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Logistics 4.0 – Evolution of Transport for the Pharmaceutical Sector

Evolution and Application Analysis of Autonomous Vehicles for Pharmaceutical Logistics in Portugal

João Henrique Balau Figueiredo

Master (MSc) in Management of Services and Technology

Supervisor:
Doctor Henrique O'Neill, Associated Professor,
ISCTE - Instituto Universitário de Lisboa

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BUSINESS
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Department of Marketing, Operation and Management

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Acknowledgements

Firstly, I want to thank Professor Henrique O'Neill for the availability, shared knowledge and support in the past year, giving the best inputs and pieces of advice for the conclusion of this thesis.

Secondly, I would like to thank Jorge Alves, Vasco Parrulas, Paula Teixeira, and Jorge Martins for contributing to this work.

Finally, I would like to thank to all my family, friends, and colleagues for the fantastic support throughout all my academic career and for giving me the support I always needed.

Resumo

A transformação digital torna o ambiente empresarial cada vez mais competitivo. As empresas devem seguir essa transformação, caso queiram diferenciar-se e construir uma posição competitiva sólida nos mercados em que operam. Neste sentido, é crucial reconhecer a importância das novas tecnologias na melhoria das operações logísticas e as vantagens que daí advêm. Entre estas tecnologias destacam-se os veículos autónomos.

Deste modo, o presente estudo tenta, por um lado, compreender de que forma é que a tecnologia dos veículos autónomos poderá transformar a maneira como os bens são transportados, e como os processos logísticos e as dinâmicas dentro das cadeias de abastecimento podem ser melhorados.

Por outro lado, visa perceber como é que as empresas da cadeia de abastecimento do mercado farmacêutico em Portugal, encaram estas transformações do ponto de vista das operações logísticas que desenvolvem. Assim sendo, esta investigação pretende avaliar se será possível implementar esta tecnologia no sector e em que atividades a sua utilização trará mais benefícios e poderá ser viável.

Os principais resultados alcançados permitem concluir que, os veículos autónomos já são uma realidade em várias atividades, nomeadamente nas operações logísticas efetuadas em ambientes restritos como armazéns. É neste segmento das atividades de armazém, que as empresas do sector em estudo estão mais recetivas em apostar na utilização de veículos autónomos.

Os resultados indicam que as empresas não acreditam na possibilidade destes veículos serem utilizados na distribuição de medicamentos a curto e medio prazo, existindo ainda fatores que limitam a introdução desta tecnologia neste mercado.

Palavras-Chave: Logistica 4.0; Veículos Autónomos; Logistica de Transportes; Mercado Farmacêutico.

JEL Classification System: L91 – Transportation: General

O33 – Technological Change: Choices and Consequences; Diffusion Processes.

Abstract

Digital transformation makes the business environment increasingly competitive. Companies must follow this transformation to differentiate themselves and build a solid competitive position in the markets in which they operate. In this sense, it is crucial to recognize the importance of new technologies in improving logistics operations and the advantages that come with them. Among these technologies, autonomous vehicles stand out.

Thus, this study attempts, on the one hand, to understand how autonomous vehicle technology can transform the way goods are transported and how logistics processes and the dynamics within supply chains can be improved.

On the other hand, it aims to understand how companies in the supply chain of the pharmaceutical market in Portugal view these transformations from the point of view of the logistics operations they develop. Therefore, this research aims to evaluate if it is possible to implement this technology in the sector and in which activities its use will bring more benefits and may be feasible.

The main results allow us to conclude that autonomous vehicles are already a reality in various activities, particularly for logistics operations carried out in restricted environments such as warehouses. In this segment of warehouse activities, companies in the sector under study are more willing to invest in autonomous vehicles.

The results indicate that companies do not believe in the possibility of these vehicles being used in the distribution of medicines in the short and medium-term, and there are still factors that limit the introduction of this technology in this market.

Keywords: Logistics 4.0; Autonomous Vehicles; Transport Logistics; Pharmaceutical Market.

JEL Classification System: L91 – Transportation: General

O33 – Technological Change: Choices and Consequences; Diffusion Processes;

Index

Figures and Tables Index

Figures

Tables

List of Acronyms and Abbreviations

ADAS – Advance Driver Assistance Systems

AGV - Automated Guided Vehicles

AV – Autonomous Vehicle

DDT – Dynamic Driving Task

EMA - European Medicines Agency

ERP - Enterprise Resource Planning

ICT – Information and Communication Technologies

ITS – Intelligent Transportation Systems

LO – Logistics Operator

SAE – Society of Automotive Engineers

SC – Supply Chain

SCM – Supply Chain Management

TMS - Transportation Management Systems

WMS - Warehouse Management Systems

Introduction

Initial Considerations

In the past few decades, the disruption of new technologies has had a crucial impact on the development of new industries. The emergence of those technologies applied to new industries allowed the development of many other sectors of activity. Logistics and distribution are among those sectors that took advantage of disruptive technology.

The transportation sector is known for its low-profit margins due to the high market competition. Investments must be made regularly to go along with the market competitiveness, or companies will be compelled to fall back by other players who take over their market position. To keep up with the innovative ideas that reach the market, logistic companies every year invest in new technologies to improve their operations by increasing capacity, efficiency and ultimately achieve better results. Among these new trends are autonomous and connected vehicles.

The dissemination of self-driving vehicles, once seen as a distant vision in the past, is gaining strength because the world's leading automotive and technology companies are starting to develop and show the first prototypes and opening discussion on crucial subjects related to this technology. Every year, the new systems and technology features capable of improving the driving experience are presented by vehicles manufacturers. The combination of those systems and features will eventually make autonomous driving a reality.

Research on the transportations sector started in the sixties with the spread of cars, public transportation, and distribution and inventory management businesses. Only in the 1980s trucking as a common carrier started to be the subject of study. One decade later, the focus was on transport Logistics and Supply Chain Management (SCM) to cover various related problems. The research on transportation over the last twenty years has contributed to applying the technologies in transportation (Grazia Speranza, 2018).

As stated by Grazia (2018), companies today can no longer compete while being segregated in their own supply chain. They must adapt as the economy pressures them to become more efficient and effective. The recent advances in transportation technology are rapidly changing the way the supply chain is managed and goods and people are transported. Logistics and SCM as a broader concept work as business functions to ensure all goods are delivered on time and in full.

The concept of supply chain is continuously changing over the years and has now a much wider coverage of the ideas. These changes and difficulties in defining supply chain grow when companies open their doors towards innovation, integration of other activities and new forms of collaborative relationships between them.

Although Supply chain is related to SCM, these definitions are often confused. Supply chain has been defined as the continuous process that involves the entire activities essential to deliver the ultimate product or service. This definition includes activities such as procurement of raw materials, manufacturing, assembling, warehousing, order processing, inventory management, distribution, delivery to customer and customer service. This relation between processes must be truly efficient so that the whole supply chain becomes competitive (Lummus & Vokurka, 1999). SCM is the coordination and integration of all the previous activities into a unified process.

According to Lummus et al. (1999), the SCM is essential in every company since it links all partners and departments included in the chain, from suppliers to transportation companies. Throughout the SCM, companies work together to make a more sustainable and competitive supply chain, exchanging knowledge, technology or even information on market behavior.

The definition of logistics has been changing over the years, mainly due to progress in technologies and industries. To find a definition of Logistics 4.0, Amr et al. (2019), started by defining Logistics 2.0 and 3.0. While the first concept of logistics goes back to the 17th century as the military way of organizing troops, logistics 2.0 and logistics 3.0 only were introduced in the late 20th century. These concepts of logistics appeared when mass production started to be a reality, and cargo handling automation was already a requirement in every industry, as well as the coordination between different organizations in the same supply chain. These are also a consequence of different revolutions and evolutions that happened inside the supply chains. Logistics 4.0 is a consequence of these events. Ultimately Logistics 4.0 aims to increase the optimization level of the entire value chain since the intensive use of technologies.

The goal of SCM and Logistics is to satisfy the customer's needs with the required quality service without compromising the efficiency of the whole supply chain(Anca, 2019; Holubčík et al., 2021). The value added of a supply chain is focused on little operational details like logistics flows optimization, having visibility along the chain, reliable data to make decisions and the ability to deliver more cargo in the shortest time.

Great ideas usually follow bigger needs, market challenges, or even technology lack of efficiency. That is the case of the automotive industry. The automotive industry goes along with the disruptive technology trends to come up with new concepts capable of adapting to the new needs of consumers and businesses. The more technology evolves, the easier people day-to-day activities are. This statement has its practical applications when we look at the evolution of autonomous vehicles (AV). Automated driving will significantly contribute to making life easier for the driver and creating a more efficient overall traffic flow, with fewer critical situations or accidents (Continental AG, 2021). This might be the fundamental idea behind the future means of transport.

Despite the literature and research focusing mainly on private passenger's vehicles, there have been considerable developments in adapting the same technologies to a larger scale to give economic sectors the resources to become more competitive. Also, the implementation of AVs might occur first in the logistic business sector. This elevates the importance of self-driving vehicles primarily in adapting to goods transportation rather than passenger's transportation. The changes in this paradigm will influence the way logistics processes will be handled in the recent future.

Low profit margins and high competition can also be discouraging factors to investments in research and development of new applications of technologies inside logistics companies(Bucsky, 2018). This means that the new technologies in logistics will have to come from the contribution of companies specialized in new machinery technology and companies which can adapt those technologies to logistics. Businesses related to operations management and logistics will be developed so that new competitive advantages will affect early adopters of these new technologies. The advances in AVs may create new businesses and revolutionize property ownership structures. However, this revolution is expected to create new challenges not only to logistics, but also to all society as machines start to take a higher role in the way businesses are conducted.

One thing is certain, the future of logistics is about reducing distances and increasing cargo transportation. For so long, this has been the industry's main goal and the trend of new advances. This is also relevant to not jeopardize the economy and environment sustainability.

Objectives and Methodology

The main research of this thesis is built upon autonomous vehicles. What is expected with this work is an overview on autonomous vehicles, the recent evolution of this technology and how these have been influencing the logistics sector. This study will take the distribution of medicines as an example of the possible application of those vehicles. It is essential to identify the type of vehicles that are being developed and the technology that is being used to do so.

This work is intended to critically analyze the future implementation of autonomous vehicles in the warehouses and fleets of logistics operators and pharmaceutical distributors. The pharmaceutical market is highly regulated, which means that all movements of this type of stock must be well scrutinized. Due to these regulations, this market may present some challenges when it comes to the use of self-driving vehicles as a feasible mean of transporting medicines.

Initially, this work will summarize the type of vehicles that are being developed and which companies are responsible for these technologies. Once this analysis is done, it is relevant to verify the applicability of these vehicles in the transportation of goods, and which is more likely to become a reality in the pharmaceutical market. It will be interesting to understand why these vehicles, like other technologies, are initially being used in the logistics industry. Further in this thesis, what advantages can be gained from the fact that the first experiences of autonomous vehicles are in the logistics sector, instead of being used for passenger transport, will be analyzed.

To verify if the pharmaceutical market is ready for this upcoming transformation, interviews will be conducted with people in charge of operations and fleet management from the various companies that make up the medicines supply chain. That is, from the company responsible for the production of the finished product to companies whose activity focuses on the storage of medicines for local distribution by client pharmacies. Together with these agents of the pharmaceutical market, it is intended to understand their perception of this theme and try to answer the following research questions.

1) Can this technology be implemented in the pharmaceutical market?

2) In which activities can autonomous vehicles be useful?

3) What might be the main benefits and drawbacks of this technology?

4) How will the companies of this supply chain adapt to this new technology?

5) How long until it is widely used in the sector?

Document Framework / Explanation

This dissertation was built upon the following structure:

Introduction: Identification of the subject under study. General brief on the problems this research will study. Specification of the objectives of this study.

Chapter I – Literature Review: Presentation of the essential concepts for this research study and a specified explanation of these concepts considering the research already carried out by other authors or organizations. This research will also allow the documentation of different methodologies already used by other authors to suit this research. The developments already achieved by various companies to expose the "state of the art" related to this subject will also be identified.

Chapter II – Methodology: Identification of the methodology that best fits the scope of this work, taking into account the pre-defined objectives. This chapter aims to define and validate the data collection method that will be used in this study, as well as the characterization of the sample on which this study will focus.

Chapter III – Results and Critical Analysis: Analysis of the results taken by the prior data collection. The purpose of this chapter is to introduce the main findings of the study. All the main results are objectively reported and contribute to answering the research questions defined. The critical analysis allows drawing the initial conclusion on the results' meaning, importance, and relevance. This analysis will relate the obtained results with the literature review and research subjects.

Conclusions: Clarification of the initial questions and summary of the main findings of the research. Identification of the study limitations and recommendations for future scientific studies.

Chapter I

Literature Review

This chapter will introduce the theoretical concepts related to autonomous driving and supply chain logistics. These notions are fundamental to study further as they cross with logistics, distribution, and transportation.

1.1 Industry 4.0 / Logistics 4.0

Over the last decade, the digital revolution experienced has been contributing to the increase of efficiency and competitiveness levels inside logistics and production operations. This is mainly due to the use of Information and Communication Technologies (ICT) like Enterprise Resource Planning (ERP), Warehouse Management Systems (WMS), Transportation Management Systems (TMS) and Intelligent Transportation Systems (ITS) (Barreto et al., 2017). These authors defined Industry 4.0 as a fourth industrial revolution. This digital-oriented revolution will embrace the development and integration of new technologies into the industry to guarantee the efficiency of the supply chain processes and the use of resources.

Industry 4.0 allowed the emergence of digital manufacturing, and with this, the flexibility of industrial operations, customers and suppliers relations and the adoption of innovative business models. Thanks to new technological developments and communication tools, companies have real-time information of their operations and can have a more flexible and efficient monitorization, coordination, and control. Logistics 4.0 can be summarized as optimizing logistics processes supported by intelligent systems to achieve a significant degree of automation. This can also be seen as a network where all processes can communicate with each other and with humans to improve and enhance the supply chain.

For Barreto et al. (2017), "*The intensive use of the technological applications is contributing to the development of several new applications – in areas such as production processes, transportation system, logistics services, health services, autonomous vehicles, machine learning and smart structures– and consequently increasing the technological improvements of existing ones*".

Autonomous vehicles have been identified to be one of the main trends in logistics 4.0. People have been thinking of self-driving vehicles for decades but were always seen as a distant reality. The first automated machines were created with the Industrial Revolution, and with them, many new economic and social developments happened. The creation of automated machines replaces the heavy work in many activity sectors and contributes to an enormous increase in production.

Today there is a constant need to compete in every market, so companies must continuously be implementing new technologies in their business. Autonomous vehicles will fulfil the need in the market to be more efficient and faster when It comes to delivery times. These vehicles are already a reality, but in the future, companies will implement this type of vehicle in their business, from warehouse automated guided vehicles, autonomous trucks to autonomous aerial vehicles, according to their own business needs.

1.2 Autonomous Vehicles

1.2.1. Concept Definition / Levels of Automation

The idea behind AVs as the driverless Car is not new. Since the beginning of the XX century, this idea has been in development, but only today have actual solutions appeared. Today is possible to think about a vehicle capable of guiding itself in a city, across the countryside, performing long distances, respecting the signs driving limits, all this with the least possible assistance of the driver. For many years, vehicle development included features, or the so-called Advanced Driver Assistance Systems (ADAS) made it possible to idealize an autonomous vehicle. This concept includes features already in use in today's vehicles, such as adaptive cruise control, lane departure warning or automatic parking. The combination of these automations allows the creation of autonomous vehicles.

Many definitions of autonomous vehicles have been identified, but the concept may sometimes be confused with an automated vehicle. An automated vehicle focuses on the driver support systems, vehicle-to-vehicle (V2V) and vehicle-to-road-infrastructure (V2I). In comparison, the concept of a fully autonomous vehicle is related to the complete automation of the vehicle's features and the needless for a human driver to monitor the environment or control the vehicle (Neuweiler & Riedel, 2017).

The capability of an autonomous vehicle to drive itself derives from the combination of different and complex technologies that work together to guarantee the vehicle's autonomy (Shanker et al., 2013). Among the technologies of AVs already existing in the market are Forward Collision Warning, Adaptive Cruise Control and Lane Departure Warning. These and other technologies in development, when working together, can enhance the experience of an autonomous vehicle.

Autonomous vehicles can perform all the driving functions to safely move from one point to another without the direct intervention of a human (DHL Trend Research, 2014). This definition may include passenger vehicles and other vehicles like trucks, drones, and warehouses vehicles standard in logistics. In

sum, it is defined as fully autonomous, the vehicle that performs all the dynamic driving tasks (DDT) and can completely replace the human driver.

To explain the complexity of the definitions around AVs technology in 2014 SAE International Society of Automotive Engineers), brought a new standpoint of 2013 NHTSA (National Highway Traffic Safety Administration) classification for AV based on the human interaction with the vehicle. The previous classification divided AVs into only five levels (0 - 4), whereas SAE classification includes one more level (0 - 5), allowing to specify the higher automation levels concerning the interaction with the driver.

These five levels are different and have been classified according to the automation needed in driving, i.e., the equilibrium between vehicle and human controls from full driver assistance to complete automated processes. The following table (Table 1.1) shows that each of these five levels has its specifications.

Table 1.1: SAE Levels of Driving Automation, 2014

	Human monitor Environment			**Vehicle Monitors Environment**		
	Manual	**Partly Automated**		**High Automated**		**Full Automation**
	Level 0	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5**
Automation	No automation. Manual Driving.	The vehicle is controlled by the driver. The driver can be assisted by some included features.	Partial Automation. The features in the vehicle can work together. Driver must always monitor the environment and take control if needed.	The features can control the car in certain conditions. The driver must be ready to control the vehicle if required by the system.	Do not require human driver. The vehicle can perform all the driving tasks. The vehicle can be controlled by the driver.	No human driver intervention is needed.
Features	No special features	- Cruise Control - Lane departure warning - Emergency brake assistance	- Individual driving maneuvers (Parking) - Collision avoidance systems	- Traffic jam maneuvers	- Vehicle features can drive the vehicle under certain conditions	- Vehicle features can drive anywhere under every condition.

Source: Adapted from SAE (2014)

Inside the levels of automation, SAE separates the six levels into two different categories. From 0 to 2 are the levels where the human driver controls the driving environment. This means that the existing automations in the vehicle are not enough to perform all the main driving tasks required.

Human Driver Monitors the Driving Environment

Level 0 – No Automation. The technology of the vehicle is not capable of substituting the driver. All the driving must be done by the driver himself, accelerate, brake, adjust speed to the environment, and to do so has to always pay attention to it.

Level 1 – Driver Assistance. The automations in this level are specific and independent from each other, and it is up to the driver to control and operate them while being responsible for driving safely. Any automation in this level does not replace the driver.

Level 2 – Partial Automation. The automation systems in this level can collect data from the environment to control the direction and speed of the vehicle simultaneously. The driver must always be focused on the driving once he monitors the good function of these systems and takes action every time needed.

Automated Driving System monitors the Driving Environment

Level 3- Conditional Automation. The autonomous systems at this level controls every driving-related task, including environment monitoring, even if the traffic conditions are challenging. In case this monitoring does not work, or if the surrounding environment goes beyond his perceptions, the system will request the driver's assistance, which in this process should be gradual, unhurried. However, this can be problematic once the driver completely loses the attention over the vehicle's driving when performing autonomous mode, and the high reaction times may put him in a difficult situation.

Level 4 – High Automation. The vehicle at this level can execute all the critical DDTs. It can now handle almost every traffic situation make complicated decisions like changing lines or overtaking another vehicle. The system is capable of predicting accidents, acting against them, and not getting involved in them. The driver can still take the wheel if needed in adverse conditions like roadblocks or unpleasant weather conditions.

Level 5 - Full Automation. The DDTs at this level vehicle are so optimized that the vehicle has complete control over itself and needs no action of a human driver whatsoever. This means that the only expected decision a person needs to make is to provide the destination or roadway he wants to pursue. There is no need for a wheel or pedals to drive the vehicle, and any hostile outside condition is easily overtaken by the vehicle alone.

At level 2 of automation, the weather conditions tend to reduce DDTs efficiency because it is difficult for the vehicle to identify road marks, traffic signals and other environment obstacles. Although in level 4,

the DDTs can deal with every aspect of the driving in all road conditions, it is crucial to the good response of level 4 autonomous vehicles, the investment in good infrastructures (Mascio et al., 2018). The author also states that many companies will try to skip level 3 of automations to have a vehicle capable of performing in more delicate conditions.

In its 2014 Trend Research, DHL enlightens that for a vehicle to be completely autonomous and capable of driving itself, four functions are essential: Navigation; Situation Analysis; Motion Planning; Trajectory Control.

Navigation: Essential route planning. Create and Recalculates a digital map that includes information on road types, terrain settings, and weather forecasts.

Situation analysis: Monitor the environment through which the vehicle is moving to ensure the autonomous system is aware of all relevant objects and their movement. The recognition techniques brought by video cameras identify obstacles like pedestrians, other vehicles, and traffic signs. Additional and precise positioning data can be obtained using markers embedded in infrastructures. In a warehouse environment, this method is seen very often, as they mark the positioning of the vehicles and the routes defined for them.

Motion Planning: Monitor the vehicle movement by using sensors to determine the precise course of motion so that the vehicle remains in its lane. Hence, it keeps correcting the direction as previously defined. Decisions are made so that the vehicle can adapt its speed or direction, and this depends on many factors like lane width and road conditions or speed limits.

Trajectory Control: Execute the pre-planned changes in acceleration, braking and steering. This assures that vehicle safety and stability are guaranteed.

A fully autonomous drive is not easy to be achieved as the vehicle must be able to perform essential processes like environment perception, modelling, path planning and decision without human interaction at any point. Anderson et al. (2014), described the gathering of environment data, the interpretation and conversion of this information into autonomous actions and the capacity of executing the plan as indispensable technologies for the vehicle to perform fully autonomously. All those processes do not exclude the necessity of a backup plan to assist the AV in case of an emergency. The main challenge to all these functions is the detailed and accurate identification and prediction of movements surrounding the vehicle.

Related to autonomous vehicles is the concept of Automated Guided Vehicles (AGVs). These are the autonomous vehicles used mainly in the indoor settings, “widely used to transport materials between workstations in flexible manufacturing systems and can perform a variety of tasks that involve automation in industrial environments” (Kalinovcic, et al., 2011; Vivaldini et al., 2015).

1.2.2. Connected Vehicles / Platooning

Connected vehicles and platooning are two concepts related to autonomous vehicles technology. These two methods can enhance the application of autonomous vehicles since they contribute to a more efficient drive and lower the risk of accidents.

According to DHL (2014), autonomous vehicles will need to include Vehicle-to-Vehicle (V2V) communication to be seen as fully autonomous. This implies the constant exchange of data between vehicles via communication systems such as Wireless Local Area Networks (WLAN’s) and enables critical recognition of dangerous situations at an early stage. This technology will ensure data sharing between vehicles to increase their performance and safety on the road.

Platooning is a technology in which a human-driven truck is automatically followed over a short distance by other trucks, without the need for human interaction. This is a very efficient way to save transport companies time and costs Bucsky (2018).

Platoons are organized convoys of autonomous vehicles that drive cooperatively in a row, similarly to trains at a very small distance from each other. While the first vehicle takes the lead, the other subsequently follow, and the velocity and distances adapt to keep road safety. This is also the way many AGV are utilized in indoor logistics (van Meldert & de Boeck, 2016).

In the case of truck platooning, this technology allows the driver to focus on other tasks while the vehicles drive in convoy, and only the first driver needs to be ready to take action if necessary. Essential vehicle-to-vehicle communication will be crucial for the convoys to form and get the most out of this technology.

1.3 Positive Impact of Autonomous Vehicles

The introduction of fully autonomous vehicles in everyday life will revolutionize the way people travel, and goods are transported.

Bucsky (2018) asserted that the associated benefits of AV technologies in transport could be categorized into three groups: (1) traffic-related gains (lower travel time, shrinking costs, less traf-fic), (2) economic (financial benefits for transport compa-nies, i.e., lower costs, restructuring of market), (3) safe-ty and environment.

According to the author, fully autonomous vehicles will bring more comfort as the driver becomes a passenger. Thus, the passenger does not have to watch the road or be capable of driving. The traffic will flow faster and with lower congestions. High speeds and intelligent collision avoidance systems will reduce travel times since this enables travel 24/7 and is less likely to cause accidents and traffic jams.

Autonomous vehicles will surely guarantee higher safety than human driving vehicles. This is because 93% of the accidents are caused by human error (inattention, speed, alcohol)(Maddox, 2012). Autonomous vehicles in an advanced stage can minimize that statistics due to the constant monitoring and adaptation to traffic or external conditions. With this, the AV technology will most likely reduce driving errors that human drivers hardly can (DHL, 2013).

One of the most significant advantages is the high-efficiency gains that will come from this technology. The lower costs with truck drivers will also lower transportations costs which means that the volume of global trades might increase. These are notable advantages for transport companies so that the investment in these new technologies can be compensated in the long term(Bucsky, 2018). Labor costs are still major for trucking companies, and eliminating that cost will allow a cost reduction in shipping and consequently a cost reduction in the final product. For Neuweiler & Riedel (2017), AVs will positively influence the cost breakdown of logistics companies. The upcoming of self-driving vehicles will impact employment, lead times, and supply chain actors are interrelated.

V2V communication can make autonomous driving much more efficient than human driving by reducing road congestion. Companies that have a vehicle capable of operating all day, every day, with no mandatory stops, will undoubtedly create costs advantages. The efficient fuel consumption of an AV will also minimize the environmental impact DHL (2014).

The benefits of AVs will prevail once the dissemination of this technology increase. There will be roads full of autonomous trucks and cars in perfect synchronization with each other. With this, the decrease in accidents caused by human error, the stress related to traffic jams, and the decrease in fuel consumption and travel times will have a meaningful positive impact DHL (2014).

1.4 Constraints of Autonomous Vehicles

Autonomous vehicles also raise some questions despite providing enormous beneficial gains in terms of safety, cost or efficiency. For many authors, these questions are considered crucial to answer before the introduction and dissemination of these vehicles. The biggest constraints to applying this technology have to do with ethical and legal regulations, social and organizational change, and mainly the costs associated with the application.

Bergvall & Gustavson (2017) stated that the initial costs and time involved in implementing this technology in a company can be an influential drawback. The author also reminds that the introduction of new technologies is often associated with changes in the organizational structure of companies and the loss of human capital.

There is a big concern if the AI systems are capable of making the right choices. For instance, in a case of an imminent collision, it is not clear if the AI system should act to save itself over other drivers and pedestrians. This topic is being involved in a debate and should be discussed before the mass introduction of autonomous vehicles on public roads to identify responsibilities and avoid accidents (van Meldert & de Boeck, 2016). The major legal challenge is faced when the subjects are fully autonomous vehicles, where the drive might not even be required. Since the EU and USA only legislate over the assumption that a human driver can always take control of the vehicle, a broader legislative framework will be needed in the near future.

When it comes to autonomous vehicles, the artificial intelligence technologies used are very difficult to test to ensure they are safe to be introduced and massively used and do not support a risk for any human life. The responsibility when there is an accident is also a very intense debate. Levalley (2013) considers that manufacturers should be held accountable every time the vehicle is in autonomous mode, as it happens with the passenger's carriers. Whereas other authors consider that the driver can influence the cause of the accident, manufacturers can argue that these systems are not entirely flawless, and responsibilities may have to be determined. AVs should be considered legal as long as the driver is at all times able to take over control of the vehicle (Smith, 2012;2013 as cited in van Meldert & de Boeck, 2016).

These AI systems also raise other questions about hacking attacks. This is also a complex subject since the vehicles and infrastructures will be equipped with state-of-the-art technology that can be hacked, putting at risk the safety of the public roads (Neuweiler & Riedel, 2017).

Another challenge of autonomous vehicles is public perception and the social changes that may result from their use. Since this is an innovative technology, society and the supply chain themselves may not be ready to adopt these vehicles (Neuweiler & Riedel, 2017).

The research about AVs is still very much related to the use of this technology on highways or flowing traffic lanes. The biggest challenge is testing these vehicles outside the highways since urban areas are more densely populated and have greater traffic. Situations where there are poorly marked GPS locations, such as off-grid businesses or industrial parks, as well as more complex loading and unloading tasks, will need to be well tested until this is no longer a challenge (Bucsky, 2018).

1.5 Autonomous Vehicles Application in Logistics

The implementation of autonomous vehicles technology is mainly associated with self-driving cars for passenger travel and trucks for goods delivery. However, these vehicles have had an enormous influence on the way warehouses operate today. Autonomous vehicles, when used in logistics, will most certainly improve order preparation and delivery times. When used in in-house operations, automations can reduce human errors, accelerate processes, and reduce costs. Many logistics service providers have a max capacity of order preparation that can be pushed upwards, using autonomous vehicles at their warehouse. Logistics professionals need to adapt and be prepared to integrate this technology into their operations.

DHL (2014), states logistics as the ideal environment for AVs study in factories, distribution centers or ports. However, there is still much work to be done so that AVs can be safely used in real-life traffic environments. Since it is often a B2B market, it might be easier to fund and adopt this new technology to this reality first. In the same report, DHL set four segments in which AVs can be used in logistics. These segments are in the following:

Indoor Logistics

Automated Guided Vehicles (AGV) have been used in indoor logistics sites like warehouses and productions plants for a long time. The control over the environment of these spaces ensures that the use of this technology is safe and accidents are avoided. Although the first vehicles made for this purpose were limited to predefined paths, the new generation of AGVs is more autonomous and flexible for logistics site operations. These vehicles can guarantee higher efficiency and productivity in material handling than human operators. The setbacks related to the mass use of this technology are still the costs and the difficulty in taking advantage of the full potential of every business (van Meldert & de Boeck, 2016).

AGVs are used to perform various types of activities inside warehouses and industrial units. These vehicles are nowadays capable of loading, transporting, unloading goods autonomously and serving as autonomous forklifts. These vehicles are already a reality in many warehouses and replace human labor as they can transport larger quantities more efficiently between workstations. The coordination between these types of vehicles within a warehouse allows processes to be faster. Another application of AGVs is in picking processes, supporting the worker preparing orders by picking products for the worker preparing them at a fixed location (G2P goods-to-person) or transporting them to picking robots (G2R goods-to-robots) (van Meldert & de Boeck, 2016).

For many years, products of all shapes and sizes have been handled and transported by semi-autonomous vehicles guided by sensors inside large warehouses. Many AGVs also followed preexisting paths and did not have complete autonomy inside a warehouse. More recently, new vision guidance technology enables 3D mapping of the warehouse and its obstacles, assuring more flexibility to these vehicles (DHL Trend Research, 2014).

Controlled Outdoor Environments

The use of autonomous vehicles in secure or private infrastructures like airports, logistics sites, or ports is fundamental to studying this technology response in the real world. This is because there is less uncertainty, fewer regulations, and there is room to test new factors that might increase business productivity. DHL Trend Research, (2014) also considers that the efficiency and competitiveness of ports, airports, and other logistic centers, will grow with the introduction of autonomous vehicles in the transportation of goods and material handling. Many advantages AVs have over human labor come from reducing human error, guaranteeing a more reliable driving while allowing the monitorization of goods and vehicles, and reducing labor and fuel consumption costs (van Meldert & de Boeck, 2016).

The main difference between indoor and outdoor use of AVs is that the vehicle will have to do longer distances with higher load volume in this second case. Therefore, autonomous trucks are used for this purpose. The goal of controlled outdoor environments is to replicate these technological advances in the uncertainty of ordinary traffic.

As different rules and regulations apply when a vehicle is in circulation in a secure and private road, there is a reason to believe that adoption of AVs will be faster in the logistic industry. The transportation of goods between warehouses or logistics sites can be done by AVs since there are fewer legal responsibility issues DHL (2014).

Long Distance Road Freight

So far, and on the contrary of indoor and outdoor controlled environments, there is no AV authorized to drive on public roads yet. This is because companies are still testing solutions in this environment, and a concrete autonomous vehicle is not yet available. It is believed that platooning will be the real added value of autonomous vehicle technology in the future of long-haul logistics (van Meldert & de Boeck, 2016). There are, however, several automation systems that already increase the performance of truck driving, such as lane keeping assistance that allows the truck to drive itself for short periods with always the human driver supervision. Automations like this are part of the level 2 of autonomous vehicles proposed by SAE and are still far from fully autonomous vehicles.

The benefits of not having a human driver when transporting goods are essential for logistics and distribution companies as they reduce salaries and fuel costs, so they will be the first to try to implement this technology. Autonomous driving will most likely be introduced in long haul logistics because predicting the environments on highways is more accurate and less complex (van Meldert & de Boeck, 2016). The authors also consider the planning necessary to coordinate the vehicles that circulate in platooning a big challenge for the companies.

Last Mile Logistics

Despite being crucial to ensure the products meet the final customer, this is also the most challenging part of developing an AV since using this technology in small, urban roads where traffic is complex, and the environment is difficult to predict brings many challenges. AVs will have to be able to drive themselves in the complex and uncertainty of urban traffic, requiring at least the level 4 of autonomous driving. Therefore, this segment is still under a lot of market speculation, and the applications will take more time to become a reality (van Meldert & de Boeck, 2016).

Despite many studies today still focusing more on the technical aspects of autonomous driving for passenger's transport, DHL (2014) considers logistics to be the area where AVs adoption will occur first. Logistics can provide the ideal settings for autonomous vehicles such as controlled warehouses, production plants, harbors, and remote outdoor locations where there is significantly less traffic and under fewer regulations and law restrictions. Logistics operations of the whole supply chain can gain from the use of AVs since the extraction of raw materials to last-mile delivery creates many business opportunities.

By applying AVs to their operations, logistics operators can obtain experience and adopt this technology faster than public roads. Another point given to the logistics sector use of AVs is that any

liability issue would be less severe while transporting goods rather than transporting passengers. Businesses are more likely to base their decision on a potential cost advantage, whereas consumers could be more receptive to trust an ethical issue (DHL, 2014)

The studies on AVs in logistics focus on indoor and controlled outdoor environments, and there is still much research to be done about AVs in other logistics segments. However, the use of AVs in logistics has particular importance, such as the businesses operations and entire supply chains will have to be restructured. AV might be available soon, and logistics-related businesses will have a competitive advantage if they adopt this technology (van Meldert & de Boeck, 2016).

1.6 Introduction and Dissemination

The applications of autonomous vehicles do not restrict passengers or goods transportation, as these vehicles have been applied to many other activities, from the military to the mining sector. This segment aims to understand how this technology will be introduced massively and what activities can benefit from using it.

Since the beginning of the XXI century, many automobile manufacturers have started researching and developing commercial autonomous vehicles. Today almost every car manufacturer has its projects aiming at a fully autonomous vehicle.

In 2013, Shanker et al., presented the four phases in the development and adoption of AVs. Other authors share a similar view.

Phase 1 (2012 -2016): Introduction of technologies capable of correcting rather than controlling the vehicle driving, such as (adaptive cruise control, crash sensing, lane departure warning). The driver is entirely responsible for driving.

Phase 2 (2015 -2019): Although the driver is still responsible for driving, the vehicle can autonomously perform some tasks, such as parking.

Stage 3 (2018 - 2022): The vehicle is completely capable of driving itself, but the driver must be prepared to intervene at any time should the need arise.

Phase 4 (until 2040): Mass adoption of autonomous vehicles. Every vehicle on the road is fully autonomous, and human intervention will no longer be necessary to perform any task.

The use of AVs will change the consumer need for a private vehicle. New autonomous public transportation will likely be created and, therefore, free up space in large cities. With the reduction of traffic, it will be possible to create small distribution hubs to facilitate the delivery of goods within large cities. Various solutions are being developed like special drop-off places to reduce the time lost in loading and unloading the small trucks that deliver the goods to the final customer. Ideally, new businesses could be created to respond to this problem (Bucsky, 2018).

The military sector is still where the first advances in technology are put into practice, so this field was an early adopter of self-driving vehicles. The concept of a self-driving vehicle can have multiple applications in military operations. Crewless vehicles can be crucial to operate in unknown areas where the risk for human life is too high, i.e., in special exploration, war scenarios or environmental catastrophes (DHL Trend Research, 2014).

Has stated before, the introduction of AVs in logistics could have notable benefits to logistics operators with significant cost reductions, efficiency gains and enhancing new business models that can theoretically re-evaluate entire supply chains. Therefore, the competitive advantages will be residing with the early adopters of this technology (van Meldert & de Boeck, 2016).

It is vital to analyze if and when full automation would be the most efficient development and if there could be situations in the case of goods transport where a lower degree of automation would also be sufficient (Bucsky, 2018).

The main challenge of using autonomous vehicles in urban logistics is that human carriers are still more efficient inside big cities. Small and busy streets where environments are difficult to predict are a massive setback to the use of AVs in these situations (Bucsky, 2018).

1.7 Existing Technology and AVs Evolution

Autonomous vehicles are already being used in different industries like aerospace and military, and many automations already exist in the vehicles we use daily. Examples of these automations are autonomous parking, adaptive cruise control, anti-lock braking systems, highway autopilot. Some of the world's leading automotive manufacturers and technology companies are already showcasing the first prototypes for autonomous vehicles (DHL, 2013). However, their research focuses on private consumers vehicles rather than trucks and logistics vehicles.

Some existing solutions for warehouse operations, outdoor logistics, line-haul transportation, and last-mile delivery are already in use. Technologies like adaptive cruise control and collision warning are

already a reality in most trucks today and allow them to travel in a non-autonomous convoy. Lane departure warning, driver alert support and stability control technologies are also already commonly used in trucks (Bucsky, 2018). The author states that 5G technology will soon enable vehicle-to-vehicle (V2V) communication to become more effective and reliable.

Among the existing autonomous vehicles solutions for logistics applications, the following can be highlighted:

Warehouse Solutions:

These solutions can provide objective evidence of the safety and success of using these vehicles indoors. For example, the Continental AMR, Knapp Open Shuttle and Karis Pro System are different AGV's capable of performing the warehousing operations entirely autonomously and in convoys. Another solution oriented to the healthcare industry is RoboCourier, an autonomous vehicle developed to transport laboratory samples, medical devices and other small items with maximum security and safety (DHL Trend Research, 2014).

A different AGV example is the Auto Pallet Mover, a self-driving forklift able to load, transport and unload full pallets from warehouse racks. This system uses laser navigation to move and can combine autonomous driving with manual activities. Amazon already has in its warehouses a technology called Kiva, an AGV capable of transporting entire shelves full of products to the person in charge of picking the order, as opposed to the usual way of doing it.

Outdoor Logistics Solutions:

There are numerous autonomous vehicles already in use in closed outdoor yards, harbors and airports. These vehicles are used to transport containers and pallets across sites efficiently in comparison with traditional trucks. Another example of sites where these vehicles are already in use is the mining industry in Australia. Caterpillar CAT 797F can operate in dangerous terrain and carry heavy material (DHL, 2013; DHL Trend Research, 2014). Similarly, the SCANIA AXL Autonomous Truck is an AV operating in Rio Tinto mining sites.

An example of a controlled outdoor environment is the Container Terminal Altenweder in Hamburg. Many AVs from different manufacturers are being tested in transport containers loaded or unloaded from ships (van Meldert & de Boeck, 2016). The contributions of these solutions are significant for the efficiency of the operations and the health and safety of the workers.

Line Haul Solutions:

Over the last few years, prototype testing has been made on closed highways, but no long-haul AV was used on public roads. That is the case of the Mercedes-Benz autonomous truck, whose platooning technology has been in tests in German highways closed especially for this purpose. The technology that Mercedes-Benz is developing is expected to be ready for mass application by 2025 (van Meldert & de Boeck, 2016).

Mercedes-Benz is testing a solution for assisted highway trucking where the driver can take control of the truck when needed but, for the most part, can play a passive role in driving. Thus, the intention is to develop an assisted highway trucking system where the vehicle can stay in the same lane, maintain a safe distance from other vehicles, and adjust its speed. Convoy systems are also being tested by many companies such as Mercedes-Benz, Volvo, Tesla and MAN. Despite most car manufacturers already developing their own solutions, when it comes to logistics, the development of an autonomous truck is mainly in the sights of these four companies.

Last-Mile Delivery:

As previously stated, the application of AVs in last-mile logistics will be more complex. There are still no fully tested solutions ready to perform with all the constraints that the city environment involves (DHL, 2013; DHL Trend Research, 2014). Traffic, people, and narrow streets contribute to the unpredictability of the city environment and the difficulty of using an AV. Nevertheless, prototypes and solutions are still under development that could serve as a basis for the future. From Autonomous vehicles that can carry the goods and follow humans to ease the delivery process to parcel stations where delivery packages can be withdrawn by AVs to be delivered to the final customer (DHL 2014). DHL has already some exciting solutions for last-mile deliveries. The company is testing prototypes such as autonomous parcels and autonomous drones, known as “parcelcopters”. Many technology companies like Amazon are developing and testing similar solutions to ensure the deliveries of their products occurs faster and with lower costs.

The level of automation is very different in the case of different transport modes, and most probably, the technology will favor road transport over other, less environmentally harmful traffic modes (Bucsky, 2018).

The interest of technology companies like Amazon, Google and Alibaba in the health sector has been growing. Although this approach to a new market may initially feel strange, the truth is that the entrance of these new players will have a considerable impact on this market. Big corporations associated with technology and e-commerce will bring new ways of approaching a traditionally and can cause a shake-up in the sector (Marketing Farmacêutico, 2019). In this way, some companies are already trying to move towards pilot projects to deliver medicines to their homes. However, it is not only in the last mile logistics

that these companies can compete. They will also be able to contribute with new solutions regarding the distribution of medicines in large warehouses.

The studies on AVs in logistics focus on indoor and controlled outdoor environments, and there is still a lot of research on AVs on other logistics segments to be done. However, AVs' use in logistics has particular importance as the businesses operations and entire supply chains will have to be restructured. AV might be available in the future, and logistics related businesses will have a competitive advantage if they adopt this technology (van Meldert & de Boeck, 2016).

Chapter II

Methodology

2.1. Method

To achieve the research objectives previously defined in the introductory chapter, a methodology was defined. Firstly, as an exploratory research and to give an overview on the main subjects of this thesis, a literature review on autonomous vehicles was made (Chapter II). Secondly, as an explanatory research aiming to answer the research questions, a qualitative research method was used (Chapter III). This chapter aims to describe the method and tools of data collection and analysis used to understand the future application of autonomous vehicles in the pharmaceutical supply chain.

To understand how different players in the pharmaceutical supply chain feel about the introduction of autonomous vehicles into their operations, interviews were conducted with heads of the Logistics and Operations departments of three selected companies.

2.2. Research Context - Portuguese Pharmaceutical Market and Supply Chain

The pharmaceutical market is divided into two types of laboratories: (I) laboratories that develop original drugs (patent holders); and (II) laboratories that produce generic drugs (whose patent has expired). The generic market has grown faster after 2000 and had gained considerable importance in the whole pharmaceutical sector, just so that big national and international companies of original pharmaceuticals wanted to invest in generic medicines. The past decade was marked by an increase in the expiration of patents and the rise of generic drugs. The generic market has 2/3 of all the drugs produced, however, this represents only 1/4 of the entire market value, because of the lower prices and lower quantities sold than original medicines. The drugs that do not have any substitute are just 1/5 of the market but represent a much higher value in revenues(Coutinho & Vilares, 2014).

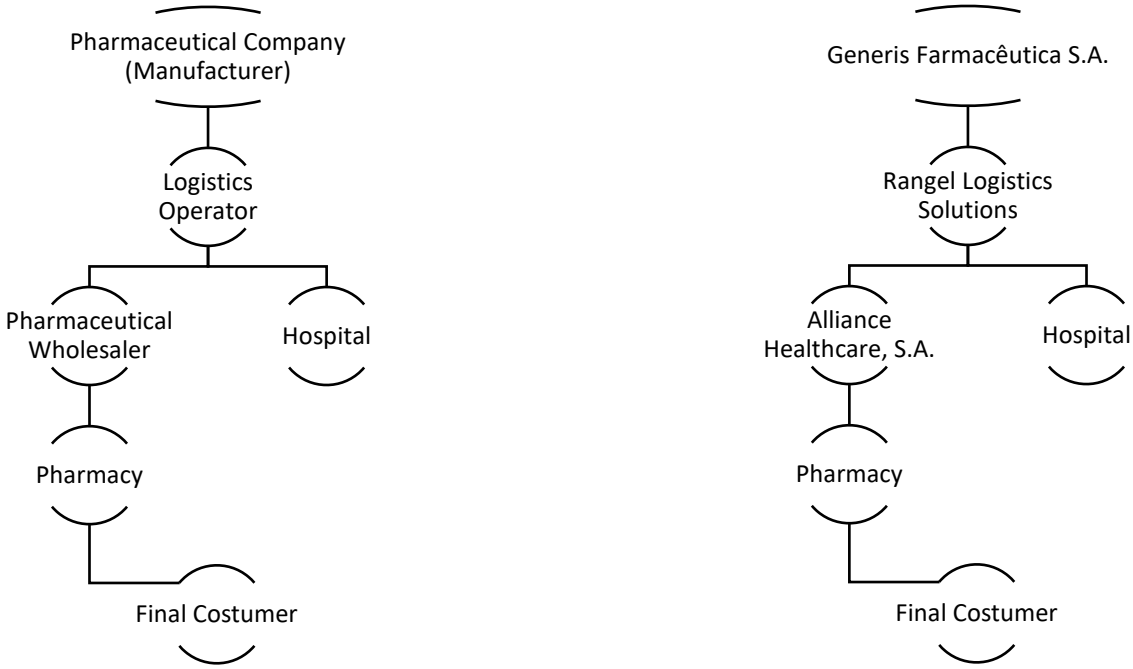
Assuming that this supply chain begins with the production of the medicines (excluding the supplier procurement process), pharmaceutical manufacturers occupy a prominent place. Still, most of these companies see no competitive advantage in the distribution of their own products. This is where the role of logistics operators (LO) and pharmaceutical distributors comes in. Therefore, logistics operators are important actors in bridging the gap between producers of medicines and their clients (Wholesalers, Hospitals and Pharmacies). They are a vital player in the supply chain since they manage the storage of the

products produced in the laboratories and distribute them to wholesalers' warehouses, hospitals, and pharmacies.

The wholesalers also have an important role in the supply chain of pharmaceuticals. They function as the main distributors to pharmacies of all brands in the outpatient market. They buy from the pharmaceutical companies and sell to their partner pharmacies, taking advantage of the redistribution of drugs in the market that the manufacturers are unable to do by themselves.

Pharmacies are the last player in this supply chain before the product reaches the final consumer. The following images compile the main players of a pharmaceutical supply chain and their responsibilities. The figure 1.1 is a simple scheme that gives an overview of where the different players that participated in this study are positioned.

Image 1.1: Pharmaceutical Supply Chain vs Companies in study



Source: Own elaboration

The Pharmaceutical market is highly regulated by a national regulator organization (INFARMED, in Portugal) and an international regulator from the EU, European Medicines Agency (EMA). These regulators work together to ensure the safety of all commercialized products. This means that good practices of scientific testing, manufacturing, distribution, pharmacovigilance, and all the technical procedures related

to medicines commercial authorizations (European Medicines Agency, 2016; INFARMED, 2015). There are now around 140 pharmaceutical companies operating in Portugal. The exports of medicines surpass the imports, despite the yet dependence of external markets when it comes to patented drugs. According to (APIFARMA, 2014), the Portuguese Association of Pharmaceutical Industry, the vast majority of those companies are from foreign capital, which can be explained by the lack of investment in the investigation of pharmaceuticals in Portugal until the XXI century. It is believed that the generic market will continue to increase its value due to the entrance of new products as the patent rights keep falling.

There are many arguments to justify the continuation of pharmaceutical market growth and, therefore, the potential growth of logistic related processes. Between those arguments, it is vital to highlight the evolution in the ageing population, and this paradigm is changing the distribution of state budgets towards health social security sectors.

On the one hand, the pharmaceutical industry is quite attached to the traditional methods of doing business and, on the other hand, is heavily restricted by all the regulations imposed. Therefore, this study tries to understand the major players in the pharmaceutical supply chain beliefs concerning the application of autonomous vehicles in their operations.

2.3. Research Design and Instruments

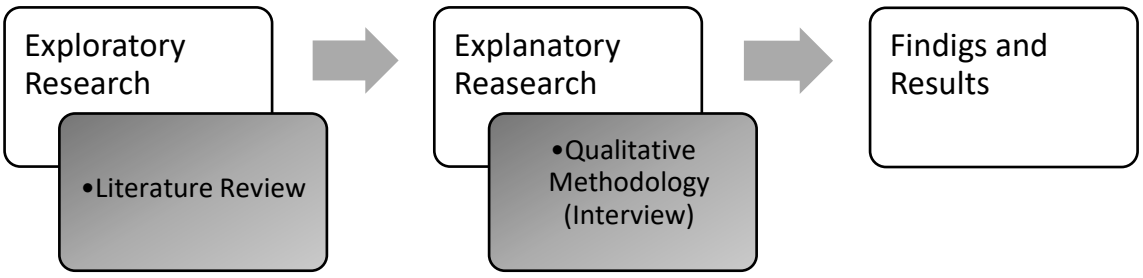
As mentioned before, the present study follows a qualitative research method. A content analysis was done since it allows the use of data collection to formulate a theory inductively.

According to (Williams, 2007), the qualitative method allows a better understanding and exploration of the complexity of a phenomenon. This method is more suitable to describe and explore in detail a specific concept. A qualitative study attempts to explain a subject from what is observed by describing, explaining, and interpreting the data collected.

The qualitative method was used through a semi-structured interview as a collection method to explore the market players insights on this topic in a flexible and versatile way.

When collecting data through a qualitative interview, the knowledge is created over social interactions between the interviewer and the interviewee (Kvale & Brinkmann, 2008). This method of collecting data corresponds to the first stage of the applied methodology.

Image 1.2: Research Design and Instruments



Source: Own elaboration

2.4. Data Collection

The present study will collect data from interviews and document analysis, which represent qualitative methods. Interviews are seen as a source of primary information, as document analysis is secondary information.

Interviews are considered a data collection technique that approximates the topic under study and discovers new elements from the interviewees, i.e., how they perceive and interpret certain aspects of their context (Biklen & Bogdan, 1994). The advantage of using interviews as a data collection technique is that the researcher can clarify specific issues as the interview proceeds. The interviewer thus has access to a variety of relevant information and the emergence of guidelines and ideas for further research(Valles, 1997). However, this technique has some limitations since it is a time-consuming activity that, in some cases, may produce irrelevant information. Thus, special attention should be paid when conducting the interview, as well as a careful analysis of the extracted content.

2.4.1. Interview

In order to gain a better insight into the possible application of autonomous vehicles in the pharmaceutical supply chain operations, four semi-structured interviews were conducted with four experienced employees of three companies with different positions in the supply chain (Generis Farmacêutica, S.A.; Rangel Logistics Solutions; and Alliance Healthcare, S.A.). The script used in the semi-structured interviews can be found in Annex A. This interview guide was created in order to achieve a thorough understanding of the main topic. This allowed the interview to be conducted with focus and some flexibility, with key closed and open-ended questions that allowed the interviewees to add relevant information beyond the

scope of the question asked, providing many relevant inputs. The script was structured to cover all the research questions, aligned with what was deemed most appropriate in the literature review, and to gather information to produce a comparative analysis later.

The participants were selected considering their proficiency and experience in the field of logistics as well as the dimension that the company has in the market and the position they hold within it. Since this study focuses on AVs in logistics, it was essential to get in touch with representatives from the Logistics, Operations and Innovation areas. The four interviewees were Jorge Alves (Head of the Logistics and Customer Service Department - Generis Farmacêutica, S.A.), Vasco Parrulas (Logistics Operations Technician - Generis Farmacêutica, S.A.), Paula Teixeira (Returns and Distribution Unit Manager - Alliance Healthcare S.A.) and Jorge Martins (Project Manager and Continuous Improvement - Rangel Logistics Solutions). Each interviewee has years of experience and deep knowledge about the pharmaceutical market and operations, including clear notions about the main topic of this thesis. Two people from the same company (Generis Farmacêutica, S.A.) were contacted to do this interview because each of the interviewees has an idea that may complement the other's vision.

Due to Covid-19 restrictions, the interviews were conducted online through Microsoft Teams and lasted approximately 45 minutes each. The interviews were audiotaped with the interviewees' previous authorizations, thus allowing a more careful further analysis. The answers were also recorded by note-taking, and all the audio recorded interviews were later transcribed.

2.4.2. Document Analysis

Document analysis was used as a source of secondary information to complement other data collected. The data obtained by document analysis is not produced nor organized, especially for a specific research purpose (Valles, 1997). It was a valuable support in contextualizing and understanding the company's background. It also allows to draw some conclusions regarding the company operations. The data collected from this method was gathered online from the companies websites and through other internal and closed-access documents.

2.5. Data Treatment Approach

In the first stage of this methodology, after the interviews were conducted, it was necessary to think about how best to process the data retrieved. "A content analysis is a research technique for the objective, systematic, and quantitative description of the manifest content of communication" (Berelson 1952: 18; Mayring, 2014). That is a technique that allows the analysis of data in a controlled and systematic way, which enables its organization and classification, as well as the acquisition of new knowledge about the subject under study.

In this sense, after considering several qualitative analysis methods of an interview, it was proceeded with a content analysis manually. In this way, it was possible to perform a more practical analysis of the relevant data for the study. For the analysis of long semi-structured interviews, this method is one of the most suitable and widely used.

After the interviews were conducted, the answers were then transcribed, and the information provided was reviewed and reduced. To analyze the data collected through the interviews, themes and sub-themes were created based on the questions asked. This allowed for a more focused comparative analysis on the relevant points for discussion and ensured a greater degree of understanding of the interviewees' views on the themes.

Once this type of data treatment has its limitations, such as the risk of subjective interpretations of the interviewees' message, a rigorous interpretation of every interview was carried out.

Chapter III

Results

As previously mentioned, this thesis focuses on study the impact autonomous vehicles may have in the logistics of the pharmaceutical market and how can this technology be introduced in this sector. The following chapter gives a characterization of each company that participate in this study, as well as a compilation and analysis of the relevant data collected.

3.1. Companies Characterization and Autonomous Vehicles Viewpoint

The following section is intended to give an insight into the companies under study and compile the main results of the interviews conducted. Thus, a small research was conducted in order to understand the origins of each company. This research was complemented at the time of each interview with relevant information about the activities developed within each company.

3.1.1. Generis Farmacêutica, S.A

3.1.1.1. Companies Characterization

Created in 2002, Generis Farmacêutica, S.A., rapidly become a leading company in Portugal generic pharmaceutical market. Acquired in 2006, the first manufacturing facility of the company was a clear influence of solid and sustained growth strategy. This facility has a production capacity of 30 million packages a year and it is a crucial asset in the brand operations.

Today Generis its part of the Aurobindo Pharma Group. Present in more than 20 countries worldwide, with 26 factories equipped with the latest technology on the market allows the group to export to more than 150 countries. Aurobindo Pharma set a wonderful example of vertical integration from the Research and Development areas to Manufacturing and ultimately commercialization of medicines.

By being part of the Aurobindo Pharma Group, Generis increased its own portfolio of commercialized products from other pharmaceutical brands like Aurobindo, Aurovitas, Labesfal and covers more than 85% of more relevant therapeutic areas in ambulatory market. This market position allows Generis to reach a larger scale of clients and a bigger number of patients.

Nationally, Generis has the generic pharmaceutical market largest portfolio of medicines built by the three previously mention brands. It counts with over 1490 prescription drugs, 250 hospital products and 67 OTC's (Over the Counter) /Health Products. In addition, the company has a great experience on contract manufacturing with clients in Portugal and more than 20 other countries all over the world. The high-tech machinery used enables the production of different batch sizes according to the clients and market needs. The work done with international expert organizations like Kaizen Institute, in continuous improvement procedures, has contributed to the maximization of the industrial operations in the factory.

Besides the industrial facility of the company, the finished products are storage at the warehouse of Generis logistics partner, Rangel Logistics Solutions. This warehouse is conveniently located close the major transportation hubs and access to major communication routes for easy receipt of raw material and dispatch of finished products.

Generis is one of the most important medicine brands of medicines in Portugal. It is a reference player in the national pharmaceutical market due to its position in the ranking and it is an important driver in the supply chain. It is the second largest selling company of medicines in the outpatient market (sales to wholesalers and pharmacies), and the first selling company in units for the hospital market.

In the future, Generis Farmacêutica, S.A. will have a second industrial unit based in Rio Maior. This new facility will be larger than the existing one and will function as a European hub for Aurobindo Group. The expansion of Generis not only it's a clear sign of costumer trust but also an indicator of the exceptional market positioning the company was able to take all over these years.

3.1.1.2 Interview Analysis - Autonomous Vehicles Viewpoint

Generis Farmacêutica, S.A. interviewees were Head of the Logistics and Customer Service Department and the Logistics Operations Technician. Two interviews were conducted to complement the collection of information not only from the logistical and operational point of view, but also from the point of view of the commercial area of the company that deals directly with other players in the supply chain.

In the initial phase of the interviews, the interviewees summarized how the logistics operations of Generis currently operate, which allowed to understand the role of Generis and the other companies along the logistic chain is.

It became clear during the interview why Generis does not have its logistic services assured by itself, and why it resorts to outsourcing these services to Rangel Logistics Solutions. Generis operation involves the storage and handling of thousands of pallets, which translates into thousands of units sold each month. In this way, the company would not guarantee an optimal level of service in the storage and distribution of its products at a reasonable cost. The outsourcing of logistical services is seen by the interviewees as the company sticking to the activities which guarantee competitive advantages. Because the logistics services are not under its control, Generis loses autonomy in making investments in the warehouse. Therefore, these investments are evaluated and made by the logistic operator according to the needs required by the operations.

Moreover, the business volume of Generis includes hundreds of products and the sales are generally made in a few large volume orders to the outpatient market, and in many smaller volume orders to hospitals. According to one of the interviewees from Generis, this difference in order volumes for both types of Generis customers would not jeopardize the use of autonomous delivery vehicles. Both distribution channels (Outpatient and Hospital) could benefit from the use of AVs with solutions adjusted to each one.

According to the interviewees, the large existing regulations in the pharmaceutical market can be a bottleneck factor in the application of new technologies in the sector. This is especially relevant regarding distribution activities, since inside the warehouses there are regular inspections in the space, temperature control, and control procedures. For this reason, there is more independence to implement these technologies in warehouses. In these logistic sites, there is more opportunity for improvement and process optimization. There is a legal void for the use of new technologies in warehouses, unlike in distribution, where the use of autonomous vehicles will have to be closely scrutinized.

When asked about the investments that have been made in new technologies, the interviewees shared that investments have only been made inside the warehouses to make processes more autonomous. Nevertheless, they are not enough since no pharmaceutical logistic operator has fully automated processes and is highly dependent on human capital. The interviewees were reticent in relation to the autonomous vehicle solutions existing in the market. They believe that the existing automatisms still require too much of the human factor and ultimately do not pay off. The cost of human capital in Portugal is still a preponderant and relatively low factor in the logistics and distribution sector. In this sense, the companies prefer to periodically hire more workers than to make significant transformations in automation and still depend on people.

There are, in their opinion, room for improvements in the logistics processes. Some technology apart from autonomous vehicles, like picking by light, could be commonly used in warehouses to make the picking process faster and more efficient.

The interviewees stated that autonomous vehicles could and will surely be part of the future of operations, especially within warehouses. However, they also consider that given the reality of the market, as it is structured, perhaps these vehicles could also be easily applicable in a node further up the supply chain like in wholesale distributors. Both interviewees consider that the pharmaceutical market is highly resistant to change, but many companies have been changing this panorama and investing in automation for their warehouses.

Generis believes that in the medium term, between 5 and 10 years, will start to see some proper autonomous vehicles solutions being applied in the market. These vehicles will undoubtedly be applied inside the large distribution centres, though, for example, bilateral autonomous forklifts that circulate among the racks and autonomously supply the conveyors for order preparation. The human factor will only be used for the final part of picking validation and checking. They reinforced the idea of applying these vehicles in unloading and reception activities, pallet storage, order picking, and loading trucks for dispatching. Still, for these to be a reality is crucial that the warehouses must be prepared to receive this technology. In warehouses where there is a high turnover of pallets, i.e., a lot of pallet handling, it may make sense to replace the human factor with autonomous vehicles, as the medium to long term costs may pay off.

It was clear during these two interviews that there will be a good acceptance of autonomous vehicles by the companies in the sector, but their use in distribution raises many doubts. This technology creates much enthusiasm but is still far from the current reality of a very unadventurous market like the pharmaceutical one. For there to be better market acceptance of these technologies, the interviewees consider that the roles of all players will have to be well defined and well-regulated between all parties. Only in this way can critical issues in the distribution of products to customers be avoided, aggravated when deliveries with autonomous vehicles are considered. In addition, Generis considered crucial the need for companies that form this supply chain to adapt to this digital transformation, at the risk of becoming in a position in the market that is not favourable to them. At this moment, this digital transformation does not seem to be a reality, and as such, companies have not yet started to invest in this development.

One of the interviewees supported this statement by referring to the 5G technology to be the one that can bring effective changes to the reality of companies. According to the interviewee, this technology

will allow significant advances and open new possibilities in terms of automation and connectivity between machines and systems. He believes that this will be the differentiating factor in the short to medium term and may directly impact the application of autonomous vehicles in logistics.

Still, both interviewees believe that the future of human resources is not in question at all. Even in large warehouses with more and more sophisticated automation solutions, there are always people at the end of the line. Human resources will always be needed. At least considering the reality as we know it, human resources are still necessary. In the first phase, the introduction of autonomous vehicles, whenever it is done, will have to be hybrid, with the intervention of human resources.

The interviewees consider that the biggest challenge of logistics is to optimize all operations at the lowest possible cost. They related this challenge to the application of new technologies such as autonomous vehicles. Even though it may seem counterproductive, the interviewees admit that the best way for logistics to remain competitive is to invest in new solutions that bring advantages in the medium and long term. However, the initial costs that are necessary and all the developments that have to be made may be a preponderant factor for companies to move onward with this digital transformation. Moreover, the fact that this technology has not yet been used on a mass scale in the industry means that companies are not yet fully aware of their potential gains.

Despite being in favour of the introduction of autonomous vehicles in logistics, the interviewee warns that being an autonomous vehicle or a human driver delivering the medicines is the same for the final customer. As long as service levels are not impacted, i.e. as long as there are no delays or order failures, the final customer might not see any differences in having an autonomous vehicle making the delivery. Assuming that with the introduction of autonomous vehicles the delivery times will decrease and do not impact the product conditions, the interviewee believes that this will be a plus for the whole supply chain.

Both Generis interviewees consider that it might take a few years so that this technology can be widely used in the distribution of medicines. The fact that pharmacies and hospitals are less keen on making changes to optimize their processes can impact the introduction of this type of vehicles in the pharmaceutical chain. However, implementing these vehicles can bring advantages in the exchange of fast and precise information both in the company's system and to its customer/partner or via telephone applications, which will be a great asset.

Finally, it was evident from these interviews that the company does not plan any investments in autonomous vehicles to distribute its products. However, it is not ruling out any investments that the

logistics operator, responsible for Generis' storage and distribution operations, may want to make. On the contrary, an eventual investment aiming to automize in-house operations will be evaluated and might be implemented. One of the interviewees goes further by saying that a future implementation of this technology could follow the same evolution of other developments already made in the market. A first phase with the introduction of this technology in the logistics operators, and a second phase of introduction in the wholesalers' operations. The third phase would be the application of this technology in last-mile delivery.

3.1.2. Rangel Logistics Solutions

3.1.2.1. Companies Characterization

Founded in 1980, the Rangel Group brings together several companies operating in the logistics and distribution market. The Rangel Group quickly assumed an important position in the market, being recognized as a global logistics operator with the ability to integrate a wide range of transport and logistics services. The Rangel group is composed of a diversified business portfolio in the area of transportation and logistics from several Business Lines (e.g., Customs Broker, Road Freight, Contract Logistics, and International Express). Rangel Group operates with companies from different industries, from retail, e-commerce, automotive and even pharmaceutical industries.

In 2009 Rangel created Rangel Pharma & Healthcare, a company that gather the expertise of professionals of the pharmaceutical market to provide logistics solutions to pharmaceutical companies that don't see competitive advantages in having their own warehouse and distribution centers. One of this companies is Generis Farmacêutica, S.A whose outsourced services to Rangel include goods reception, storage, labelling, distribution and the collection and handling of returns.

Rangel Pharma & Healthcare is the market leader in Portugal, responsible for the logistics operations of some of the largest pharmaceutical companies in the world. It is a pioneer company in implementing technological solutions in drug distribution, with temperature-controlled distribution solutions and innovative traceability systems. As the pharmaceutical and healthcare market is extremely demanding, complex, and heavily regulated, this segment is unique and available to a limited number of logistics operators.

Thanks to years of experience in the field of logistics, Rangel managed to build a global network of partners and is capable of moving cargo between more than 220 countries by land, sea, or air. Besides the group's headquarters and main warehouses in Portugal, Rangel also has facilities in Angola, Mozambique,

Cape Verde, Brazil, South Africa, and Mexico. The main Warehouses in Portugal are in Lisbon (Montijo) and Porto (Maia), nevertheless has distribution centers all over the country.

By 2020 Rangel employed more than 2300 people throughout its warehouses, which covered more than 312 thousand square meters, 24 thousand of those dedicated just to the pharmaceutical sector operations. In 2019, the business volume exceeded 112 million units and 460 thousand orders shipped in the pharmaceutical sector alone. The trend is for growth and for this business volume to continue to grow.

3.1.2.2. Interview Analysis - Autonomous Vehicles Viewpoint

The interviewee from Rangel Logistics Solutions was the Project Manager and Continuous Improvement, responsible for implementing new customers and operational solutions.

Like previous interviews, this began with a summary of Rangel's role in the supply chain and how the company's operations are set up. The interviewee highlighted the company's critical role in the logistics chain of medicines and the ability to develop pioneering solutions in the logistics sector. It was given the example of the geo-referencing service that allows the real-time location and control of the status of the shipped cargo. Rangel was the first logistic operator with a dedicated fleet for the pharma sector. This type of service brought innovation to the sector and was important for its affirmation in the market.

Rangel is responsible for the product reception, the unloading of the cargo, product inspection, storage, order preparation, picking, order checking, route organization and distribution activities. The picking activities can be done by pallet, by box, and by unit and with the use of technology. The picking process can be done manually (almost non-existent), using the technology of picking by light technology where the operator does the picking with the support of a wrist terminal, without paper, and picking using a multi-order picking cart. This last tool allows the preparation of several orders simultaneously. Rangel also has trilateral heads, forklifts capable of handling pallets in narrow aisle racking systems. The technology to turn these machines into fully autonomous vehicles already exists and could be implemented. A sorter machine is also used for order preparation to delivery. It distributes the orders by fleet.

These technologies are part of a series of improvements in the optimization of Rangel's processes. This optimization is done with the help of new, technologically more advanced resources that meet the clients' needs. The interviewee shared that Rangel is evaluating the creation of a project with autonomous vehicles in its warehouses. AGV's that automatically go along with the picking operators. As soon as an

order is given, it can autonomously take and unload the order to the shipping dock and go back to the operator to load a new order. This way, the operator will not need to travel, saving time and making his work more efficient, and the operation will gain a lot in terms of processes.

Many more processes can be optimized in the warehouse with the use of autonomous vehicles. The interviewee gives the example of the use of autonomous drones for warehouse inventory. He holds that the options for autonomous vehicles are limitless. Many of these solutions, however, are still a few years to be a reality. Autonomous vehicles are already a reality in many warehouses of other sectors of activity. It will be a matter of time until the application of such vehicles also in the warehouses of pharmaceutical products.

As for the use of this technology in distribution, the interviewee is more reticent, not having guarantees that the existing solutions are only prototypes and that it may take many years until there is a solution that can cope with the challenges of the market. The respondent mentions that there is still an autonomy problem to be solved, assuming that these vehicles will be electric. The vehicles need to make over 400Kms. The state of public infrastructures is also an important issue to the application of this technology. Autonomous vehicles can be used more efficiently in industrial sites, as there will be less room for errors. In point-to-point logistics, it can be perfectly feasible to have an autonomous truck making that trip. Given the current reality, the interviewee prefers to see this as a more reasonable possibility rather than a last-mile solution that is still a long way off.

There is always room to improve logistics operations. It may not be with the use of autonomous vehicles, but it can be the optimization of spaces or warehouse mapping, for example. When asked about market regulations and whether they delay the development and application of new solutions in warehousing and distribution logistics, the interviewee considered that these regulations are very bureaucratic. He considers necessary to have these regulations, but sometimes it can be challenging to ensure their compliance, especially further down the distribution chain and for products whose storage conditions are more sensitive. Still, it is his belief that these regulations do not prevent companies from investing in their digital transformation and in technologies such as autonomous vehicles. More and more, the logistics costs in the pharmaceutical sector are approaching the logistics costs of other sectors. The interviewee gave the example that warehousing is more expensive due to the temperature conditioning of the warehouses, which is regulated. However, he guarantees that the incentive for investment deep down does not depend on these regulations but is in the genesis of each company.

It was mentioned that there are exciting solutions, and the warehouses that want to distinguish themselves by this differentiating factor can do so with an investment of a few thousand Euros. Not all companies are willing to make this investment. The interviewee considers that the return can be direct in terms of productivity or indirect, contributing to the increase of prestige and the way the company is seen in the market, making it acquire new customers.

For the interviewee, the biggest challenge of the autonomous vehicles' application is in distribution, especially in the last mile. The supply chain is not prepared, and his perception of the partners leads him to state that an eventual change in the way medicine deliveries are made may cause some doubts, especially among pharmacies and hospitals. The first step for the introduction of these vehicles should be the transfer of stock between warehouses, and only then should the market think about deliveries to the customer.

When it comes to the future of human resources, the respondent states that more and more the workforce will have to be specialized. It might not be needed to have engineers, but there must be people capable of managing and programming these vehicles. New needs are going to arise, and the supply chain must have the capacity to adapt. If a company do not adapt to the new automations, it will go back decades. No organization should stop its technological development because it believes it will reduce employment.

Finally, the respondent does not believe that it is time yet to make investments in autonomous vehicles for distribution. This differentiation between autonomous vehicles for in-house operations and for distribution is because the level of complexity is different. The technology for in-house logistics already exists, and the difference in costs between the two types of solutions is extremely limitative.

3.1.3. Alliance Healthcare

3.1.3.1. Companies Characterization

Alliance Healthcare is one of the largest pharmaceutical wholesalers and distributors in Europe. As a wholesaler, their core business is the supply, storage and delivery of medicines for resale or use in medical services, health units and pharmacies. This English multinational company has its origins in the creation of the UniChem group in the late 30s of the 20th century and was intended for the distribution of medicines to independent pharmacies. The company grew and started its activities in Portugal in 1990 and later

merged with the Alliance Santé group to form Alliance UniChem. The organization went through several internal transformations until it became Alliance Healthcare in 2007.

The company is responsible for the distribution of drugs and health products to pharmacies, bridging the gap between drug-producing laboratories and pharmacies. Currently alliance healthcare Portugal counts with the support of more than 450 workers distributed by its six warehouses (Lisbon, Porto, Almancil, Castelo Branco, Azores and Madeira).

Alliance Healthcare is the leader wholesaler in the pharmaceutical distribution market in Portugal and offers its partner pharmacies, in addition to efficient distribution and special commercial conditions, complementary solutions to support their activity. The logistics solutions presented to support the process of direct sales to pharmacies, can be cross-docking (order previously prepared by the laboratory for delivery to the pharmacy) or direct sales from stock at the Alliance Healthcare warehouse (like cross-docking, but from the stock resident at the Alliance Healthcare warehouses).

Alliance Healthcare is one of the most important partners of Generis Farmacêutica, S.A. as the company's position in the pharmaceutical market ensures the distribution of products produced by Generis to a larger number of pharmacies, resulting in greater exposure to Generis brands and a gradual increase in business volume.

3.1.3.2. Interview Analysis - Autonomous Vehicles Viewpoint

Alliance Healthcare interviewee is the Returns and Distribution Unit Manager, responsible for the distribution and reverse logistics activities.

The interview started with a brief explanation of the company's activities regarding the distribution of medicines to pharmacies. It was clear that this wholesaler's close relationship with its customers is reflected in the daily deliveries to pharmacies. In many cases, the orders are placed on the same day they are delivered, which makes all operations more complex and demanding.

It was interesting to understand that these tight schedules the company has to deliver the medicines to its clients need a great level of warehouse automation to be met. In this sense, Alliance has its warehouses completely equipped with automatisms that make picking and order preparation processes more straightforward and more efficient.

During this interview, it was clear that Alliance does not see the market regulations to be a setback to potential investments in any technology in its warehouses. On the contrary, it was interesting to see that the company has clearly defined investment in its warehouses as a priority. According to the interviewee, only in this way can Alliance maintain the level of customer satisfaction, guaranteeing fast deliveries and the best level of service. There will always be questions concerning regulations and new innovative solutions. Nonetheless, the most important thing in all projects is to anticipate these questions and demystify how things are so that no misinformation and no barriers are put in the way.

The investment in automation is essential since the company works with a high number of drug references, and every process needs to be very well defined. The interviewee also pointed out that companies in this area that do not invest in technical capacity and in the development of their warehouses can hardly meet the market demands.

Besides the automation that the company has been doing in its warehouses, it is currently in the implementation phase of a new operating system for its warehouses, which will allow it to close some existing gaps and make processes simpler. At the distribution level, the interviewee shared that Alliance does not have its own fleet and uses outsourced services to make the deliveries. Even so, there have been many developments in this area since the company has already advanced with two different projects in the distribution of medicines. Shared distribution with a competitor, aiming at reducing transportation costs and home delivery of medicines through a partnership with client pharmacies.

When asked about the possibility of introducing autonomous vehicles in the medicine distribution chain, the interviewee agreed that it will certainly be a reality in the future but added that evaluations must be made to understand how it will be possible to introduce these vehicles in the sector. The interviewee still has some reservations concerning the last-mile distribution of medicines. Her concern is that it is not clear what roles each player has to play during the distribution process. Medication deliveries today are made by a human driver who drops off the order where the customer asks. If this process is done by an autonomous vehicle, all the processes will have to be revisited.

The interviewee also believes that it might be difficult to change the mentality of the partners for this technology to be implemented successfully. Many associated questions have to be asked and evaluated since the solutions may not be as obvious as they might anticipate.

The interviewee recognizes the existence of autonomous vehicle solutions for in-house operations. Although Alliance still works only with automats, the future may bring 100% autonomous vehicles to the

warehouse. However, the reality is that in all Alliance warehouses, the order preparation line is already automated. The integration of autonomous vehicles in the warehouse will have to add value to other processes such as the goods reception or in the expedition process. Not every solution can be applied to every sector, and at this point of the pharmaceutical supply chain, the wholesalers have their operations very well organized, so any application of autonomous vehicles needs to be carefully evaluated.

The respondent does not foresee any radical changes to guarantee the application of autonomous vehicles in the supply chain for distribution purposes in the short or medium term. She refers that, like many other disruptive technologies in the past, a change in the mentality of every player is needed for this application to be successful. Nevertheless, in her opinion, the idea that this technology will replace the human factor inside the companies is nothing but far from reality.

In addition, the interviewee mentions that the most significant setback of the introduction of autonomous vehicles in logistics may be the implementation costs and timing. Once these types of ventures take a long time to be implemented and require many initial investments in the technology and infrastructures, this might be a barrier for many companies to invest in this technology.

From her experience, the interviewee claims that this is a very traditional sector and that there is still much resistance to change on the part of some players. In an initial phase, it will always be seen in a less positive framework, but things stay and solidify once this barrier is overcome. It is vital to rethink processes, question how companies currently operate and identify points for improvement.

In any case, the interviewee affirms that a future application of these vehicles will be much more likely to occur inside a warehouse rather than in distribution. This is because the application of this technology in distribution gives fewer guarantees of better performance and because the implementation costs might not be shared with other players. In warehouse logistics, with a controlled environment, the company can control the activities in which the autonomous vehicle participates.

Finally, the interviewee envisions the hypotheses for the company to invest in autonomous vehicles in the future. However, being a significant and innovative investment, this implementation could be associated with a pilot project that another company might want to test and develop together with Alliance. She also considers that the initial investment may pay off in the future with efficiency gains and cost reductions. Alliance is aware of these new technologies, but for projects like these, it will always have to be with the association of a partner from an area with knowledge in autonomous vehicles or that already works with these vehicles.

3.2. Comparative Analysis

Once have presented each company that has helped gather data about the pharmaceutical market, how operations are carried out, and their overview on the use of autonomous vehicles, it is now important to make a comparative analysis between them. This comparison will allow us to draw conclusions that will support the answers to the questions under investigation. To this end, the analysis will be divided into four different topics, each followed by a cross-comparison table that summarizes the main conclusions of the analysis developed.

3.2.1. General Features

The first topic is related to the general characteristics of the companies to understand the context in which each company operates. The following table (Table 3.1) summarizes the main characteristics of each company under study, namely: its origin country; the geographic dispersion of its operations; the position in the supply chain of the pharmaceutical market; what are the current operations; if they use of autonomous vehicles in these operations.

It is possible to understand that two of the companies (Rangel Logistics Solutions and Alliance Healthcare) that make up this study are multinationals. At the same time, one (Generis Farmacêutica S.A.) only operates in Portugal, despite being owned by an international group. As mentioned before, the companies chosen for the study have distinct positions in the supply chain. Generis is a laboratory whose operations are limited to the production of pharmaceuticals, Rangel is a logistics operator with expertise in pharmaceutical logistics (warehousing and distribution), and Alliance is a wholesale distributor of pharmaceuticals bridging the gap between the laboratory and pharmacies.

All three companies are leaders, each in its segment/position in the supply chain. Thus, the sample of companies under study is highly representative of this sector since they are all large companies with high added value in the pharmaceutical market.

It is also important to mention the presence throughout the national and international territory of companies responsible for the distribution of medicines produced in Portugal. A clear sign of the expansion of logistical operations over the years.

In addition, it is essential to note that none of these companies has entirely autonomous vehicles in their operations, only production and warehouse automation, but still far from full automation.

Table 3.1: Multiple Comparison I - Companies Characteristics

	Generis Farmacêutica SA.	Rangel Logistics Solutions	Alliance Healthcare Portugal
Year of foundation	2002	1980 (2009 – Rangel Pharma & Healthcare)	1938
Nationality	Portuguese	Portuguese	British
Geographic Dispersion	Portugal (Main Exports: Angola, Mozambique, Lebanon...)	Portugal, Angola, Mozambique, Cape Verde, Brazil, South Africa, and Mexico.	Europe
Main location in Portugal	Venda Nova, Amadora	Lisbon, Montijo and Maia	Alverca, Porto, Castelo Branco, Almancil, Azores and Madeira
Supply Chain Position	Pharmaceutical Production Laboratory	Logistic Operator	Pharmaceutical Wholesaler / Distributor
Current Operations	Produce Medicines	Storage and Distribution of Medicines	Medicine Distribution to Pharmacies
AVs in Current Operations	No – Only Manufacture automations	No – Only Warehouse automations	No – Only Warehouse automations

Source: Own elaboration

3.2.2. Autonomous Vehicles In-house vs Autonomous Vehicles in Distribution

Each company presented its idea and vision regarding how autonomous vehicles might eventually be used in logistics operations throughout the supply chain (Table 3.2).

Market regulations are often pointed out as crucial factors in companies' investment in new technologies. As previously mentioned, the pharmaceutical market regulators work to ensure compliance with good practice in the production, storage, and distribution of pharmaceuticals. These preventive measures may have a negative effect when it comes to investing in the companies operations. The companies' surveyed acknowledged that regulations can be less demanding in warehousing activities where they will always have to be complied with and are subject to higher scrutiny. In distribution, the application of AVs will have to meet the new requirements imposed to ensure the safety and condition of the medicines.

The market players in this study agree that the regulations will have to be adjusted to the new reality. The sector cannot wait and be surpassed because the regulations block any investment in new

technologies. The regulators should predict and anticipate the digital transformation inside the companies and make the necessary changes that allow organizations to develop their operations.

Another point of agreement between all entities was that there is still much room for improvement in many companies' activities. The use of new technology like autonomous vehicles is seen as an improvement that could facilitate some processes. Generis and Rangel highlighted the use of AVs in activities of handling cargo at the reception, picking and expedition. However, for a company like Alliance, whose activities are already optimized with warehouse automations, the use of autonomous vehicles may not be applied. Like the other players, the wholesaler could see an advantage in using autonomous vehicles for handling cargo in inbound and outbound logistics, i.e., when new cargo is unloaded, and shipments are loaded to trucks.

Besides these activities, Rangel, as a logistics operator, sees advantages in using other autonomous vehicle solutions for secondary activities which take place in the medicine warehouses. Activities that go beyond the preparation and distribution of orders, such as warehouse inventories performed by drones and even sampling processes, labelling, and decommissioning of pharmaceutical units, can be improved with innovative solutions using autonomous vehicles.

When it comes to the use of autonomous vehicles for transporting medicines on public roads, between warehouses and to the final customer (pharmacies and hospitals), the agents are more sceptical. This disbelief is explained by the lack of concrete solutions in this area. While Generis and Alliance are optimistic and believe it can be a reality in the medium term, Rangel does not foresee the existence of mass delivery vehicles in the medium term. The three companies are sure that this technology is still far under the market needs. There are legal issues that are important to be solved before moving forward with the introduction of these vehicles. Nevertheless, eventually will be a reality, and the market must be ready to accept it.

Therefore, it is the opinion of the agents of the distribution chain that the application of autonomous vehicles can be made in three different steps. Ideally, in a first phase with the application of already existing solutions, to improve internal processes within the warehouses. In these environments, the control of the companies is greater, and the risks of failure can be more easily managed. Later they admitted it would be possible to extend this technology to the transfer of goods, with the introduction of autonomous vehicles capable of moving freely between two logistic centers. At this point, the environments in which these vehicles circulate should also be considered. Controlled environments close

to the public, such as industrial parks and logistics platforms. After successful tests in these scenarios, it will be desired to move forward with 100% autonomous solutions for transporting goods to the customer.

Rangel believes the introduction of these vehicles in distribution will come from automotive companies. The automotive industry has been developing exciting solutions for autonomous vehicles, from passenger vehicles to trucks. That being said, the solutions of AVs in logistics will be made from the outside into the logistics industry. This is also the opinion of Alliance that supports the application of vehicles developed by engineering and automotive companies, in contrast to what has been done over the years in which large logistics companies invest in improvements to the vehicles they use in warehouses. All these advances will take many years before this type of vehicle becomes a reality throughout the sector.

Table 3.2: Multiple Comparison II - In-house Operations vs AVs in Distribution

	Generis Farmacêutica SA.	**Rangel Logistics Solutions**	**Alliance Healthcare Portugal**
Regulations impact investment	No – Guidelines for AVs application	Yes – In distribution No – In warehouse	No – Regulators must adapt
Room for improvements	Yes	Yes	Yes
Activities where AVs can be used	- Inbound Logistics - Picking - Order preparation - Outbound Logistics - Distribution	- Inbound Logistics - Picking - Order preparation - Outbound Logistics - Distribution - Warehouse Inventory	- Inbound Logistics - Outbound Logistics - Distribution
AVs in in-house operations	- Already existing solutions - Crucial for operations improvement	- Under development projects - Company is independent to invest	- Open to AVs introduction
AVs in distribution	Optimistic view	Still distant from reality More challenging	Optimistic view

Source: Own elaboration

3.2.3. Benefits and Drawbacks

This section aims to compile the benefits and drawbacks identified in the interviews made to each company. A summary of all the points raised is presented in the resulting table (Table 3.3).

The application of new technologies forces companies to adapt. This digital transformation will bring many advantages and help improve existing processes. It contributes to the emergence of new needs and can bring more challenges for industries. Markets are constantly changing and always present new challenges. Process reinvention is critical for companies that want to remain at a competitive advantage.

Generis highlighted the use of 5G technology to be the central transformation in the coming years. This technology will allow many more possibilities to emerge, among which are autonomous and connected vehicles. According to the pharmaceutical company, the introduction of AVs in logistics can certainly bring advantages in terms of increased productivity and cost reduction. This has been the great challenge of logistics, and technology investments have proven to be extremely important. While Rangel points out the saving in transportation costs and environmental advantages from using AVs in distribution, Alliance underlines the benefits in security and availability of the transports. Both companies support the idea that the use of AVs in warehouses and public roads will lower the number of accidents and increase security since the technology is more precise and can anticipate and react quickly to possible dangers.

Among the arguments emphasized by the three companies, the future of human resources was one of the most interesting. It is the opinion of the managers that there may be a reduction in the number of employees in the sector of logistics and distribution of medicines. However, many processes still depend on the human factor, and not all partners will be interested in eliminating the human interaction from their business. Therefore, Alliance proposes a hybrid system where deliveries are made both by autonomous vehicles and human drivers. The possibility of a change in the human resources structure was raised, giving as examples warehouse operators that could give way to engineers or drivers that could see their functions restructured. Alternatively, Rangel also assesses an investment in human capital positively to give workers skills that allow them to operate with autonomous vehicles.

Bearing in mind the points raised as challenges to the application of autonomous vehicles, it can be verified that they are mainly related to the costs associated with a digital transformation of these dimensions and the capacity that the supply chain of medicines must apply this transformation. The companies are concerned that the initial costs necessary to support the AVs introduction might be too high and take a long time to pay off the investment.

Not every solution of an autonomous vehicle can be applied to the distribution of medicines. In fact, the complexity of the pharmaceutical market, the difference between types of customers and orders and the need to deliver quickly make the utilization of AVs in the pharmaceutical industry more complex.

Besides, this sector is not very dynamic and is very resistant to change. Some stakeholders may not be able to reorganize their activities to apply autonomous vehicles to their business.

Table 3.3: Multiple Comparison III – Benefits and Drawbacks

	Generis Farmacêutica SA.	Rangel Logistics Solutions	Alliance Healthcare Portugal
Benefits	- Reinventing the logistic processes - More qualified workforce - Reduction in HR and distribution costs - Efficiency and productivity increase - Downtime reduction - Real time order information	- Highly skilled HR - Fuel consumption efficiency - Environmental benefits (Reduction in CO2 emissions) - Productivity increase - Less accidents - Less mandatory stops	- Reinventing the logistic processes - Fully available distribution network -- Lower distribution failures (Accidents, breakdowns) - Hybrid distribution system (delivery with AVs and humans)
Drawbacks	- Elimination of the human factor - Potential failures in shipment control - Application and maintenance costs - Potential infrastructure costs	- Legal and insurance issues - Initial investment costs - Lower distribution failures - Different order sizes require different solutions - Potential autonomy flaw - Change in mentality - Vehicle management complexity	- Complexity of delivery (pharmacies/hospitals) - Lack of support infrastructures - Partner's mentality - Other delivery tasks (validation/complaints/recalls) - Cliente inconvenience

Source: Own elaboration

3.2.4. Overview on Autonomous vehicles in the pharmaceutical market

This segment summarizes how the companies inquired in this study envision a real investment in this technology and gives an ultimate overview of AVs introduction in the pharmaceutical market (Table3.4).

It was the opinion of the three firms that investments in AVs technology could start to appear in the market soon. Up to this day, no company in the supply chain of medicines distinguishes itself from others by using autonomous vehicles in its warehouses. The application of AVs in distribution even feels more distant as there is still no practical solutions in the market and other problems like autonomy issues need to be addressed first.

The interviewees pointed out the existence of many projects in development for AVs in distribution, but there is a feeling that pilot projects do not materialize in concrete application. Although they believe that it will certainly be possible to use autonomous vehicles to distribute medicines, all players understand

that it will take a few more years before this becomes a reality, not only in the pharmaceutical sector but also in all others. A mass implementation of these vehicles in distribution will require a significant development of the logistic chain, not only for distributors but also for all agents. Infrastructures will have to be created that allow the use of these vehicles. Yet, not all market players are ready to receive autonomous vehicles, nor do they know how this technology could be helpful.

In this sense, while Rangel and Alliance see possible a short- to medium-term investment in AVs for their in-house operations, Generis does not have the same motivation as their logistics operation is outsourced. Nevertheless, a future investment of AVs that proves to guarantee an increase in productivity and improvement in the services performed at equal or lower cost will be welcomed and fully supported. Rangel is already studying the possibility of placing autonomous vehicles in his warehouses and is in the pipeline to do it soon. Similarly, Alliance also considers investing in AVs but this would have to be articulated in order to complement a partnership with a technology developer. This could be a university or a technology company willing to go forward with a pilot project to distribute pharmaceutical products to pharmacies.

All the players agreed that the market would look to an eventual AV application by the companies in their business. Specially for distribution operations, the market reaction would be of strangeness at first, especially within pharmacies and hospitals. Eventually, this feeling would give way to a recognition and change of the mentality and processes.

It is a common thought among all three players that the company that first introduces AVs into its operations will win the admiration of the market and will be seen as a pioneer and disruptive. Additionally, for a company like Generis, the recognition and promotion of its activities within the market would positively impact its brands.

Table 3.4: Multiple Comparison IV – Overview on AVs introduction in the Pharmaceutical Market

	Generis Farmacêutica SA.	**Rangel Logistics Solutions**	**Alliance Healthcare Portugal**
Available to invest	No – Investment by the Logistics Operator	Yes – In-house AVs	Yes – As partnership / Pilot project
Partners overview	Brand recognition and prestige	Disruptive	Reluctant
Years to AVs mass application in warehouses	2 – 5 years	2 - 5 years	2 - 5 years
Years to AVs mass application in distribution	5 - 10 years	10 – 15 years	8 - 10 years

Source: Own elaboration

3.3. Critical Analysis – Improvement proposal

The focus of this thesis is to study how autonomous vehicles could be introduced in the pharmaceutical market. The first objective, and the one that was most important to be answered initially, was whether there would be a way to implement this technology in the pharmaceutical market. The results indicate that the players in the supply chain are looking favorably on the possibility of implementing this technology to close some gaps in their operations.

The results show that there is room for improvement in both warehouse operations and in the distribution of medicines. The regulations and specifications of the pharmaceutical market do not prevent companies from investing in new technologies. On the contrary, investment is seen as essential, and it is up to the market to adapt itself.

Nevertheless, as regards the second objective, in-house logistics is where the fastest development of autonomous vehicles occurs. Not only that, but existing technology is more developed to improve logistic processes. As reported by (DHL Trend Research, 2014), the first implementation of autonomous vehicles will follow the trend of other technologies and will first be implemented in the logistics sector. The results also point in this direction, as the environment in which they operate is considered safer, less complex, and the agents are more self-sufficient to make decisions.

The introduction of autonomous vehicles in logistics is not restricted to the transportation and handling of products. As reported by Vivaldini et al., (2015), this technology can be used for the most diverse activities within the warehouses and industrial environments. The results show the need for logistics operators to have autonomous vehicle solutions capable of performing secondary activities to the preparation and distribution of orders, such as supporting reverse logistics processes, physical stock counting or product labelling.

The third objective was to determine the main factors that could positively and negatively influence the investment in the adoption of autonomous vehicles in logistics operations. Advantages were highlighted in terms of cost reduction and productivity gains of various orders, but also improvements in terms of safety and environmental benefits. This analysis supports the theories of (van Meldert & de Boeck, 2016) and (Bucsky, 2018) that the AV introduction in logistics could have major benefits in terms

of efficiency gains and cost reduction as well as contribute to a re-evaluation of entire supply chains and logistic processes.

Despite this, relevant points have also been raised that need to be considered. Weaknesses related to initial costs, legal issues, the conservative mentality of the market, the future of human resources, and the lack of technological optimization stand out. This is aligned with previous findings acknowledging that the main drawbacks to AV application can be the costs but also legal, ethical, and organizational changes that need to be addressed.

Regarding objectives four and five, the results indicate that there will be resistance to change in an initial phase as the supply chain is still not prepared for the mass application of this technology. This can be overcome with the redesign of logistics and delivery processes and with a change in the partners' mentality as well. Collected data suggest that players will react differently considering their position in the market. The investment in AVs will much more likely be made by logistics operators and wholesalers rather than pharmaceutical companies. Even so, it is essential to note that wholesale distributors already have many of their internal activities automated, so the adoption of autonomous vehicles may not make sense in all warehouses. Not only that but, different solutions are required to meet each players different needs, according to their dimension and business volume.

Results indicate that companies are keen on applying autonomous vehicles, but initially only for their in-house operations. This is because existing technology does not yet assure the mass, legal and safe use of autonomous vehicles in distribution. A similar finding was acknowledged by (Bucsky, 2018) when stated that one of the main challenges of adopting this technology is in its use outside of controlled environments like logistic centers.

Based on the market players involved in the study, it is possible to infer that logistics operators and wholesale distributors will adopt autonomous vehicles. Since the pharmaceutical company subcontracts the logistics services, it has no direct advantages in investing in this technology. The results point to an investment in this technology for their warehouse operations in short to medium term. This means that new solutions will start to be seen in the pharmaceutical logistics centers in less than five years. However, the study also revealed that the players do not believe in the adoption of AVs for distribution in a term inferior to eight years. These findings go along with(Shanker et al., 2013) theory that a mass introduction of AVs in distribution can occur in the next two decades.

This experiment provides a new insight into the relationship between different supply chain players regarding the introduction of a technology that could benefit the entire market. The mass application of this technology as a digital transformation process and evolution to Logistics 4.0 in the near future is a clear sign that companies realize that it is necessary to innovate and improve their activities. In this way, they will continue to ensure that they remain competitive in the market.

To better understand the implications of these results, future studies should consider the inclusion of other market agents such as pharmacies, hospitals, and costumers. This would allow a more comprehensive study on how the use of this technology in the distribution of medicines could impact the final costumer. Also, further research could help to determine the relationship between the early adopters of this technology and their market position.

Conclusions

Logistics 4.0 and the related digital transformations are forcing organizations to reinvent themselves and rethink their activities and processes. By doing this, many companies start searching for technologies that might give them new competitive advantages. Among these technologies are self-guided vehicles.

The purpose of this research was to find if an application of autonomous vehicles in the transportation of medicines is possible, as it is considered a highly regulated market. It was also appropriate to understand the market players views on making investments in this technology and at what point they are considering doing so.

According to the inferred conclusions, the adoption of this new technology can be possible in two different segments. Indoor logistics, these being warehouse operations and outdoor logistics, as the use of AVs for distribution of medicines. The conclusions take point to the first application of this technology within the spaces controlled by logistics operators and wholesale distributors. As for the use of autonomous vehicles to transport medicines outside warehouses and in public spaces, there are still no practical solutions in the market to make this possible.

From the research results, we can extract that companies believe that introducing this technology in their activities will have significant productivity gains and medium to long term cost reduction. Still, it was concluded that the initial investment in this technology and in the necessary support infrastructures is the biggest obstacle to its application.

Companies that perform logistics and distribution activities in the pharmaceutical market expect to introduce this type of solution in their warehouses in the short term since the technology is already available. For distribution activities, the application of this technology is expected to take some time and will be mass-applied only in the long term.

This study is limited by considering only three companies from the entire supply chain. For future scientific work, it might be interesting to include the viewpoint of pharmacies, hospitals, and patients. Furthermore, this study was based on a qualitative analysis subject to some subjectivity. The subject of this work is still an underdeveloped technology below its potential, so the players do not have the experience in using it to make objective observations. It would be interesting to revisit this subject once the first AVs solutions for distribution appear in the market.

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Annexes

Annex A: Interview Script

Source: Own

Theme: Logistics 4.0 – Evolution of Transport for the Pharmaceutical Sector
Evolution and Application Analysis of Autonomous Vehicles for Pharmaceutical Logistics in Portugal

Duration: 40 Minutes (for each Interview)

Methodology and Expected results description:
This series of interviews will be a key point for the qualitative analysis of this thesis. The main goal is to evaluate how the different agents of pharmaceutical supply chain in Portugal. This series of interviews are a major milestone to get the broad perspective of the introduction of AV's in the transport of medicines. It is expected

Interview Goals:

- Get an overview of the Pharmaceutical Supply Chain in Portugal.
- Current and future state of the logistics operations with the introduction of new technologies.
- Understand the standing point of the representatives of different companies about the introduction of AV's in the Supply Chain.
- Understand if the specifications of the market will influence the introduction of AV's.
- Identify the potential costs of this technology introduction.
- Distinguish the benefits and drawbacks of the introduction of new technologies in the market.
- Understand in what technologies companies consider to be essential to invest in to adapt and not to become obsolete.

Interviewee(s) Identification:

Generis Farmacêutica, S.A. – Jorge Alves (Logistics & Customer Service Manager)

Generis Farmacêutica, S.A. – Vasco Parrulas (Logistics Operations Technician)

Rangel Logistics Solutions – Jorge Martins (Project Manager and Continuous Improvement)

Alliance Healthcare – Paula Teixeira (Returns and Distribution Unit Manager)

Block	**Goal**	**Questions / Comments**
A. Legitimacy of the interview and motivation of the interviewee.	Interview goals explanation. Motivate the interviewee to respond sincerely and freely	. Interviewer presentation. . Guarantee if the interviewee allows the recording of the interview.

		. Information about the goals and objectives of the interview. . Request interviewee contribution to ensure the goals are met.
B. Interviewee Profile	Collect information that allow the interviewee characterization	. Academic History . Type and nature of functions performed. . Interviewee areas of interest.
C. Theme introduction	Perceive the interviewee knowledge about the new technology developments around autonomous vehicles.	. Give the interviewee a summary of the state of the art around AV's.
D. Pharmaceutical market (Theme Block B) **3 Questions**	Overview of the Pharmaceutical Supply Chain in Portugal. Company mission and market insight.	Question 1: What are the key activities of (COMPANY)? Question 2: Where does (COMPANY) situates in the Pharmaceutical Supply Chain? Question 3: Do you consider this market highly regulated? If so, does these regulations push back companies to invest in new technologies?
E. Current Logistics Operations (Theme Block C) **2 Questions**	Summary of the current operations of the organization.	Question 1: Could you do a summary on how the operations inside (COMPANY) are managed today? Question 2: Has it been an investment in operations, especially in digital transformation technologies?

F. Future of Logistics Operations (Theme Block D) **5 Questions**	Understand what the particularities of the market in terms of regulation are, and how can they affect investment in new technologies. In which activities could autonomous vehicles be used the most?	Question 1: Is there room to improve the logistics operations in the Pharmaceutical market Question 2: Do you consider that autonomous vehicles can be a reality in the future of this market Question 3: How autonomous vehicles could be implemented in the market? Indoor logistics (closed circuits) or distribution? Question 4: Does the market regulations mentioned earlier influence in introduction of AV's in distribution? Question 5: How many years do you think until a full implementation of AV's in logistics?
G. Organization adaptation to new Technologies (Theme Block E) **4 Questions**	Understand what the challenges and benefits are of this new technology adoption by the market. Verify if the Supply Chain is ready for AV's.	Question 1: Is the supply chain adapting to new technologies? Question 2: What do you consider to be the biggest pros and cons of AV's introduction in logistics and distribution? Question 3: Will these investments be crucial in a near future? To reduce costs and increase productivity?

		Question 4: What do you think about digital transformation and the future for the human resources?
H. Market Challenges (Theme Block F) **2 Questions**	What can be the biggest challenges of the organizations in the future of the Pharmaceutical Market.	Question 1: What does (COMPANY) considers to be the biggest challenge in the Pharmaceutical Market? Question 2: How does a company like (COMPANY) stay competitive in the market?
I. Expectations for the Future (Theme Block G) **3 Questions**	Understand the viewpoint on how the operations could look like in the future with the AV's	Question 1: Do you reckon the application of AV's in pharmaceutical distribution in a near future? Question 2: How do you think the (COMPANY) partners will react to the introduction of these technologies Question 3: Is the investment in new technologies like AV's part of (COMPANY) the strategy in the next few years?
J. Thanks		