mile delivery via self-driving vehicles. The aim of this research is to analyse the impacts of this new automation technology on the transport of goods at an urban level, focusing on the costs this brings to businesses but also on other efficiency-related issues such as speed and sustainability, and to understand the opportunities and limitations of this technological choice.

In this thesis, the author, aims to fill the aforementioned academic gap by linking all these topics by analysing existing works on the vehicles that are used for this type of delivery today, autonomous vehicles, urban logistics, last-mile logistics, and cost-efficiency in logistics. The research question that encapsulates this aim is, therefore:

RQ1: *How does the use of self-driving vehicles impact the efficiency of the deliveries compared to the traditional delivery system?*

Sub-question 1: *Which are the main cost factors that impact last-mile delivery?*

2. LITERATURE REVIEW

The literature review section investigates what has already been studied in earlier research in order to provide a theoretical basis for the study under review. In particular, this section is divided into three parts: in the first part, starting with the definition of the concept of "city logistics", were is assessed how the advent of digitalization has brought about changes in this regard, up to the most recent contributions made by the advent of the Covid-19 pandemic. The growing role of e-commerce to concerning the transport of goods is also further detailed at this point. The second part explains the arrival of the latest autonomous driving vehicles with an overview of the distinct kinds of solutions that are in use in this field. Finally, the third part covers earlier studies on efficiency in this sector and what variables need to be considered.

According to Lim et al. (2018), the concept of Last-Mile Logistics (LML) indicates the last step of a Business-to-Consumer package delivery service,[142] thus a service that goes from a transportation hub

[142] Lim, Jin, & Srai, 2018: *Consumer-driven e-commerce - A literature review, design framework, and research agenda on last-mile logistics models*

to a final destination.[143] Actually, Last-Mile Delivery represents more than 50% of the share of global freight delivery.[144]

It can be said that urban freight distribution has a dual purpose: first, it has to limit the overall expense of transporting goods by taking advantage of the delivery of several goods at the same time and working over short distances; the second objective is to deliver goods correctly, without being too costly and providing good customer service that satisfies consumers.[145] Indeed, being Last-Mile Delivery the last step in the transportation system, it impacts both customer satisfaction and market share for logistics,[146] so that the higher is the quality of the delivery, the higher is the satisfaction itself: for customers, having fast delivery represents added value and so they are willing to pay more for this benefit, and, for the companies, by charging a higher price, they can cover distribution costs, which, in turn, go up.[147] Moreover, this is the least efficient part of the transportation chain in terms of routing and the subsequent increase of costs that it takes,[148] and therefore it is necessary to understand the barriers that are encountered during the internal process and mitigate them as this is the most important part of the process and it is also essential in order to ensure quality and customer satisfaction.[149]

In recent years, thanks to the technological transformation of vehicles we are witnessing the emergence of new modes of transportation such as self-driving vehicles and new services based on these recent technologies.[150] These AGV (Autonomous Guided Vehicle) can deliver packages without the need for human intervention in the delivery process customers are alerted via a notification of the date and time their package will be delivered, and they will be instructed on how to pick up their package from the vehicle via an application embedded within it.[151]

In order to increase last mile delivery efficiency, lots of new and innovative solutions have been found to help companies overcome the limits that this industry has experienced until now, like for example the high probability of failing the deliveries. According to Mangiaracina et. al (2019), the efficiency of the last mile delivery sector is based on the components that affect the costs of the service and on

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[143] Xia & Yang, 2018: *Is Last-Mile Delivery a "Killer App" for Self-Driving Vehicles?*
[144] Alfandari, Ljubic, & De Melo da Silva, 2021: *A tailored Benders decomposition approach for last-mile delivery with autonomous robots*
[145] Viu-Roig & Alvarez-Palau, 2020: *The impact of e-commerce related last-mile logistics on cities: a systematic literature review*
[146] Chen, Demir, Huang, & Qiu, 2021: *The adoption of self-driving delivery robots in last mile logistics*
[147] Jacobs, et al., 2019: *The last-mile delivery challenge*
[148] ASviS, 2022: *LA CITY LOGISTIC*
[149] Weber & Badenhorst-Weiss, 2018: *The last-mile logistical challenges of an omnichannel grocery retailer: a South African perspective*
[150] Saeeda, Burris, Labi, & Sinha, 2020: *An empirical discourse on forecasting the use of autonomous vehicles using consumers' preferences*
[151] Bouton, et al., 2017: *An integrated perspective on the future of mobility, Part 2: transforming urban delivery*

the innovative solutions that companies are trying to elaborate on to increase the value of the cost-efficiency. They elaborated a relationship scheme between the factors and the cost components.

3. METODOLOGY

The research strategy used in this thesis is a qualitative approach, that allows to drill down to people's beliefs, focusing on people and what causes them to engage in certain behaviours rather than others.[152] For what concern the research design, in this research, the comparative design will be applied to a qualitative strategy through the use of a multiple case study. The research method has followed the subsequent path: first of all, the general research question has been chosen; after that, the collection of secondary and then primary data began; the data collection was followed by the analysis and interpretation of these data; finally, the conclusions of the paper were drawn.

Concerning the collection of primary data, they have been collected through the use of semi-structured interview. This process involves the interviewer having a ready guide to the questions she wants to ask the respondent, but the respondent itself has a wide margin over the answer. Potential interviewees were contacted via a message on their companies' email and personally via LinkedIn and the message sent to them is reported in Appendix C. The sample analysed is 6 persons, all CEOs or high responsibility roles in companies that use self-driving vehicles for deliver via robots or drones, and all companies are based in Sweden. All the interviews have been audio-recorded by the author. As for the analysis, it has been done through the use of a thematic analysis.

The type of analysis chosen to process the data for this research is thematic analysis. [153] This kind of analysis has been used to set up the presence of possible patterns within the collected interviews. The interviews have first been fully transcribed and then carefully reviewed by the interviewer who has then went ahead to schematize the information collected by coding the information. These codes have then been grouped into broader categories, that allowed for the identification of the most frequent responses among respondents. After that, the relationships between the various themes, which may be positive, negative, or non-existent, have been sought and through them, a critical analysis of the quantitative results was conducted.[154]

Secondary data were collected by researching papers previously written by the authors concerning the concept of 'delivery' in general and then more in-depth for 'Last-Mile Delivery', efficiency in the

[152] Bell, Bryman, & Harley, 2019: *Business Research Method*
[153] (Turunen, 2013): *Content analysis and thematic analysis: Implication for conducting a qualitative descriptive study*
[154] Bell, Bryman, & Harley, 2019: *Business Research Method*

delivery sector and the diverse types of existing self-driving vehicles used, or planned to be used, in deliveries. About research quality, this research primarily meets trustworthiness.

4. ANALYSIS

In this section, the empirical results are also elaborated in the light of the previously conducted literature review. The focus is indeed on the analysis of primary and secondary data, both those collected through the literature review and those collected through the semi-structured interviews. The object is to put the data together in a logical manner and to derive a single view of the cost-efficiency situation of the transport of parcels at the urban level through self-driving vehicles. The section presents two main paragraphs: one is about self-driving vehicles and contains the data analysis about the choice of using these vehicles in companies and the differences with the traditional way of delivery; the second paragraph is about the efficiency in the last-mile delivery industry, which contains data analysis about the efficiency, the costs in using self-driving vehicles and the future trends regarding efficiency. In each section, the data collected by the different companies are compared and merged, and the data from the literature are then integrated to support these.

The type of vehicles used by the interviewees in this research is autonomous vehicles, and in particular, when analysing the type of vehicles used by the six companies responding to the interviewer's questions, the first thing to point out is that the vehicles they use fall into two broad categories: ground vehicles and aerial vehicles.

Self-driving Vehicles

The motivations for companies to use this type of vehicle are therefore shown in the table below, divided by category and whether the information was found through Empirical Findings or Literature Review. With this table we also want to highlight how new factors emerged from the interviews compared to those reported in the literature reviewed by this research, which are for robots the cost of drivers and flexibility in terms of time, and for both categories of route planning. Furthermore, some factors highlighted in the literature review were also confirmed by the findings, such as CO_2 emissions, the avoidance of human contact (this being a need born in the pandemic period) and the obstacle or traffic factor; the other factors present in the literature, such as the number of deliveries, labour shortage and the cost of delivery, were not reflected in the empirical findings as to the motivation of using self-driving vehicles. Regarding the decision to use self-driving vehicles as early as the company's or product's start, all companies confirm that the decision was made from the beginning and was therefore not a later innovation.

Factors	Robots (EF)	Robots (LR)	Drones (EF)	Drones (LR)
Drivers Costs	x			
Route Planning	x		x	
CO2 Emissions	x	x		
N. of deliveries		x		
Labour Shortage		x		
Obstacles/Traffic			x	x
Human Contact			x	x
Delivery Costs				x
Time Flexibility	x			x

Figure 1: Factors contributing to the choice of automated vehicles according to literature (LR) and findings (EF). Source: produced by the author

In both literature and empirical findings, it has been found that there are fundamental differences between vehicles traditionally used for deliveries and autonomous vehicles. It has also been found that the decision to use autonomous vehicles is made by companies at the beginning of their business.

The main differences that have been found both in the literature and in the empirical findings can be best summarised in three categories identified by the author: the first, termed 'absence of labour', encapsulates the discourses of risk, labour, delivery time, route planning, speed of delivery and overcoming obstacles. The second category, called 'costs and resources', encapsulates the differences in cost, quality, and resources, where the latter concept is linked to that of sustainability. The third category, called 'vehicle characteristics' encompasses those differences related to speed, areas of possible deployment and vehicle capacity. The table below shows that the factors on which the difference between normal and self-driving vehicles emerged from this study are sixteen:

			Differences with traditional vehicles (Source)				
			Robots (LR)	**Robots (EF)**	**Drones (LR)**	**Drones (EF)**	**Traditional Vehicles**
Factors	**Absence of labour**	Human Intervention	Not needed	Necessary, for contingecies	Not needed	Necessary, from the ground	Needed
		Traffic Dependency	Low	Low	None	None	High
		CO2 Impact	Low	Low	Low	Low	High
		Routing	Optimised	Optimised	Flexible	Flexible	Not optimised
		Distances		Short		Short	Long
		Delivery Time	Low	Low	Fast	Fast	Fast
		Accuracy	High	High			Low
	Costs and resources						
		Construction Costs		Low		Low	High
		Quality	High		High		Low
		Delivery Costs	Low	Low	Low	Low	High
		Driver Costs		Low		High	Medium
		Resources	Energy	Energy	Energy	Energy	Petrol
	V. Characteristics						
		Speed	Low	Low	Fast	Fast	Fast
		Safety	High	High	High	High	Low
		Implementation areas		Small		Small	Big
		Number of parcels	Few	Few	One	One	Many

Figure 2: Differences between self-driving vehicles and traditional vehicles, a comparison between literature review (LR) and empirical findings (EF). Source: produced by the author

In particular, differences between the primary data (LR) and the secondary data (EF) are noted with regard to:

Human intervention: in this case, according to the literature, human intervention is not necessary, whereas according to the interviewees, there are situations where it is still necessary nowadays, as far as robots are concerned, while, with regard to drones, it was found that human intervention is always necessary due to regulation.

Distances: The distances that can be covered by these vehicles are not analysed in the literature. However, empirical findings have shown that the distances that these new vehicles can cover are relatively short and certainly shorter than those of conventional vehicles.

Construction costs: empirical evidence showed that the cost of building the vehicles is low. This information was not present in the literature and applies to all types of autonomous vehicles.

Quality: the quality of delivery by autonomous vehicles appears to be exceedingly high according to the literature. However, this information was not found in the empirical findings, where no respondents focused on this aspect.

Driver costs: this information was taken from the empirical findings and is not found in the literature. What has been found is that, for robots, the cost of a driver, only needed on specific occasions, is low, whereas for drones it is a much higher cost than for conventional vehicles.

Implementation areas: this data, missing from the literature, states that the deployment area of autonomous vehicles is relatively minor compared to the range of traditional delivery.

Efficiency in the last mile delivery industry

Efficiency in last-mile delivery is, according to Sarma (2020) one of the pillars of last-mile operations, along with the speed of service, for which consumers are willing to pay a premium price, transparency in communication with customers, such as the ability to track an order, and, finally, the personalised experience made up of purchase offers, discounts and customised delivery options. [155]

This point is particularly important to the research because, due to the big and fast growth that this sector has experienced in the last period due to the pandemic, as reported in the literature review, it became necessary to develop the supply chain to be able to supply a more reliable, faster, and smarter service in order to have a presence to excel in the industry.[156]

The categories that, according to the literature review and according to the respondents, define the efficiency of the last mile delivery sector (namely, sustainability, failure of delivery, costs and other aspects) are shown in the table below together with the solutions that autonomous vehicles provide, increasing and thus how they contribute to increasing efficiency:

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[155] Sarma, 2020: *Change is the only constant in last-mile delivery*
[156] Sarma, 2020: *Change is the only constant in last-mile delivery*

Category of inefficiency	Type of inefficiency	AVs Solution	Source
Sustainability	Traffic and air pollution	Vehicles powered by electricity	LR, EF
Failure of Delivery	Failed delivery	Data-driven organization	EF
Failure of Delivery	Inefficient Route Planning	Data-driven and GPS optimization	LR, EF
Costs	The drivers cost impact on the total cost	For robots only: absence of driver	EF
Other Aspects	Slowness	Improved in drones delivery	LR, EF
Other Aspects	Flexibility	Route and time management data-	EF
Other Aspects	Quality	Increased by precision	LR, EF
Other Aspects	Time Waste	Possibility of working in peak-off	EF

Figure 3: Illustration of inefficiencies in last mile delivery and ways in which the use of autonomous driving vehicles overcome them. Source: produced by the author

The inefficiencies shown in the table emerged from the analysis of primary data, while the solutions appeared from the analysis of secondary data and are not present in the literature analysed in this research. Inefficiencies in the use of self-driving vehicles, on the other hand, include the inability of drones to cut costs on the driver and the presence of ancillary services, which, according to the literature, contributes to the definition of efficiency in this sector.

When respondents were asked what they thought were the costs that affected most on the efficiency of last-mile delivery compared to traditional vehicle delivery, there were different answers. These differences are particularly noticeable when comparing the two categories, i.e., there is a substantial gap between respondents from companies operating with robots and those operating with drones. This is due to the differences between the two types of vehicles and also to the fact that they are subject to different regulations.

These factors influencing costs are shown in the following table, which aims to update the framework in Table 1 of the thesis, with the results obtained from this research.

	Cost Factors						
Innovative Solutions	Resource Consumption	Driver Cost	Delivery Automation	Traffic/ Obstacle	Transport Automation	Customer Density	Development Cost
Drones	–	–*	+	–	+	–	–*
Robots	–	+*	+	–*	+	–	–*

Figure 4: Mangiaracina et al. (2019) framework updated with evidence. Source: produced by the author

In the diagram, relationships that have been added are showed with an asterisk next to the symbol showing the type of relationship between the vehicle implementation and the cost factors involved. The cost factors added are the cost of drivers and the cost of development, while the traffic/obstacles category has been updated by adding the relationship with robots which, from empirical evidence, was found to exist and to be negative.

5. CONCLUSIONS

What has emerged from the entire analysis is that there are two types of vehicle categories to be taken into consideration, namely "drones" and "robots", which in some cases can be treated in the same way, while in other cases this is not possible and different contributions for the two categories will be highlighted. As described in the introduction to this thesis, the project is based on the main research question and a sub-question. In order to fully answer the main question, we will first analyse the answer to sub-question 1, which was previously formulated as follows:

Sub-question 1*: "Which are the main cost factors that impact on last-mile delivery?"*

Given the data analysed in Chapter 5, it can be said that the cost factors that must be taken into account when analysing last-mile delivery are to be found, for both types of vehicles, in the resources used, driver costs, delivery automation, traffic and obstacle costs, transport automation, consumer density and development costs.

In fact, both types of vehicles require upstream investment in research and development on the part of the company in order to develop the necessary infrastructure for implementing automation and also the research so as to develop the vehicle that best suits its needs and those of the customer. In addition, successful delivery implies costs related to drivers, which in the case of robots, having to intervene in a targeted and occasional manner, represent a gain compared to the initial situation. In the case of drones, on the other hand, this reasoning is more complex, and the cost is higher as it is necessary to hire a pilot, and therefore face a much higher cost. The gain perceived in both cases is the automation of delivery and transport, which, according to the analysis, brings precision, security, reliability and flexibility. Another factor to consider with regard to both types of vehicles is the cost related to traffic, which is certainly more present in robots than it is in drones and can cause difficulties in terms of management. Customer density certainly affects the cost of both types of vehicles and in particular robots, which are better suited for deliveries in small, concentrated areas rather than in large areas, while drones are certainly suitable over long distances but cannot make a large number of deliveries.

With the information also gathered by answering sub-question 1, the main research question can be answered. It was stated as follows:

Research Question 1: *"How does the use of self-driving vehicles impact the efficiency of the deliveries compared to the traditional system?"*

According to the data analysis, the main differences between robots and conventional vehicles were found, in terms of cost, the need for human intervention, route optimisation, delivery accuracy, delivery costs, and the number of parcels that can be delivered at a time. The conclusion that the respondents also drew from the data was that despite the differences in terms of speed, where robots are slower than conventional vehicles, and in terms of capacity, where robots can transport far fewer parcels than conventional vehicles, it is still cost-effective to use these vehicles. This is because, compared to traditional vehicles, drivers intervene sporadically, which helps to reduce driver costs. Other costs that are lowered are those of the delivery itself, which is also less expensive in terms of the type of resources used, i.e., energy instead of petrol. Also important is the impact of routing, which helps optimise delivery times thanks to data-driven solutions.

As far as drones are concerned, the main differences between autonomous vehicles and robots are that in this case the driver required to complete the deliveries is much more expensive than the drivers of normal trucks, and this factor weighs heavily on the overall cost. Furthermore, in terms of capacity, drones can only deliver one parcel at a time. The distances over which they can move are short, but they have the advantage of being extremely fast. The characteristics that negatively affect costs mean that delivery by drones is, according to research and the respondents, not cost-efficient. Nevertheless, this type of delivery is very efficient when looking at efficiency from the point of view of speed and accuracy. However, as the cost of delivery remains high, to make this efficient it is necessary to find products that are of such value that using a drone makes sense, and because this way the consumer will be satisfied to pay this extra price. This is the case with medical devices, because if you think that the items that need to be transported serve to save a life, the content of the delivery becomes invaluable, and speed of delivery becomes important.

In short, it can be said that Last-Mile delivery is cost-efficient if done by robots, while it is not cost-efficient if done by drones, but in the latter case, it is speed-efficient. In general, for both categories, there is also a cost gain in terms of increased brand value, increased in particular by the sustainability of the initiative and the punctuality, and flexibility in terms of space and time that self -driving vehicles can guarantee, in addition to the high quality standards.

In addition, this research has made it possible to analyse what factors will increase the efficiency of this new home delivery system in the future. There are many aspects that have room for improvement in the future, resources can be made efficient by building vehicles that consume less and less energy, using lighter materials. The organisational structure must also be improved: the most efficient transport combination will be the simultaneous transport of people and goods. Another factor is the implementation of a fully autonomous vehicle in all respects. In addition, component costs will be considerably lower in the future, which will reduce vehicle construction costs. As far as the concept of automation itself is concerned, this will cover the whole of society and thus automation of every stage of all delivery processes will be possible, with new ways of collecting and sorting parcels using drones. Furthermore, future improvements will concern infrastructure, battery replacement and recharging, and increasing the efficiency of vehicle propulsion. Finally, again in the area of aerial vehicles, work will be done on vehicle regulation, in order to find more efficient but at the same time safe solutions.