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Exploring the evolution and future trajectory of transportation technologies

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Abstract

The need for people to relocate due to the environmental difficulties they experienced centuries ago gave birth to the concept of transportation; It has become one of the indispensable needs of people such as food, drink, health and shelter. In order to meet this displacement requirement, various tools have been developed and used according to the continental or marine characteristics of the Earth, and the need for transportation has continued to develop dynamically and become an integral part of our daily lives. In this study, the development of the need to relocate, which is among the basic needs, from past to present under the umbrella of transportation, its technological evolution and popular demand factors were investigated. As a result of the study, it has been reached that electric vehicles have become popular in the 21st century with the increase in urban population, people's demand for individual transportation vehicles and the development of sustainable energy-based fuel technologies. Urban air mobility solutions, including electric vertical take-off and landing (eVTOL) aircraft and drones, have the potential to relieve congestion on roadways and offer efficient transportation options for urban commuters. Additionally, autonomous and connected vehicles have the potential to optimize traffic flow and reduce congestion, thereby improving the energy efficiency of transportation systems. However, more concrete and quantitative comparisons are required to determine their impact on fuel consumption.

Keywords: *future transportation modes, sustainable transport, innovation, autonomous vehicles, flying cars, eVTOL.*

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Ulaşım teknolojilerinin evrimini ve gelecekteki yörüngesini keşfetmek

Öz

Yüzyıllar önce insanların yaşadıkları çevresel zorluklar nedeniyle yer değiştirme ihtiyacı, ulaşım ve taşımacılık kavramını doğurmuş; insanların yeme, içme, sağlık ve barınma gibi vazgeçilmez ihtiyaçlarından biri haline gelmiştir. Bu yer değiştirme ihtiyacını karşılamak için yeryüzünün karasal veya denizel özelliklerine göre çeşitli araçlar geliştirilerek kullanılmış ve ulaşım ihtiyacı dinamik bir şekilde gelişmeye devam ederek günlük hayatımızın ayrılmaz bir parçası haline gelmiştir. Bu çalışmada, temel ihtiyaçlar arasında yer alan yer değiştirme ihtiyacının ulaşım çatısı altında geçmişten günümüze gelişimi, teknolojik evrimi ve popüler talep faktörleri araştırılmıştır. Çalışma sonucunda, 21. yüzyılda kent nüfusunun artması, insanların bireysel ulaşım araçlarına olan talebi ve sürdürülebilir enerji temelli yakıt teknolojilerinin gelişmesi ile elektrikli araçların popüler hale geldiği sonucuna ulaşılmıştır. Elektrikli dikey kalkış ve iniş (eVTOL) uçakları ve dron'lar da dahil olmak üzere kentsel hava hareketliliği çözümleri, karayollarındaki tıkanıklığı hafifletme ve şehir içi yolcular için verimli ulaşım seçenekleri sunma potansiyeline sahiptir. Ayrıca, otonom ve bağlantılı araçların, trafik akışını optimize ederek ve tıkanıklığı azaltarak ulaşım sistemlerinin enerji verimliliğini artırma potansiyeline sahip olduğu belirtilmiştir. Ancak, bu potansiyelin yakıt tüketimine etkisi konusunda daha somut ve nicel karşılaştırmalar yapılması gerekmektedir.

Anahtar kelimeler: *geleceğin ulaşım modları, sürdürülebilir ulaşım, inovasyon, otonom araçlar, uçan arabalar, eVTOL*

1. Introduction

The need to relocate has been among the basic needs of societies such as nutrition, shelter and treatment since the existence of humanity and will continue to exist today and in the future.

As the developments experienced have been kneaded with transportation requirements, the vehicles used have diversified and have been put into the service of people according to the geographical characteristics of societies and the raw materials used for fuel. The study examines the means of transportation developed and used from the past to the present.

In addition to the diversity of transportation vehicles according to where they are used, it is obvious that they have also developed with the fuel technology they need. Due to the limited availability of non-renewable fuels and fossil-derived fuel resources and in order to leave a livable world heritage for our future, technological studies for the development of sustainable transportation vehicles have gained momentum, especially in the 21st century. In addition, demographic characteristics, increasing demand for urban living spaces and global epidemics have recently led to an increase in the need for individual transportation.

In parallel with the global increase in interest in transportation vehicles that are both suitable for independent use, have renewable energy-based fuel technology, and are cheap and easily accessible. For this reason, the need to address this issue has arisen and the research conducted at this point have been the subject of the study to investigate the future of the technologies offered at this point and to determine the steps that can be taken to determine the needs of the supply-demand needs and to determine the steps that can be taken to develop them.

After introduction given in Chapter 1, the paper is organized as providing some background information in Chapter 2, and the methodology used in Chapter 3, presenting research findings in Chapter 4. Conclusions are given in Chapter 5.

2. Background

The fact that people started transportation on foot, followed by animal-drawn vehicles and finally the use of public transportation vehicles is a sign that the history of road vehicles is very old and still widely used. Since the provision of transportation in areas connected to water such as oceans, seas and lakes, which are natural formations, does not require any infrastructure investment, it can be said that the history of maritime transportation vehicles dates back to ancient times, just like road transportation vehicles. Railway transportation vehicles, which are connected to the land and move on the rail system developed instead of roads, started to be used in later times thanks to the technologies developed due to the high infrastructure, maintenance and operation processes and costs compared to road and maritime vehicles. At first glance, it was thought that the emergence and development of airline transportation vehicles would be rapid. However, the perception that transportation activities in the world would be limited to inter-city transportation from the earliest times led to the idea that there was no need for airline transportation vehicles. The geographical discoveries in the world, the discovery of new countries, the increase in scientific and technological activities, and especially the distances between countries and continents have led to the need to accelerate these transportation activities. As a result, the use of airline transportation vehicles has become widespread.

Today, the use of road, airway, maritime and railway vehicles and technologies, which constitute the transportation sectors, has made it possible for people all over the world to access almost every point. From ancient times until today, both the change in settlement patterns, modern urbanization or the diversification of needs have been met with the benefits offered to people by today's transportation technologies.

The most important development in the history of means of transportation was the invention of the wheel. The invention of the wheel was made by the Sumerians and dates back to approximately 3500 BC. In the first vehicles using the wheel, the wheel consisted of a single piece and did not have any rotational capability. From 2000 BC onwards, wheeled vehicles began to be widely used, especially in the Middle East, with the transition to fixed axles where the wheels could rotate separately. Approximately 5000 years later, wagons and carts pulled by oxen and horses were used [1].

The first steam train in the world was invented by Richard Trevithick in England in 1804. Then, in 1829, George Stephenson invented the steam engine locomotive called "Rocket" (Figure 1), which has a higher speed [2].

Figure 1. A working replica of the Rocket, a pioneering steam-powered locomotive invented by Stephenson in 1829 [3].

In 1876, Nikolaus August Otto invented the internal combustion engine technology that forms the basis of today's automobiles. In 1886, Carl Benz invented the first gasoline-powered automobile (Figure 2) [1].

Figure 2. The world's first gasoline-powered automobile invented by Carl Benz [4]

Kites, which date back 3000 years and were used in China, have been described as the inspiration for airline vehicles. The first usable means of air transportation in history was the hot air balloon built by the Montgolfier brothers in 1783. The first airship was built by Henri Giffard in 1852. The first motorized airplane (

Figure 3), which forms the basis of today's airplanes, was invented by the brothers Orville and Wilbur Wright in 1903 [5].

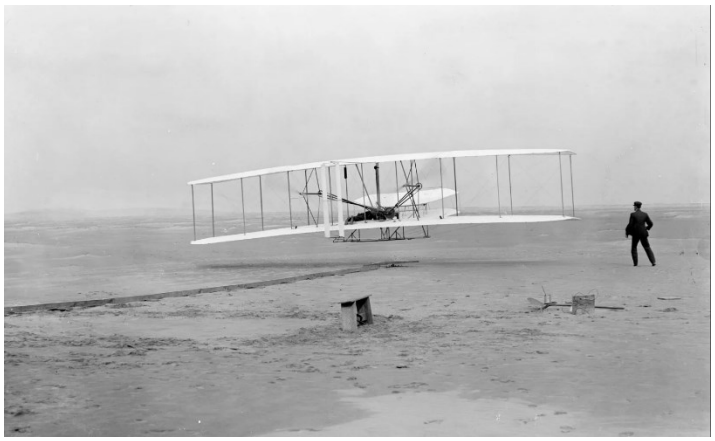

Figure 3. First flight by Orville Wright December 17, 1903 [6]

Since prehistoric times, people have used canoes and rafts as a primitive means of maritime transportation. The first known examples of ships are reed boats built by the Egyptians in 4000 BC (Figure 4). Reed boats, also called papyrus boats, were well-known in ancient Egyptian waters, both on the Nile and the Red Sea. Kuwait is home to the remnants of what is believed to be the oldest reed boat. The ends of the reed boats in Egypt were knotted together, giving them a unique shape. On Ethiopia's Lake Tana, reed boats were (and are) in use [7].

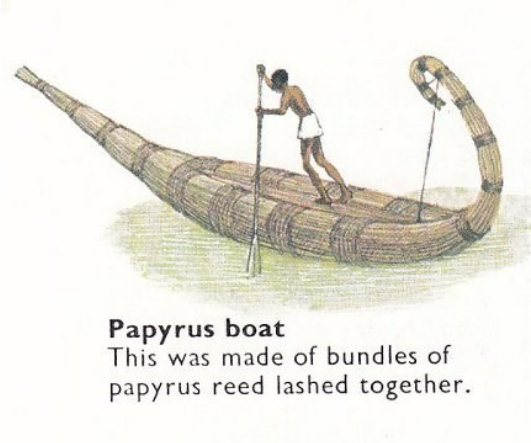

Figure 4. Image of the ancient Egyptian reed boat [7]

3. Methods

Countries have important responsibilities when planning the transportation technologies of the future. Issues such as the rate of population growth in societies in the future and the rate of increase in the elderly population, the changing attitudes and behaviors of young people towards transportation as a result of changing environmental norms, and the extent to which the digitalization of services, also known as digitalization, will reach will affect future transportation technologies as external factors. These factors can be further multiplied, but the biggest impact will be made by digitalization, which will have a major impact on the future mobility of passengers and businesses.

Some of the regulations that will reduce the need to travel with digitalization are some digital areas that will affect the need for labor force and mobility, i. e. transportation,

such as telecommuting, the internet of things, where many jobs and transactions are done over the internet by introducing objects. Although these issues are not the direct responsibility of governments, these impacts should be taken into account when planning future transportation technologies [8].

In this study, comprehensive research has been made on the history of the developments in transportation technologies and insights are presented for the future developments in transportation sector. Analyses were made based on available data in the literature and on the internet. In the scope of the study, there are several research questions to be investigated.

Research questions can be defined as follows:

- How was the transportation need emerged and how did the technology in transport evolved?
- What innovations and trends will shape the development of transportation systems in the coming decades?"
- How will advancements in technology impact the sustainability and efficiency of transportation systems in the future?
- How will emerging transportation technologies, such as vertical take-off and landing (VTOL) aircraft, impact urban mobility and travel patterns?

4. Research Findings

In order to reduce carbon emissions on the earth, it is a priority for European countries to pursue a transportation policy that shifts from road-oriented transportation to other transportation sectors such as maritime, railway and airline. It is also aimed to limit road freight and passenger transportation to shorter distances and to carry out individual transportation with technologies and systems that do not harm the environment.

Depending on the need for raw materials and resources, transportation technologies and vehicles develop according to the need for international mobility. It continues to evolve according to access to cheap labor, education, research or environmental factors.

4.1. Examples of innovative transport technologies

Produced by Sweden, the "Jetson One" aircraft has a helicopter-like appearance. This vehicle, which can be flown and operated by one person, can reach a speed of 102 km/h. It is stated that the all-electric vehicle can stay in the air for 20 minutes with a pilot weighing 85 kg (kilograms). It is expected that this vehicle will be widely used within 10 years by increasing the duration of its stay in the air [10]. Figure 5 below shows the electric motorized aircraft named "Jetson One".

Figure 5. “Jetson One” electric motorized aircraft [10]

Figure 6 below shows the airplane called "The Bird of Prey" by the "Airbus" company. Its most striking feature is its wings that resemble bird wings and its tail design, which is also of the bird tail type.

The development of the aviation sector in line with the goal of sustainable transportation will be possible with cleaner, greener and quieter air transportation vehicles. This aircraft is built on this principle. The aircraft, which can be used as electric and hybrid, is also known to operate very quietly. With a range of 1500 km, this aircraft is reported to be able to carry 80 people [11].

Figure 6. Bird-like passenger plane [12]

Figure 7 below shows a flying car called "Aircar" produced in Slovakia. The vehicle, which can transform from car to airplane and from airplane to car in about three minutes, is being studied to be able to travel on water in the coming years. It successfully completed its first cross-city flight test in June 2021. This flight lasted a total of 35

minutes. Capable of 190 km/h, this vehicle is expected to reach a speed of 300 km/h and a range of 1000 km after prototype-2 studies. Currently, the type-1 prototype can carry two people, including the driver. The vehicle has a parachute system against engine failure and runs on gasoline [13].

Figure 7. Flying car "Aircar" [13]

Unlike other existing trams, hydrogen fuel cell trams are propelled by the electric energy produced by the hydrogen fuel cell that is stored within. The fundamental technology of hydrogen vehicles is hydrogen fuel cells, which directly generate electricity through an electrochemical reaction between hydrogen and oxygen.

The hydrogen fuel cell tram (Figure 8) being developed by Hyundai Rotem employs a hybrid technology that combines a battery and a hydrogen fuel cell. Using hydrogen from a hydrogen tank, the hydrogen fuel cell generates electricity and stores secondary power in an energy storage system

Figure 8. Hyundai Rotem's hydrogen fuel cell tram [14]

(ESS), specifically the battery. While the energy from the fuel cell is utilized for operating at a constant pace or slowing down, the power stored in the battery is used when a lot of energy is needed, such as when starting the engine or increasing speed. The hydrogen fuel cell tram made by Hyundai Rotem has a 150 km range on a single charge.

4.2. Autonomous vehicles

Autonomous vehicles are defined as driverless, self-driving or robotic vehicles. They are vehicles that travel without a driver by managing their environment and route with

artificial intelligence. The first autonomous cars were produced in the USA and Germany in the 1980s [15].
Thanks to technologies such as cameras, sensors, GPS, radar, odometry, LIDAR (Light Detection and Ranging) and artificial intelligence, autonomous cars are able to detect objects in the area and move without the need for a driver [16].

The introduction of autonomous taxis and buses in urban transportation will lead to a reduction in operating costs. According to a study conducted in the UK, driver costs account for 40% of total operating costs of buses and 40-50% of total operating costs of taxis and rental cars [8].

By 2040, driverless private hire vehicles, taxis and Demand Responsive Transport (DRT) vehicles, i. e. autonomous paratransit vehicles, will start to perform public transport service tasks in the UK [8].

The concept called "Pop. Up Next", shown in Figure 9 is a joint design of "Audi" and "Airbus". Thanks to an autonomous unmanned aerial vehicle of "Airbus" and a passenger cabin that can be integrated into the chassis of "Audi", two passengers can be transported autonomously both by air and by land.

"Pop. Up Next" has an all-electric system. It is a concept vehicle system with zero carbon emissions, designed to reduce traffic congestion in crowded cities. "It was unveiled at the Geneva Motor Show. It can reach 150 km/h and has a range of 50 km in air flight. This range is considered quite sufficient for urban use [17].

Figure 9. Joint concept of autonomous car and autonomous aircraft [17]

Figure 10 shows Türkiye's first autonomous flying vehicle produced by Baykar, known as "Cezeri". It is designed for military and health sector use. "Cezeri", which can take off and land vertically, is reported to be able to stay in the air for 1 hour with a full battery. It has a speed of 100 km/h and a range of 70-80 km. This is considered sufficient for urban use. The flight cabin is designed to carry both passengers and cargo. It has a 2 km flight altitude.

"Cezeri", which operates entirely on electricity, is known to be environmentally friendly and very quiet. It is expected to relieve urban transportation in the coming years [18].

Figure 10. Türkiye's first autonomous flying vehicle [18]

Figure 11 shows the "iFLY", a single passenger autonomous flying taxi designed in the USA. The vehicle, which is fully electric and can take off and land vertically, also has a flight patent in the USA. The vehicle has eight electric motors. Users will be able to call the "iFLY" taxi with the "SKYBorg" application, which can be used on "Android" and "iOS" devices, and will be able to select the desired location and provide transportation. This vehicle has a parachute system just in case. In addition, if the battery level drops below a certain level, the taxi will be able to return to its departure location or land its passenger at a safe landing site [19].

Figure 11. Autonomous Flying Taxi "iFLY" [20]

Figure 12 shows the "EHang 216", a two-passenger autonomous aircraft produced in China. The vehicle, which can take off and land vertically and is fully electric with 16 electric motors, is known to have a range of 35 km when fully loaded with passengers. With this range, it is considered suitable for urban transportation. "EHang 216" can reach a maximum speed of 130 km/h. It can reach an altitude of 3 km and has a remote control mechanism in case of any security problems. Its electric battery can be fully charged in 2 hours. It has been subjected to hundreds of load flight tests, endurance tests, reliability tests, environmental tests, etc. , the first of which was conducted in 2016. As can be seen in

Figure 12, it is used as a fire vehicle by the Chinese fire brigade. It is known that this aircraft, which is the "F" type of EHang 216, can carry up to 150 liters of fire extinguishing foam. In emergency situations, it is essential not to be affected by traffic congestion and not to lose time in responding to fires in the city. Therefore, it is critical to use such fast, non-polluting aircraft that are not affected by traffic congestion in emergency situations [21].

Figure 12. Autonomous firefighting aerial vehicle "EHang 216" [21]

Today, unmanned aerial vehicles (UAVs) are increasingly being used in various sectors such as logistics, cargo, construction, agriculture, etc. , although they are mainly used in the military field. An example of these is shown in Figure 13 below.

"XC Heavy", an air freight transport vehicle designed in the USA, is fully autonomous and can take off and land vertically as it is equipped with unmanned aircraft technology. It is designed to transport containers on cargo ships and in ports in a cost-effective and fast way. It can operate as electric and hybrid. Although the maximum amount of cargo it can carry is not specified, it is designed to carry very heavy ship containers. ADF (Adaptive Ducted Fan) technology provides up to 30% energy savings, 35-40% more thrust and noise reduction [22].

Figure 13. "XC Heavy" unmanned aerial vehicle used for cargo transportation [22]

5. Conclusion

In recent years, with the global pandemic and climate crisis, it has been concluded that the use of vehicles powered by renewable energy and electricity, which have no negative impact on the environment and are more economical than fossil fuels, is increasing significantly. According to recent reports, global electric vehicle (EV) sales increased by 43% in 2020, despite the pandemic, reaching over 3 million units. Additionally, the share of EVs in global car sales rose from 2.5% in 2019 to 4.2% in 2020. In countries like Norway, electric vehicles now account for more than 50% of all new car sales, showing a clear trend toward greener transportation. Furthermore, the International Energy Agency (IEA) projects that the number of electric cars worldwide could reach 145 million by 2030, driven by both government incentives and technological advancements in renewable energy infrastructure. In this context, it is seen that studies on transportation vehicles using renewable energy sources, which are one of the future transportation technologies and especially designed in a way that will not disrupt urban transportation, continue. The studies conducted in the World countries on this subject were examined and the results were presented in this study.

The emergence of transportation needs can be traced back to the basic human desire for mobility and the necessity to overcome geographical barriers. Initially, transportation needs were primarily driven by subsistence activities such as hunting, gathering, and migration. As human societies evolved and settled into more complex civilizations, the need for transportation expanded to facilitate trade, communication, and the movement of people and goods.

The evolution of transportation technology has been a continuous process spanning thousands of years, marked by significant innovations and advancements. Early forms of transportation relied on human and animal power, such as walking, animal-drawn carts, and sailing vessels. These methods were limited in speed, capacity, and range, constraining the extent of human interaction and economic development.

The advent of the Industrial Revolution in the 18th and 19th centuries ushered in a new era of transportation technology. Steam power revolutionized land and sea transportation with the invention of steam locomotives and steamships, dramatically increasing speed and efficiency. This period also saw the construction of canals and the development of road networks, further facilitating trade and travel.

The 20th century witnessed unprecedented advancements in transportation technology, driven by the invention of the internal combustion engine and the proliferation of automobiles, airplanes, and trucks. These innovations revolutionized personal mobility and cargo transport, making travel faster, safer, and more accessible to a broader segment of the population.

In recent decades, advancements in electronics, materials science, and computer technology have further transformed transportation. The development of jet engines, high-speed trains, electric vehicles, and automated systems has pushed the boundaries of speed, efficiency, and sustainability in transportation.

Overall, the evolution of transportation technology has been shaped by a combination of societal needs, economic imperatives, and technological innovations. From humble

beginnings rooted in human necessity, transportation has evolved into a complex system of interconnected networks, enabling global trade, travel, and communication on an unprecedented scale.

The shift towards electrification and the use of sustainable energy sources such as solar, wind, and hydroelectric power will continue to gain momentum. Electric vehicles (EVs), including cars, buses, and trucks, are expected to become more prevalent as battery technology improves and charging infrastructure expands. Additionally, advancements in hydrogen fuel cell technology may offer another sustainable alternative for transportation.
The development of autonomous and connected vehicles promises to revolutionize the way people and goods are transported. These vehicles rely on artificial intelligence, sensors, and communication technologies to navigate roads safely and efficiently. Autonomous vehicles have the potential to reduce accidents, alleviate traffic congestion, and optimize transportation systems.

With advancements in drone technology and electric propulsion, urban air mobility is emerging as a potential solution to urban congestion and transportation challenges. Electric vertical take-off and landing (eVTOL) aircraft and drones could provide efficient, on-demand transportation within and between urban areas, reducing travel times and carbon emissions.

However, further research in this field is needed to deepen the understanding of the growing use of renewable energy and electric-powered transportation vehicles. Future studies could focus on comparing electric vehicles, hydrogen fuel cell technologies, and autonomous vehicle systems with more concrete data, conducting cost analyses, and quantitatively evaluating their impact on urbanization and transportation systems. Additionally, the potential applications of urban air mobility and eVTOL technologies should be explored in future research, examining their effects on urban traffic and carbon emissions. Such studies would contribute to more comprehensive solutions for improving the sustainability and efficiency of transportation systems.

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