



## THE EFFECTS OF AUTONOMOUS VEHICLES ON THE LOGISTICS SECTOR AND THE INNOVATIONS THEY BRING

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### ABSTRACT

This study comprehensively addresses the role and impact of autonomous vehicles in the logistics sector. With the integration of intelligent systems, these vehicles not only reshape logistics operations but also play a critical role in urban digitization. The ability of autonomous vehicles to quickly adjust their routes based on real-time data enables the efficient and secure transportation of goods, from storage facilities to distribution centers and international logistics. This situation reduces costs and optimizes time management. However, the implementation of these technological advancements requires careful consideration of factors such as safety, legal regulations, and societal acceptance. The study also details our company's application of electric bus initiatives and the activities and needs associated with them. Therefore, this study highlights not only the role of autonomous vehicles in logistics but also their impact on society.

**Keywords:** Logistics, Autonomous vehicles, Smart transportation, Automotive, Industry 4.0

### OTONOM ARAÇLARIN LOJİSTİK SEKTÖRÜNE ETKİLERİ VE BERABERİNDE GETİRDİĞİ YENİLİKLER

### ÖZET

Bu çalışma, lojistik sektöründeki otonom araçların rolünü ve etkisini kapsamlı bir şekilde ele almaktadır. Akıllı sistemlerin entegrasyonu sayesinde, bu araçlar yalnızca lojistik operasyonlarını yeniden şekillendirmekle kalmayıp, aynı zamanda kentsel dijitalleşmede de kritik bir rol oynamaktadır. Otonom araçların, anlık verilere dayanarak rotalarını hızlı bir şekilde değiştirebilme yeteneği, depolama tesislerinden dağıtım merkezlerine ve uluslararası lojistiğe kadar malların verimli ve güvenli bir şekilde taşınmasını mümkün kılmaktadır. Bu durum, hem maliyetleri azaltmakta hem de zaman yönetimini optimize etmektedir. Ancak, bu teknolojik ilerlemelerin hayata geçirilmesi için güvenlik, yasal düzenlemeler ve toplumsal kabul gibi çeşitli faktörlerin dikkate alınması gerekmektedir. Çalışmada, kendi firma uygulamamız olan elektrikli otobüs çalışması ve gerçekleştirilecek faaliyetler ile ihtiyaçlar da detaylı bir şekilde ele alınmaktadır. Dolayısıyla, bu

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çalışma, otonom araçların lojistikteki rolünün yanı sıra, toplum üzerindeki etkilerini de vurgulamaktadır.

**AnahtarKelimeler:** Lojistik, Otonom Araçlar, Akıllı Ulaşım, Otomotiv, Endüstri 4.0

## 1. INTRODUCTION

Today, autonomous vehicles are increasingly important in the logistics sector. These vehicles are equipped with artificial intelligence and sensor technologies that are driverless and able to move automatically [12]. In logistics, autonomous vehicles are responsible for the process of transporting materials, products and services. These vehicles are used in a variety of logistics tasks, such as transporting materials from storage facilities, taking them to distribution centers and delivering them to final consumers. In addition, the impact of autonomous vehicles is not only limited to logistics companies, but also plays a decisive role in the digitization process of cities [8]. The concept of intelligent systems and digital organisms collects and analyzes large amounts of data in order to optimize the infrastructure and services of cities. This data provides important information about traffic density, weather, road conditions and other variables [6]. The analysis of the data collected is of great importance for the effective use of autonomous vehicles. This data allows autonomous vehicles to plan their routes more effectively, while helping them to identify potential obstacles both in advance and instantaneously [13]. In particular, thanks to artificial intelligence algorithms, these vehicles can choose the most suitable routes even in complex traffic conditions, thus minimizing travel times. In addition, driverless vehicles are capable of other than the definition of study, to safely transport their cargo during transport processes. This enables them to act based on data from intelligent systems, enabling them to react appropriately to instantaneous conditions [8]. For example, unexpected obstacles encountered when carrying a passenger or cargo are analyzed quickly by these systems, developing alternative routes or strategies. These developments offer groundbreaking potential in the logistics industry in terms of efficiency, safety and environmental impact. Autonomous vehicles not only transform existing logistics processes but also play an important role in shaping future city infrastructure and transportation systems.

- What steps need to be followed for logistics with autonomous vehicles?
- What requirements must be met for the use of autonomous vehicles in the logistics sector?
- What are the data obtained in the application of sample autonomous bus study?

The aim is to answer these three main questions, and case studies related to them will be provided. In this context, the effects of autonomous vehicles and enterprises in logistics will be examined in detail, and a perspective on the future will be presented.

## 1.1. History of Autonomous Vehicle Technologies

The concept of autonomous vehicles dates back to the 1920s. In 1925, a French electrical engineer came up with a radio controlled vehicle ride [12]. After this stage, in 1939, as a result of the joint research and development activities of General Motors and Sarnoff Laboratory of America, the idea of autonomous vehicles was presented to the public for the first time at the New York World Fair. The idea of the exhibited autonomous vehicle also included a highway system that would assist the vehicle. In 1958', testing of such vehicles was carried out for the first time and tests of a self managing autonomous car were carried out [5].

## 1.2. Earnings from Autonomous Vehicles

With the increase in transportation, negative situations such as pollution, accidents and human losses are also increasing. Autonomous vehicle technology may reduce some of these negative effects [14]. Autonomous vehicles can be used by all family members at the same time and can be used commercially in taxi, bus and transport services [4]. In addition, they can reduce parking demand in urban centers, contributing to the opening of these areas to other economic activities and increasing urban density. However, the factors of reliability, comfort and time can encourage long journeys and cause urban sprawl [5].

## 2. STRUCTURE OF AUTONOMOUS VEHICLES

### 2.1. Hardware Systems

Autonomous vehicles are often formed by the integration of a number of complex technologies. The hardware system is given below.

#### a) Motion Control;

In autonomous vehicles, the system regulates the vehicle's speed, direction, and position using sensors, actuators, and control systems. This technology enables the vehicle to move safely at the desired speed and accuracy by sensing environmental data. As shown in Figure 1, motion control is a key component that enables autonomous vehicles to travel efficiently and accurately.

- Motor Control Unit (MCU) : Controls the speed and torque of the electric motor. Regulates the electrical power to ensure the correct operation of the vehicle's engine. Optimizes the speed and power of the engine for an efficient drive.
- Electric Power Steering (EPS) : It is an electric steering system. The electric motor provides the steering wheel rotation. Provides a more precise and efficient driving experience.

- Electro Hydraulic Brake (EHB) : It is a combination of electronic and hydraulic systems. Manages braking processes more quickly and precisely. Charges the battery with regenerative braking and provides energy recovery.
- On Board Diagnostic (OBD) : Continuously monitors all electronic systems in the vehicle. Detects faults and sends a warning to the driver. Optimizes vehicle performance.
- Electronic Parking Brake (EPB) : It is an electronic parking brake. It replaces the manual parking brake and offers easy use. It uses the space in the vehicle efficiently thanks to its compact structure.
- Lithium Battery : It is the energy source of the electric vehicle. It provides energy with high energy density and long life. It offers fast charging and long range.
- Vehicle Control Unit (VCU) : It functions as the central brain of all motion control systems. It coordinates components such as MCU, EPS, EHB and battery. Optimizes the performance and safety of the vehicle.

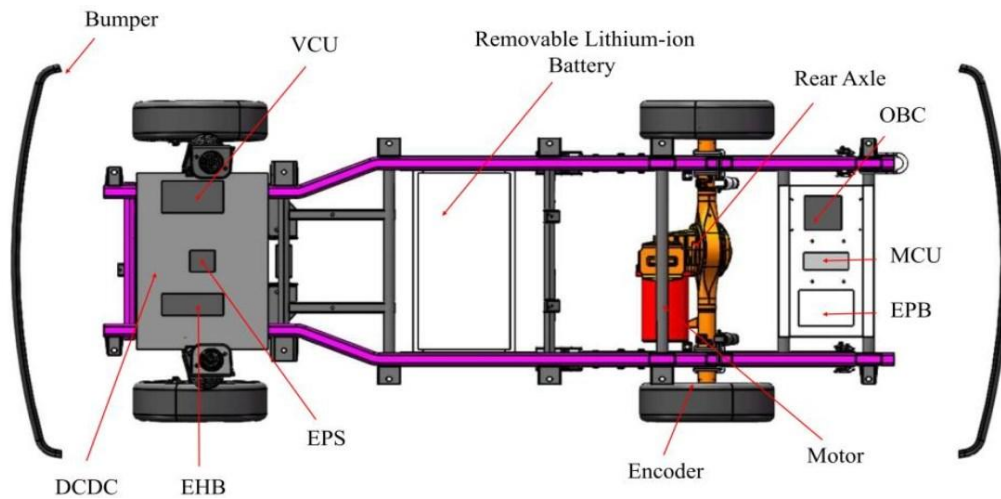


Figure 1. Mobile based (chassis) sensors and control units [2].

#### b) Task Manager;

Optimizing and monitoring the studies of robots plays a critical role in modern logistics systems. In this regard, the Task Manager has the ability to create optimized logistics routes based on delivery locations and time windows [7]. Not only does this process ensure that the shortest and most efficient roads are identified, but it also takes into account variables such as traffic situations, weather conditions and other external factors. The Task Manager continuously monitors each stage of the delivery processes and provides quick response in case of any glitches. Thus, the system can develop alternative solutions to deal with unexpected situations. In the event of a road closing or an increase in traffic intensity, it minimizes time loss by rescheduling the current route. It is critical to ensure that all deliveries

are working as expected. The Task Manager ensures that each delivery is delivered on time and safely, while also monitoring the effective use of resources. The integration of these systems increases the efficiency of logistics operations, reduces costs and increases customer satisfaction.

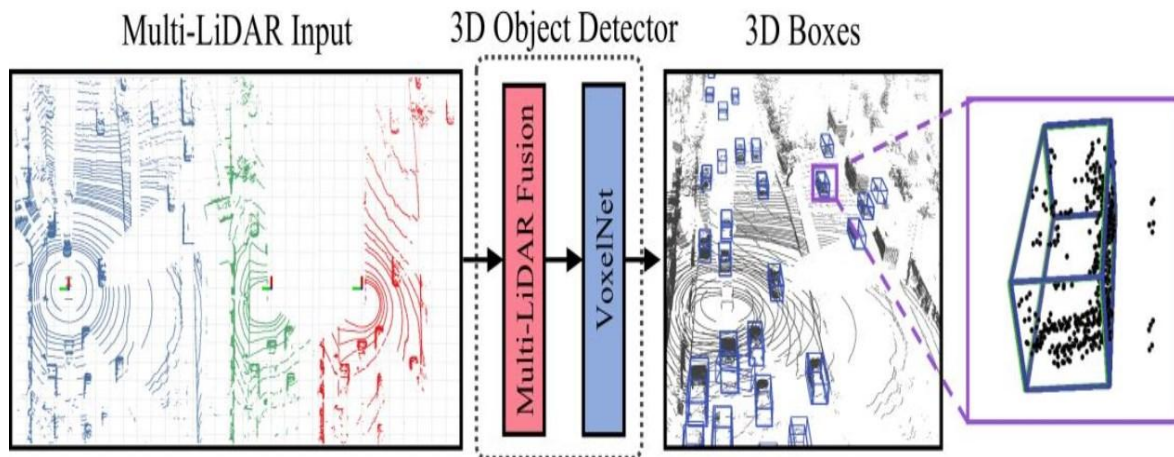
### c) System Control;

These systems continuously process and analyze the data necessary to control the movement of the vehicle. The information obtained through sensors, cameras and other data collecting devices allows the vehicle to detect the surrounding environment. The processed data is used to effectively manage the basic functions of the vehicle, such as steering, acceleration and stopping [13]. During the routing process, the system determines the optimal route, taking into account GPS data, map information and the location of surrounding obstacles.

Acceleration and stop study are performed by analyzing the current speed, road conditions and traffic situation. Thus, the system can detect in advance dangerous situations such as sudden stops or accelerations to ensure a safe ride. The integrated structure of these systems is capable of continuous learning and adaptation using advanced algorithms to improve driver and passenger safety. Therefore, the performance of the vehicle improves with time and can respond more quickly to changing conditions. These characteristics play a decisive role in the future of modern transport, increasing the efficiency and safety of autonomous vehicles.

### d) Sensors;

Autonomous vehicles use a variety of sensors to detect their surroundings [12]. These sensors are usually lidar (range detection by light), radar (range detection by radio waves), camera, and ultrasonic sensors, as shown in Figure 2. Lidar can calculate distance by sending light waves [2].

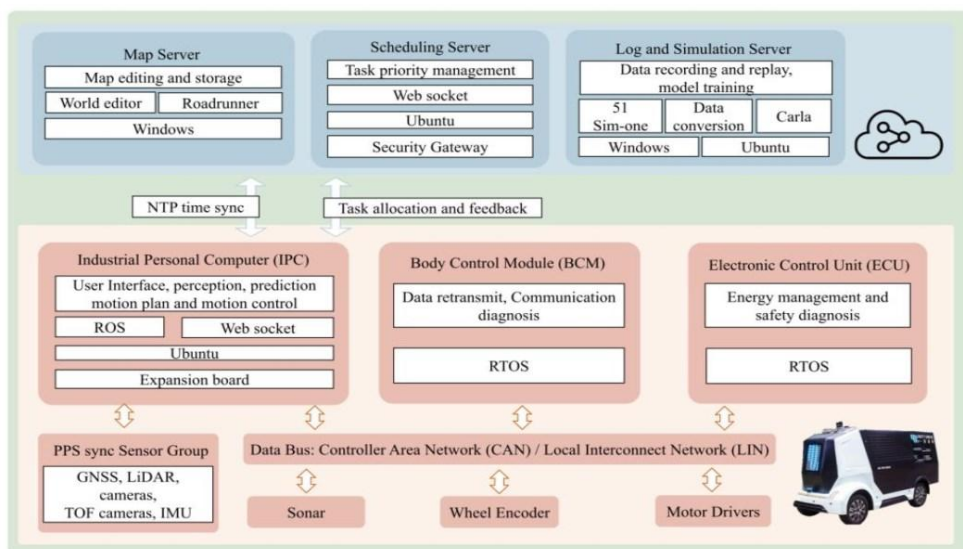


**Figure 2.** Overview of the 3D object detection module. Inputs are captured by multiple synchronized and well calibrated Lidars [2].

With the developing technology, multiple automation systems are being developed in vehicles. Vehicle infrastructure communication enables data flow between autonomous vehicles and road and traffic infrastructure [5]. Vehicle to vehicle communication is the situation in which the car communicates with other vehicles and transmits and receives data. Besides these communications, there are various technologies available to monitor vehicles by scanning the surrounding situation. Perimeter radar can operate at different ranges and detect objects. Lidar obtains 3D images using lasers [11]. Ultrasonic sensors are affordable and have limited range and are affected by weather conditions. These sensors are used in different areas and are integrated with GPS [12]. The vehicles are equipped with anti collision systems, which direct the vehicle in case of a possible accident [5]. While the GPS signal is used as a starting point, the HD map, Lidar and camera also contribute to positioning algorithms [2].

## 2.2. Software System

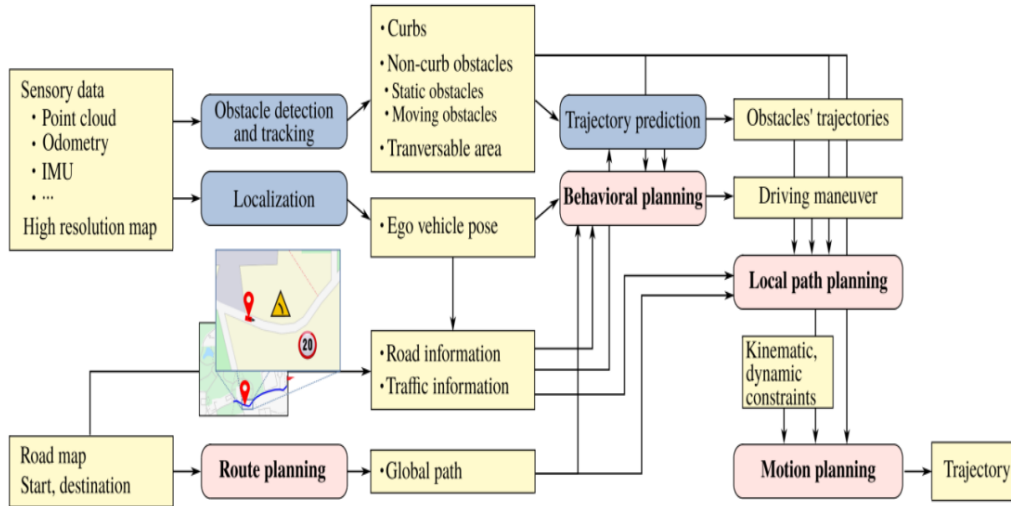
The software architecture of our autonomous vehicle is shown in Figure 3. It can be divided into two parts generally, These are data transfer on the vehicle and data transfer on the cloud. Map and timing servers are critical in the management of autonomous vehicles. The map server stores prebuilt maps and integrates them with sensor data [15]. The timing server performs task allocations, collects vehicle statuses and manages the access role. These integrations are vital for the safe and effective routing of vehicles [12]. Testing real world scenarios with simulations is a critical step in the development and improvement of autonomous vehicles [2]. Autonomous tools use artificial intelligence (AI) and complex software algorithms to process the information they perceive, understand environmental conditions, and make decisions.



**Figure 3.** Software architecture of our tool. The part shown in the yellow box is working on the vehicle, while the part shown in the blue box is working on the cloud [2].

### 3. PLANNING IN AUTONOMOUS VEHICLES

Planning to determine the movements of autonomous vehicles is a challenging process. Because traffic conditions are vague and dynamic, planners need to observe safety and traffic rules. Therefore, it is usually divided into four layers. These are given in Figure 4.



**Figure 4.** Schematic diagram of the planning of our autonomous vehicle [2].

#### a) Route Planning;

The route planner is used to determine a route when a road network is given. In structured environments, this planning process is usually done using open road maps. However, in places such as industrial parks or residential areas, vehicle routes are usually not registered in the road network. Also, some of the transition areas in these areas may be unstructured and not clearly defined [2].

#### b) Behavioral Planning;

Behavioral planning determines the manoeuvres of the vehicle and presents a general representation. It receives information from global maps and meets requirements in different environments. Information from traffic signs and other vehicles supports the decisions of the vehicle. This information enables the vehicle to understand its surroundings and move safely [2].

#### c) Local Road Planning;

Local road planning creates a geometric path from the start to the target position of the vehicle. This process is usually done in a limited range in real time as time complexity increases depending on the length of the path. Struggles to create collision free roads, taking into account the limitations of the car [2].

#### d) Motion Planning;

Motion planning allows the vehicle to determine an optimized trajectory with dynamic constraints. But the local planning process can be time consuming and require low updating. The motion planner optimizes the trajectory by considering information on obstacles. A higher update rate may be required for security [2].

## 4. AUTONOMOUS VEHICLE PILOT STUDIES

### 4.1. Autonomous Vehicle Hercules Study

Since the beginning of 2020, 2019 coronavirus disease (COVID 19) has spread rapidly around the world. To prevent transmission of the virus from person to person, a controllable approach is required by discontinuation of contact. To alleviate this situation, the idea of minimizing contact has emerged by using autonomous logistics tools. These types of vehicles reduce the risk of virus transmission with the need to contact drivers and customers. These demands have been a motivator for the development of the Hercules logistics autonomous vehicle. Within the scope of this study, tests in Table 1 were carried out in three different cities [2]. As a result of pilot studies, 9.6km of vegetable distribution in Zibo city, 1.2km of food in Suzhou city delivery and 1.6km of food delivery in Shenzhen city. With this work the future data to shed light on autonomous vehicle study have been obtained.

**Table 1.** Evaluation of the autonomous vehicle Hercules

Cities	Task	Distance (m)	Duration (min)	Load (kg)	Conditions
Zibo	Vegetable Delivery	9600	75	600	Light Traffic
Suzhou	Food Delivery	1200	30	80	Light Traffic
Shenzhen	Food Delivery	1600	20	64	Heavy Traffic

### 4.2. Logismile Study

Within the scope of the study, Pluto and Ona autonomous vehicles were tested in three different cities in different conditions. This study was conducted to examine different use cases and how autonomous vehicles can be integrated in different urban settings.

Pluto, is used to move high capacity packages from a warehouse to a specific service area, creating large scale economies. The long range and high travel speed of the autonomous vehicle (AV) make it possible to operate on metropolitan highways.

Ona, is responsible for making final deliveries to its recipients. Smaller capacity of about 1m<sup>3</sup> due to this vehicle, it is more flexible to busy city centers where access regulations can be for AV and it becomes appropriate. Unlike other current concepts, it includes different types of sensors for navigation multiple delivery tool [7].

#### **a) Pilot City in Germany : Hamburg**

Hamburg's goal is to quickly transition to a model city that focuses on making mobility safer, more efficient, more comfortable and climate neutral for everyone in and around the city centre. Thanks to its characteristics, Pluto is less dense and perfectly suited for rural areas. The Port Authority of Hamburg is used as a testing and development area of unmanned systems. The vehicle has successfully automated driving using proper planning algorithms to ensure the maneuverability required in a narrow driving environment. A total distance of more than 17 km has been covered, highlighting the use capabilities of Pluto in more complex scenarios [7].

#### **b) Pilot City in Spain : Esplugues**

The city divides municipal boundaries between a relatively flat region. This geographical distinction provides an advantage for testing autonomous robots within different urban settings. Part of the city is located within the Barcelona Low Emission Zone (LEZ), which may introduce some types of logistics vehicles in the future. City logistics focuses on reducing study costs, parking problems, emissions and traffic congestion, as well as providing more flexible and fast deliveries. The single lane 750 m track has been performed with a maximum speed of 30 km [7].

#### **c) Pilot City in Hungary : Debrecen**

The municipality of Debrecen aims to reduce vehicle traffic and promote sustainable transport. In particular, the focus is on the use of autonomous technologies such as Pluto and Ona to reduce the traffic of parcel service providers' vehicles. In the long term, it is aimed to remove traditional trucks from the city center. A 500 m test was carried out [7]. In the study phase, it was determined that deficiencies in the regulation of autonomous vehicles were a significant challenge. In particular, the issue of which transport category Ona will be classified creates uncertainty. This suggests that the decision making process is slow and complex.

### **4.3. Autonomous Truck Study**

South Korea is one of the countries with the highest level of preparation for autonomous vehicles and is autonomous significant research efforts are being made for trucks. Economic impact of autonomous trucks it has been studied and, in particular, the U. S. and the EU are expected to lack 800.000 drivers by 2030 years, which is it means labor costs will increase. Autonomous trucks, driver costs are significant it can reduce to a great extent, which accounts for about 40% of total costs. Using cost benefit analysis and scenario planning, the impact of

different types of autonomous trucks on operating costs and cost estimates of various scenarios has been investigated. The route is 57 km long with a speed limit of 90 km/h and includes intermittent and continuous flow intersections [9].

### Five Scenarios;

In the 1950's, Kahn pioneered the scenario planning approach. This work embraces scenario planning as a method of recreating the imagination of potential futures. The basic scenario focuses on the interpretation of the results, as it corresponds to the real world situation. Scenarios take place at a point where autonomous truck technology is widely available.

Some assumptions have been made for the analysis: it has been assumed that the connection between the cost components will remain stable, there will be no downtime in the transport or logistics processes, and the economic effects of autonomous trucks will be the same in different scenarios [9]. While the base case scenario is the expected optimum as shown in Table 2, the evaluation is made on the best and worst results.

**Table 2.** The overall change in the total operating cost caused by autonomous trucks

Variables	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
	The Most Pessimistic	Pessimistic	Main	Optimistic	The Most Optimistic
Vehicle Driver	-%100	-%100	-%100	-%100	-%100
Vehicle Acquisition	%25	%10	%5	-%10	-%25
Driver Insurance	-%100	-%100	-%100	-%100	-%100
Vehicle Insurance	%0	-%5	-%10	-%15	-%20
Vehicle Maintenance	%25	%10	%0	-%10	-%25
Fuel Consumption	-%10	-%15	%0	-%20	-%25

While driver cost is ignored in all scenarios, it has been acknowledged that autonomous trucks will require costs for new technologies. When making changes to the cost of vehicle acquisition, fuel consumption is assumed to decrease in all scenarios. While Autonomous Trucks will eliminate driver insurance and change maintenance costs, other expenditures are considered to remain constant [9]. The findings indicate that even if the process continues over the most pessimistic, autonomous trucks can contribute to cost reductions and economic productivity for logistics companies. A decrease of up to 47% in costs is foreseen.

#### 4.4. Autonomous Cargo Ship Study

Due to intense logistics competition, the recent rise in transport costs has led to a reduction in the number of crew members to ensure cost competitiveness, making it difficult for transport companies to manage. Also, the difficulty of the crew in providing poor working environment and sailors with professional capacity is so serious that 85% of the maritime accidents are due to man made disasters. Therefore, the demand for autonomous cruise and automatic control technology to operate the ship economically and safely is increasing [10]. The autonomous ship in Figure 5 is based on the periodically uncrewed ship (PUS), defined in the Norwegian autonomous ships forum.



**Figure 5.** Norwegian autonomous freighter [10].

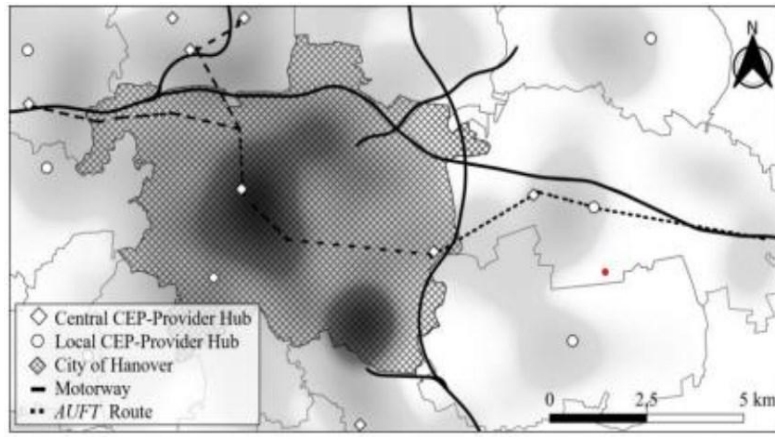
The methods of study and control of autonomous vessels can be broadly divided into three categories. The ship is located at the entrance and exit of the port by remote control with an operator. It travels autonomously through the entire process from the port exit to the next port. China has launched an unmanned freighter development association within CSIC and aims to establish technical standards under the leadership of CCS.

Japan is partnering with Smart Ship Application Platform equipment manufacturers, shipyards, shipping companies and ship classification organizations that it launched to set standards for information exchange between ships and coasts. In Europe, the creation of the concept of unmanned ships through automated maritime studies called Munin and the development of fully unmanned automated ships by 2035 are encouraged.

Rolls Royce encourages the development of a remote-controlled ship and an autonomous ship capable of navigating the ocean in 2035, while Yara Birkeland and Kongsberg are jointly promoting the commissioning of unmanned autonomous vessels aimed at replacing approximately 40,000 trucks per year in fertilizer transport on the Norwegian Coast [10].

#### 4.5. Autonomous Underground Vehicle Study

The rapid increase in the number of packages in urban areas and the delivery flights accordingly increased the importance of urban freight transport traffic. Agent based transport models have provided the opportunity to examine this increase in more detail. Automated underground freight transport systems can make the supply chain more efficient by reducing city traffic and road traffic. However, the effects of these systems on urban traffic flows have not yet been fully studied. This study analyzes the daily travel distances and kilometers of delivery traffic of a freight transport service through a simulation case study as shown in Figure 6 [4].

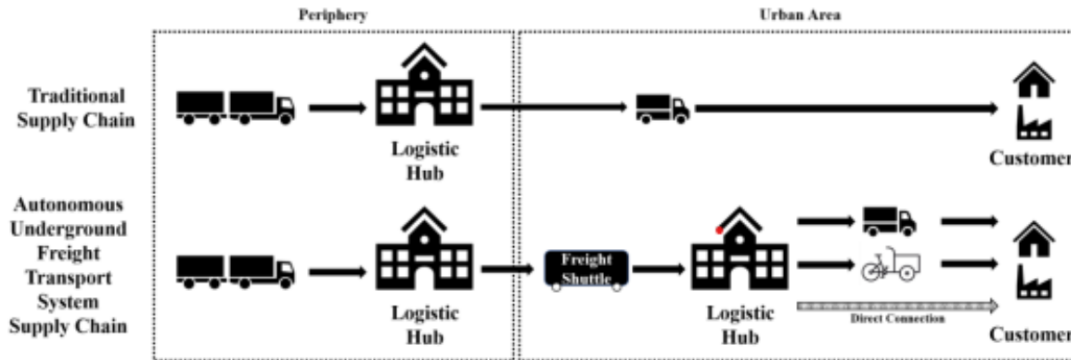


**Figure 6.** Planned Route of Autonomous Underground Cargo Handling (AUFT) System [4].

The Cargo Sous Terrain (CST) study from Switzerland has a modular, intermodal structure and uses autonomous vehicles as cores. CargoCap and Smart City Loop, one of the systems developed in Germany, also attract attention. Autonomous vehicles are independent, providing complete guidance in the tunnel system, separating the freight transport part from other traffic. Various loads are transported in tunnels using electric and autonomous vehicles. In centers located outside the city center, cargo is transferred from trucks to the underground system [4].

Autonomous vehicles contribute to the cargo handling service by carrying out cargo deliveries on time. The last mile carriers offer delivery requests to operators, and operators ensure that the cargo reaches the destination point in accordance with these requests. Industrial and retail studies are carried out directly with the freight forwarding service. Planned deliveries are arranged at specific time intervals, and last mile vehicles expect the cargo to reach the destination. Three separate simulation studies were performed for each scenario and average results were obtained. Simulations have demonstrated the advantages of autonomous logistics infrastructure in terms of traffic and operational planning compared to mixed traffic, as shown in Figure 7. Compared to passenger traffic, especially in the existing road infrastructure, it has been seen that the traffic density can be reduced with the autonomous logistics infrastructure

of Autonomous Logistics Infrastructure (OLA). However, it was determined that the impact on overall traffic was marginal and that a reduction of 1% to 5% in freight traffic volume was achieved.



**Figure 7.** Comparison between a traditional supply chain and an autonomous transport system supply chain [4].

Given that the loading and unloading studies are not included in the model, it can be considered that the actual impact of the saved trips may be higher than predicted. It has been estimated that operating costs may increase as the creation of new underground infrastructure will require significant investments. It has been calculated that the number of large vehicles used in OLA will not reduce operating costs, and may even reduce them by 0.5% to 1.2%. In the concept developed, it is stated that the use of relatively small capacity centers in the city center has small positive effects on traffic flow and volumes. However, it has been emphasized that whether these positive effects exceed high costs will be determined by economic studies. OLA is said to provide advantages in cooperation of different players in terms of environment and city life and increased use of cooperation with increasing efficiency. In future research studies, it is stated that the total architecture and processes of OLA will be discussed in more detail in the model [4].

#### 4.6. In Factory Autonomous Transport Vehicle Study

A North Portugal based automotive company that produces tires has focused on 3 action points in the study developed in line with the company's target on autonomous vehicles [1].

- Inspection of internal processes related to the transportation of products and semi products,
- To evaluate the different technologies available in the market for autonomous transport of goods,
- Evaluation of Autonomous vehicle application potential in one of the internal logistics areas of the company (pilot study),

The process began with the identification and examination of internal material flows. The starting and destination points, the tasks carried out for the characterization of the transport

system, the cargoes carried and other relevant data are defined, but not all logistics processes are suitable for autonomous vehicles. For this reason, it was determined which studies are most prone to and the following criteria for autonomous [1].

- There must be repetition and routine,
- Human error sensitive processes should be considered and safety improvements should be prioritized,
- Digital processes should be processed,
- Processes with high volume and high priorities should be taken into account,

After the evaluation, the warehouse, which is selected as the most suitable for the criteria, was selected as a case study and pilot study to prove the concept of autonomous transportation. A case study was conducted on the use of autonomous vehicles instead of forklifts used manually for transporting products. This study includes issues such as estimating the required number of autonomous vehicles, restructuring new logistics flows and layout plan. It is also necessary to identify the pre requisites for assessing the potential of autonomous vehicle suppliers flows [1].

- **Process** : Whether the process will lose its validity in the future. How long the investment can remain valid.
- **Infrastructure** : Based according to this system of the factory and the personnel.
- **Finance** : Autonomous vehicles require high initial investments, so the availability of this investment must be assessed.

Management of logistics flows directly affects the performance of the overall system. In the second step, it is aimed to select collection and delivery locations, which aims to reduce the distance traveled. However, due to the distance of the delivery location, the delivery point needs to be reevaluated. The delivery location is located about 83 m from the Workstation.

It has been noticed that autonomous vehicles move more slowly and generate traffic due to the failure of security systems to capture the process speed. In this case, the proposed solution is to create a different location for autonomous vehicles to distribute loads and to ensure smooth running of logistics flows by separating their routes from forklift routes. Thanks to the proposed new logistics flow for autonomous vehicles, the, autonomous vehicles will only travel 83 m instead of a distance of 16 m [1].

As shown in Figure 8, The number of autonomous vehicles was limited to 8 because more than that would disrupt proper functioning. It creates bottlenecks in the functioning of the system. The simulation allowed to determine that it would be impossible to drive only 1 vehicle due to the system efficiency. During the period of the study, it can be expected that at least 8 movements can be guaranteed in 216 hours of production. The number of 3, 5 and 8 autonomous vehicles has met the required efficiency and provided more movement than expected.

Scenario		Replications		Controls	Responses						
<input checked="" type="checkbox"/>	Name	Status	Required	Completed	NoAGVs	AGVs_UtilRate	C_Output	D_Output	E_output	F_Output	Total_Pallets_Moved
<input checked="" type="checkbox"/>	Scenario1	Idle	10	10 of 10	1	99,0678	33	33	31	29	126
<input checked="" type="checkbox"/>	Scenario2	Idle	10	10 of 10	3	88,0757	75	70	56	46	247
<input checked="" type="checkbox"/>	Scenario3	Idle	10	10 of 10	5	78,185	78	71	56	44	249
<input checked="" type="checkbox"/>	Scenario4	Idle	10	10 of 10	8	67,7711	81	72	56	44	253

**Figure 8.** Results obtained by simulating the autonomous vehicle system using Simio software for a period of 8 hours [1]. (NoAGVs: Number of vehicles, AGVs\_UtilRate: System utilization rate, C/D/E/F Output: Number of pallets carried, Total\_Pallets\_Moved: Total number of pallets carried)

However, the higher the number of autonomous vehicles, the higher the investment, and the less interesting the study is. So when we look at the usage rate, it seems that 3 autonomous vehicle scenarios 2 will be enough to perform the task [1]. As a result, this study identifies and synthesizes relevant literature on autonomous vehicles, providing an example from the real world.

## 5. MATERIAL AND METHOD

### 5.1. Electric Autonomous Bus Study

Today, more than one billion conventional vehicles have met the need for mobility and continue to be an important research topic due to their environmental impacts and the loss of life and property in traffic accidents. In this context, autonomous vehicles have emerged as an important innovation. Autonomous vehicles operate using sensors that can detect light and distance, high-frequency vibrations, and map their surroundings. These sensors provide the sensory input the vehicle needs and enable the data to be converted into a specific route through software applications. In this way, the vehicle's acceleration and braking systems are activated, allowing the autonomous vehicle to follow the desired route. Artificial intelligence algorithms have made it possible to perceive the environment and take action by making appropriate choices for various situations.

In the abstract of this work, the Güteryüz R&D Center aimed to produce 8.5 m electric autonomous buses, as seen in Figure 9. At this level, the system could manage emergencies independently, but could also request drivers to take over when necessary. Passengers could check their phones or watch a movie, knowing that the system could handle emergencies.



**Figure 9.** 28 feet (8.5 m) Electric autonomous bus

## **5.2. Identification of Requirements**

Autonomous vehicles are continuously improving in line with evolving technology and user needs. Autonomous driving is defined by five levels, with Level 4 vehicles providing high automation by determining their operational position. Equipped with features such as automatic lane changing, these vehicles ensure continuous driving even when the driver's eyes are closed. The potential benefits of autonomous vehicles include lower costs, increased safety, enhanced mobility, and higher customer satisfaction. Additionally, a reduction in traffic accidents and, consequently, lower insurance costs are expected. These vehicles are also anticipated to improve traffic flow and provide greater mobility for children, the elderly, and people with disabilities. However, challenges arise when artificial intelligence encounters complex scenarios, such as maintaining eye contact with drivers or dealing with suddenly appearing objects. Furthermore, there is a risk that sensors may fail to gather information in adverse weather conditions. Therefore, the development of sensors capable of adapting to harsh conditions is considered crucial for the future of autonomous vehicles.

## **5.3. Scope of Work Tasks and Actions**

### **a) Integration of Electric Components and Transfer Bodies;**

The parameter values of the electrical and mechanical components to be used in the vehicle were analyzed and the electric motor selection and integration were carried out. The powertrain was integrated with an axle suitable for the electric vehicle. The drive system

consisted of a combination of an electric motor, shaft and differential, and in this context, the connections between the electrical components were established.

#### **b) Energy Storage System;**

The electric autonomous vehicle management system and control unit worked in an integrated manner with the battery energy storage system. The energy consumption values of the existing internal combustion engine buses were analyzed, and energy consumption was measured along the vehicle route. In this context, 1 km of energy required 1.036 kWh therefore, a suitable storage system was designed. Battery capacity, vehicle weight, and range were determined by considering the requirements, and battery packaging design was realized in cooperation with battery manufacturers. Additionally, energy wiring design was created through current calculations, and the battery management system was communicated with the vehicle management system via CanBus protocols. The battery cooling system was designed using air conditioning R134A gas to cool the battery. The optimum position of the cooling system was determined to achieve maximum and long-term performance from the battery.

#### **c) Electric Vehicle Systems and Integration;**

The regenerative braking system is integrated with the hydraulic brake mechanism. In this system, the electric motor acts as both a motor and a generator, charging the batteries. When the pedal is released, the motor can switch to generator mode during the vehicle's deceleration and charge the batteries. An inverter system that can perform DC/AC and DC/DC conversion is needed to use the engine and other electrical systems in the vehicle. While electric motors provide an additional advantage by recovering energy during stopping, this requires an additional power pack to operate the hydraulic, pneumatic and air conditioning systems in the vehicle. For this reason, the integration of the vehicle's auxiliary systems has been carefully planned.

#### **d) Integrating the Systems Needed for Autonomous Driving;**

The Lidar system enables the vehicle to detect the distance of objects or surfaces in front of it using laser pulses. In this context, Lidar connections were established and detection accuracy was evaluated. The camera system is equipped with interior and exterior cameras to support the vehicle's surroundings and this system is integrated into the vehicle's CanBus system. The radar system, positioned at the front, rear, and sides of the vehicle, supports the Lidar system and contributes to the perception of environmental effects, as shown in Figure 10. Directional perception and vision screens were positioned and necessary integrations were made to display all detection and guidance systems integrated into the vehicle. With Drive by Wire integration, the electric motor was integrated into the steering box and the functions of the engine were determined. This system facilitated the vehicle's direction in sudden maneuvers. All these systems were evaluated in terms of in-vehicle wiring and positioning and the most applicable solutions were determined.



**Figure 10.** Integration of Lidar and Camera verse into vehicle superstructure (Camera at the top, Lidar at the bottom)

#### e) Electric Autonomous Vehicle Management System and Control Unit;

Data transfer between components enables instant communication and interactive operation of infrastructure elements such as engine, battery and vehicle management system via information communication technologies (CanBus). The driver's dashboard is programmed by determining Can addresses according to the functions of the electric vehicle and autonomous driving. The vehicle control unit is responsible for engine management and necessary controls. This unit constantly monitors the operating conditions of the engine, calculates the instantaneous battery status, performs its controls with the data it receives from the sensors and determines the parameters in the vehicle. The calculated data (vehicle speed, engine speed, battery status, etc.) is transferred to the multiplex system and reflected on the driver's dashboard. Using the data from the Lidar and radar systems integrated for autonomous driving, the system is programmed to decide which movements to make. The vehicle produced as a study output was tested on a specified route at the University of Buffalo campus in the USA and further developed throughout the process. The company aims to increase its exports by 10% in the American market and 15% in the European market with the purchase of this vehicle type. As a result of the study, it was planned to produce 8.5 m electric autonomous city buses that can compete at an international level.

## 6. FINDINGS AND DISCUSSION

### 6.1. Autonomous Driving Solution

In recent years, autonomous driving technologies have been extensively researched. However, conditions in irregular traffic environments are more challenging. In these environments, there are often various traffic participants, such as pedestrians, bicycles and cars, and these participants may not necessarily follow traffic rules. Due to the size of the urban population in China, urban residents often live in apartments. This means that the population density around apartment complexes is high. Autonomous vehicles such as those in Figure 12 may encounter

complex interactive objects such as automatic barrier gates, pedestrian crossings, bicycle riders in apartment environments [3].



**Figure 12.** Typical scenario reflecting the complexity of moving vehicles [3].

Figure 13 has various traffic participants such as bicycles, electric bikes, motorcycles on urban roads. Each has its own kinematic characteristics. Some drivers may use their vehicles in unusual, unsafe or illegal ways.



*a.*

*b.*

**Figure 13.** Typical scenarios reflecting the complexity of moving vehicles [3].

**a.** Crowd and irregular transportation   **b.** Dangerous and unsafe transport

Traffic congestion in cities such as Figure 14 has become inevitable with increased motor vehicle ownership. Autonomous driving technologies can solve this problem by focusing on complex traffic conditions [16]. However, existing solutions need to adapt to these challenging conditions. The safety of autonomous vehicles is a top priority in the

development and maintenance process, and specific safety standards for delivery vehicles must be set. Alternative solutions must be found without hindering traffic flow [3].



**Figure 14.** Typical traffic scenario reflecting the complexity of moving vehicles [3].

## 6.2. Challenges Local Governments Will Face in the Implementation Phase

Although smart transportation will take a big place in future urban transportation in Türkiye with its developing technology and information communication infrastructure, the applicability context needs to be handled carefully [13]. In an order where globalization and international competition are at the forefront, there are challenges that local governments will face in the implementation phase in the field of multimodal transportation that will be reconsidered with the smart mobility approach. To explain these challenges briefly [6].

- Legal and administrative deficiencies; in the field of smart transportation, the legal framework in Türkiye, especially in the field of autonomous vehicles, individual mobility and applicability in terms of legislation, insufficient institutional and individual awareness, moreover, the absence of a commonly defined terminology,
- Application problems; inadequacy in domestic production in software and hardware, lack of short term and long term planning, integration problems of smart vehicles and smart transportation infrastructure, etc,
- Problems of governance; lack of coordination between university industry institutions and organizations, absence of a common intelligent transportation system,
- Maintenance problems; due to high costs, the problem of acquiring maintenance repair and new products, dependent on the outside on technology,

- Lack of qualified human resources; lack of specialized personnel in institutions and insufficient R&D studies, as an example.

The question of which category of transport to classify autonomous vehicles creates uncertainty. This suggests that the decision making process is slow and complex. Current EU rules may be a starting point for different countries, but they may take time to adapt [7].

## 7. CONCLUSION

The combination of autonomous vehicles and intelligent transportation systems leads to fundamental changes in the transportation sector. Autonomous vehicles combine with advanced technology in intelligent transportation systems, allowing logistics activities between cities and countries to be carried out in a fully autonomous way. However, various challenges are being faced for the dissemination and successful application of these technologies. In this direction, what we should do and what should be taken are explained with 10 important steps.

- The future of transportation and the potential of autonomous vehicles and intelligent transportation systems are leading to fundamental changes in the transportation sector. These technologies offer significant opportunities in areas such as traffic management, safety and transportation efficiency. In order to fully realize the potential in this field, more investments must be made and advanced technological research should be supported. Integration of autonomous vehicles and smart systems can reduce traffic accidents, ease traffic congestion and improve transportation efficiency. However, further development is needed technologically and infrastructure to fully realize this potential.
- Data security and privacy, together with the use of autonomous vehicles, is the subject of the production and processing of large amounts of data. The security and confidentiality of this data is an important issue. Strong data protection policies need to be established. In addition, effective measures must be taken against data breaches and cyber attacks. However, in order to ensure the protection and confidentiality of users' personal data, legal regulations need to be updated and appropriate security measures should be taken. In this way, by reducing the concerns of autonomous vehicles about data security, users can be assured to trust this technology.
- The possibilities in the logistics sector can provide great benefits in the logistics industry with autonomous vehicles. This technology can shorten delivery times, reduce costs and allow deliveries to be carried out more efficiently and reliably. However, in order to fully evaluate this potential, necessary research and studies in the sector are required. These studies will guide the industry by determining how autonomous vehicles can be most effectively used in logistics processes.

- Its role in e-commerce, especially in the field of e-commerce, autonomous vehicles can play an important role in delivery services. However, more R&D work needs to be done in order for this technology to become widespread and to be used effectively. With these studies, the potential of autonomous vehicles in the e-commerce sector can be evaluated more effectively and delivery processes can be made faster, safer and more efficient.
- Future goals and responsibilities should focus on technological innovation and cooperation for a safer, more efficient and more sustainable future in the transportation sector. In order to achieve these goals with the decisions to be taken at both individual and institutional level, regular communication and cooperation between sector stakeholders must be ensured. In addition, research and development activities should be supported and incentives should be created for innovative solutions. In this way, more solid and sustainable steps can be taken towards the future of the sector.
- Reinforcement of legal infrastructure should include clear and consistent regulations on the use of autonomous vehicles, classification, driverless cruise permit and responsibilities. The creation and strengthening of these regulations are critical to the proliferation of technology. In this context, it is necessary to establish a clear and consistent framework by regulatory bodies and to strengthen the infrastructure, because the challenges faced with technological advances can only be overcome in this way.
- Considering environmental impacts, along with the proliferation of autonomous vehicles, it is important that environmental impacts are not ignored. The impact of these technologies on environmental sustainability needs to be assessed and minimized. In this context, various studies should be carried out to promote green transportation strategies. These include measures such as increasing the use of electric and hybrid vehicles, ensuring energy efficiency and reducing the carbon footprint. In this way, the environmental impact of autonomous vehicles can be minimized and a sustainable transportation system can be contributed.
- With the proliferation of education and awareness, autonomous vehicle technology, education and awareness are of great importance for the society to adapt to this technology in a proper way. In this context, accurate and safe use of technology should be encouraged through information and training programs for drivers and other road users. In this way, the potential benefits of autonomous vehicles can be realized more effectively and their acceptance in society can be increased.
- Setting safety standards, setting and implementing international standards for the safety of autonomous vehicles are extremely critical. It is necessary to support the necessary work to ensure the hardware and software security of these tools. Further research on the safety and reliability of autonomous vehicles is also important, as this research will lay the foundation for increasing the safety standards of the technology.
- It is important that society accepts and embraces this technology, along with the adoption of social acceptance and ethical issues, and the spread of autonomous

vehicles. For this reason, taking into account the ethical and social dimensions of autonomous vehicles, it is necessary to ensure social acceptance and address ethical issues. In this direction, communication and education should be carried out with the public.

- Public should be given clear and transparent information about the benefits and potential risks of autonomous vehicles, and awareness-raising activities should be organized on ethical standards and safety measures. In this way, the society can approach autonomous vehicle technology from a more positive perspective and use this technology with confidence.

As a result, autonomous vehicles and intelligent transportation systems are initiating a significant transformation in the transportation sector. However, in order for this transformation to be successful, many factors must be taken into account in terms of technological, regulatory, social and security. The steps in this direction can lead to significant progress towards a safer, more efficient and sustainable transportation future.

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## **CONFLICT OF INTEREST STATEMENT**

The authors acknowledge that there is no known conflict of interest or common interest with any institution/organization or person.

## **RESEARCHERS CONTRIBUTION RATE STATEMENT**

In determining conceptual processes, data collection, data analysis and drafting of articles, Çınar Akın AK, in the critical examination of intellectual content, Koray ALTUN, management of conceptual processes, and, Hasan ŞAHİN contributed to the final approval and full responsibility.

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