Power System Technology
ISSN:1000-3673

Received: 06-04-2024 *Revised: 15-05-2024* *Accepted: 28-06-2024*

The Role of Autonomous Cars on Development of Smart Urban Space

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Abstract

The process of developing smart urban space as one of the most important challenges of contemporary society has started a new expansion with the arrival of autonomous cars as an effective and transformative factor. This article examines the essential and influential role of autonomous cars in the development of smart urban space. Therefore first, the concept of smart urban space as a comprehensive system that takes advantage of population gathering, information and communication technology, and intelligent management is examined. Then the issue of autonomous cars, which as one of the advanced technologies in the field of transportation, play a very important role in the development of smart urban space, are introduced. These cars have the ability to provide new solutions for traffic problems, creating trouble and improving urban security. Among the important components identified in the role of these cars, it can be mentioned that increasing productivity and reducing travel time, creating smart public transportation networks, and supporting sustainable and green movement in cities. Then, focusing on various components of the urban environment including transportation, traffic, safety and infrastructure, the role of autonomous cars in improving and optimizing these components is analyzed. This analysis includes examining positive effects such as reducing traffic and travel time, increasing safety and improving

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ISSN:1000-3673
Received: 06-04-2024 Revised: 15-05-2024 Accepted: 28-06-2024

access to public services. Finally, in this study, the components and analyzes necessary to identify the effective indicators of the role of autonomous cars in the development of smart urban space have been introduced. Therefore, it was shown that autonomous cars in the urban form were combined in three groups of principles, which include the impact on urbanization, influence on road infrastructure, and influence at the level.

Keywords: autonomous car, smart urban space, urban space

1. Introduction

In recent decades, with the advancement of technology and the introduction of autonomous cars into transportation field, the concept of smart cities as a new approach in urban space management has been highly regarded. As one of the great developments in this field, autonomous cars have the ability to provide new solutions to improve traffic, safety and sustainability in cities. In this regard, evaluating and analyzing the role of these cars in the development of smart urban space and identifying indicators affecting this role is a fundamental and necessary matter that has attracted the attention of researchers and decision makers in the field of urban planning (Julian, 2023). In this research, we investigate the role of autonomous cars in the development of smart urban space. By reviewing the existing literature and providing detailed analysis, we try to identify and evaluate the essential and effective factors on this role. Also, in this research, it is tried to examine the positive and negative effects of the presence of autonomous cars on traffic, safety, environment and the development of smart cities.

Hence, in recent decades, a significant increase in the number of vehicles worldwide is clearly evident. Approximately, the number of vehicles in 2015 reached about 1.3 billion vehicles, most of which were passenger vehicles. This growth is projected to double by the end of the 2020s or early 2030s as the upward trend continues. In the meantime, the presence of driverless cars or autonomous vehicles (AV) has been raised as an important topic of discussion in various forums as well as for governments and universities. The focus of more research is on the technical aspects of this technology, and its effects on urban spaces and the future of people's mobility have been less investigated. In other words, autonomous cars combined with sharing are likely to dramatically change the face of individual transportation and urban space over the next three decades. Research shows that autonomous car technology is developing and advancing rapidly. It is predicted that by 2040-2050, fully autonomous cars will enter the market in the world's largest cities. However, technical, political, legal, and economic issues related to this technology are still being discussed globaly. The presence of autonomous cars does not only affect people's daily trips, but its effects on the appearance and shape of cities can also be seen. Therefore, the effects of autonomous car technology on urban space and its architecture should also be investigated and analyzed (Abrar, 2020).

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ISSN:1000-3673

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This article examines the problems of introducing autonomous cars and its effects on urban form and architecture. Due to the rapid development of this technology, the changes made to cities and their spaces will be irreversible. Therefore, it is very important to know the consequences of the implementation of autonomous cars and prevent its negative developments. However, for now, the interrelationship between autonomous vehicles and the urban space and the corresponding urban infrastructure and platform should be explored in a more coordinated and bidirectional way. Cities are now facing many changes in their spatial structure and architecture after centuries of their initial structure. In this regard, long-term construction and urban development activities are considered as one of the most important stages of physical-spatial changes in the city. Changes in the urban spatial structure, especially in the development of trade, tourism, recreation and changes in urban infrastructure have had significant effects on the urban space. These changes were created and benefited by the increasing population and construction needs (Kili et al., 2018).

Much of the nature of the emergence of autonomous cars, whether this is an evolution or a revolution in the urban space, will gradually and soon become clear. But without a doubt, this technological progress is a revolution in the history of modernity. The long-term impact of this development on our daily lives, the safety of our citizens, and the environments in which we live and work, on our streets and in our metropolises, will redefine our society, and this impact will be greater than any other technology which has appeared before.

It is clear that the literature supporting autonomous vehicles is essential for smart and sustainable development. This research is one of the first efforts in the field of investigating the adaptation components of the texture and spatial structure of cities on the traffic and use of autonomous cars. It explains the effects of this technology on the urban space, the environment, sustainable urban development, the livability of streets and passages, the improvement of the urban landscape and visual factors, the effects on neighborhoods and different urban areas, and their mutual effects on each other. Until now, most of the studies have focused on the production and technical performance of autonomous cars, or their environmental or economic aspects have been researched at the level of the cars' performance. In this research, an attempt has been made to examine the way cars travel and the adaptation of the spatial structure and texture of cities, and to highlight the importance of street redesign in localities and the comfort of users, which has been neglected in previous researches.

In short, this research emphasizes that innovation, from the point of view of the possibility of using this emerging technology in existing cities or new cities, has important and extensive effects, including the well-being and comfort of users, improving the livelihood of city residents, affecting the quality of life, and is based on the dimensions of sustainable

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ISSN:1000-3673
Received: 06-04-2024 Revised: 15-05-2024 Accepted: 28-06-2024

development. This research aims to help achieve these components and provide solutions for better and more effective management of urban space and transportation in cities.

2- Theoretical framework

2-1- Theoretical definition of autonomous car

Theoretical basis related to autonomous cars are often based on legal definitions and technical concepts. For example, Section 8 of the Nevada State Code of 1988 defines an autonomous vehicle as a motorized vehicle that uses artificial intelligence, sensors, and a global positioning system to drive itself without the intervention of a human operator. This definition provides a basic basis for knowing the autonomous car and emphasizes its importance in determining the limits and characteristics of this type of vehicle. A autonomous car is known as a type of car equipped with an artificial intelligence system that allows moving between two places without the intervention of the driver. This concept is the basis on which driverless cars are seen as an example of technological advancement in the field of transportation. In this model, the main role of the human driver is in driving as recognizing and determining the destination, while artificial intelligence systems and sensors are used to control and manage driving operations. These theoretical concepts show that the autonomous car is not only a means of transportation, but also a representative of technological advances in the field of automobile manufacturing, which offers more facilities for the comfort and safety of passengers. In addition, these basic definitions emphasize the importance of more detailed analysis of the various effects and impacts of this technology in the field of urban space and transportation.

2-2- urban space

Urban space generally reproduces the general order of the human world (Rob Carrier), if we want to clarify the concept of urban space without imposing aesthetic criteria, we must consider all examples of the space between buildings in cities and other places as urban space. This space is geometrically surrounded by various symbols. It is only the revelation of its geometric features and aesthetic qualities that allows us to consciously consider the outer open space as an urban space. The two fundamental elements in this field are street and square (Jean-Pierre) More urban spaces inside or around cities are places specific to the social life of citizens, which include green and civil spaces, sidewalks, squares, and playgrounds. The use of these spaces is numerous and includes: traffic, recreation, play, meeting, etc. On the other hand, urban space as a platform for social functions plays a prominent role in facilitating these functions and campaigns related to it, which appear in the form of institutions, organizations, etc., and facilitates relationships and refines social construction. Since the urban space, by interfering in the facilitation and refinement of social construction,

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is generally involved with social strategies and sometimes strengthens, consolidates or weakens them, therefore it has a social role due to the generality, certainty and repetition of its effects. (Khazaei, 2015, Bagh Mohammadi and Salavarzizadeh, 2019: 94, Garg & Praliya 922: 2021)

2-3- Components of urban space and their qualities

In the last two decades, various theorists at the global level have addressed the components of urban spaces and examined their role, effectiveness and quality from various dimensions. Among the different dimensions and contexts of urban space quality, three functional, experiential-aesthetic and environmental components are deduced as the shaping forces of urban space.

According to karmona (2003), on the one hand, the functional components include the provision of movement and easy and convenient access to attractive and focal urban centers, and on the other hand, they include other functions such as passive recreation, watching various events, etc. To guarantee the vitality and richness of the spatial experience of the city. Also, the experimental-aesthetic components deal with the perceptual, cognitive perceptions and environmental preferences of people in front of the routes as an urban space and finally, the environmental components in its micro dimensions including categories such as: micro climate regulation of urban spaces (sun, air flow, wind, shading, etc.) and in its macro dimensions, it has been concerned with environmental sustainability such as balance in the environment, reduction of pollutants and cleanliness of the environment, etc. (Mohammadi et al.: 2013)

In the following, based on time precedence, the most important indicators of the quality of urban space are discussed according to functional, experimental-aesthetic and environmental components from the point of view of theorists.

Table 1. Opinions of experts on the components of urban space and their qualities

theorists	Functional component	Experimental-aesthetic component	Environmental component
Jane Jacobs 1961	The priority of order of activities over visual order, mixed use, permeability, possibility of monitoring and care, variety and wealth of activities	Attention to the element of the street, the possibility of social mixing, wealth of activities, flexible spaces	-
Cullen 1961	Creating connections between elements of the	Personal perceptions, relative aesthetics, order	-

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ISSN:1000-3673
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	physical environment such as trees, landscapes, buildings and urban traffic, functional connections	and sequential views, environmental grace	
Kevin Lynch 1983	Adaptability, access, control and supervision, efficiency, justice	vitality of life, meaningfull	Biological vitality
Violich 1983		readability of the environment, freedom of choice, different urban forms, the possibility of social life, listening to the past (reading cultural heritage)	Attention to local-regional links
Wilkinson 1983	Selectivity, evoking a sense of mastery	Balancing and calming human dynamics, the ability to create social relationships, a sense of self-fulfillment	Communicate with nature
Transic 1986	maintaining movement sequence (communication)	Enclosure of spaces, continuity of edges, control to axes of vision and perspectives, combination of inside and outside.	-
Green 1992	Performance includes: access and communication, diversity of users, security	Order includes: doing, clarity, consistency Identity includes: center of unity, personality Attractiveness includes: scale, visual fit, functionality, vitality, harmony	Climatic comfort
theorists	**Functional component**	**Experimental-aesthetic component**	**Environmental component**
Tibbalds 1992	Mixed use, attention to the needs of all groups, flexibility, growth and	attention to places more than buildings, learning from the past and	Climatic comfort of pedestrians

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	gradual changes, attention to pedestrians	respecting the existing context, human scale, legibility	
Brian Goody 1993	Permeability, flexibility, measured and controlled growth and development	Vitality, harmony with the existing platform, diversity, human scale, possibility of personalization, readability, wealth	-
Planning Advisory Committee London 1993	Safety, use and mixed activities, existence of public spaces and special spaces, ease of movement on foot and on horseback	Appropriate structure, legibility and identity, visual wealth, human scale and compactness of the city fabric, optimal urban management.	cleanliness
Prime Minister's Special Urban Design Force 1994	Responding to local characteristics and needs, the relevance of plans to the conditions of the local world	Restoring plans to adapt to ongoing future developments, and strengthening ties to the past	attention to the natural and artificial background of designs
Architecture and Artifact Environment Commission 2000	Adaptability, diversity, freedom of movement	Readability, character, continuity, quality of public space	
theorists	**Functional component**	**Experimental-aesthetic component**	**Environmental component**
Frank 2001	Distance, security, cost, time, convenience	Values and attitudes, environmental pleasant, personal habits	-
Sorkin 2002	Functional mixing, cavalry-pedestrian movement system	Circular neighborhood, preservation of edges, control of view and landscape, centrality of public places, native architecture, privacy, beauty	Greenness, sustainability

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Can 2004	Public ownership, access, interaction of space facilities	-	-
Handi 2006	Density and intensity, mixed use, street connectivity, regional structure	Scale of the route, three-dimensional space, aesthetic quality, pleasantness and attractiveness of the place	Shade percentage at noon
Varna 2014	Public ownership, control, physical composition	Enlivening (vitality), decency (Induction of social behavior)	-
Cremona 2003 2010	Providing easy and appropriate movement and access to attractive and focal centers, passive recreation, watching various events, safety and security	Perceptual, cognitive and environmental preferences of people in front of routes as urban space, vitality, richness of experience, public space and urban landscape	In micro dimensions of micro regulation of the climate of urban spaces (sun, air flow, wind, shading, etc.) and in macro dimensions of environmental sustainability, such as balance in the environment, reduction of pollutants and cleanliness of the environment, etc.
Habibi 1999	Diversity, safety, security, neighborhood, compatibility	Conductor and guidance, memorable, social role, differentiation and personality, legibility, temporal and spatial continuity, spatial contrast, milestones, detail design, pause places, human scale, flexibility	Weather conditions, road cleanliness
theorists	**Functional component**	**Experimental-aesthetic**	**Environmental**

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		component	component
Golkar 1379	Quality of behavioral camps (compatibility of activity, time, space) Quality of urban form compatibility with uses, pedestrian and bicycle network Safety quality of the environment for activities Quality of security of the environment for activities	Quality of the physical-spatial environment (objective environment) Quality of perceptual-sensory environment (perceptual environment) Quality of the perceptual-mental environment (cognitive environment) Quality of mental landscape (spatial and temporal)	
Pakzad 1383	Active and permanent presence of users in the space and social interaction of citizens	Sense of belonging, recognition of people's spiritual and psychological needs and their reflection in public spaces	
Behzadfar et al. 2018	Mixing of uses, flexibility, access, permeability, walkability	Vitality, readability, scale, variety	
Zekavat et al. 2015	Behavioral accommodation, mixing function and activity, facilitating access, functional diversity, fit and confinement, permeability, physical diversity, Safety and security, inclusiveness, flexibility and adaptability	Background and recognition of aspect, transparency, legibility, visualization, vitality, sense of belonging, collective memories, sense of place, sense of time, sensory richness, identification and identity, urban tourism, night life, livability	

2-4- Effect of autonomous cars on the city structure

Autonomous cars can be one of the biggest and most powerful challenges to influence the structure of cities. While the excitement and attraction of autonomous cars is well known to the general public, many cities are still not ready for what impact smart cars will have on

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their urban development and future, and many urban development organizations do not know the effects that autonomous cars will have on infrastructure. They have not considered the tax structure, safety and traffic equipment, and even real estate. In the future, the impact of technology on distance, speed and urban development will be determined. This means that they will change and many of them will be unpredictable. Some of these items are given in the table below.

Table 2. Impact of autonomous cars on the city structure

Effective factors	**Special characteristic**	**Sample**	
Reducing the need for parking	One of the most important effects autonomous cars on the urban structure is reducing the need for parking. Many cities generate a large amount of their revenue each year through parking fees and other parking fines.	San Francisco alone generates about 132 million dollars annually through parking. In America, cars spend 95% of their time in urban areas in park mode	Autonomous cars also reduce the need for parking permits and other costs of having a parking space.
Reduce wasted time	One of the biggest complaints and concerns of local travelers who go to cities every day is wasting their time.	Autonomous car technology will meet the needs of millions of Americans and people in other countries to improve their livelihoods.	They will be able to devote their time to other activities instead of losing their time that is mostly spent commuting.
Public transportation	For decades, urban planners have hoped to define a point-to-point, low-density transportation system without the costs that traditional transportation systems		Autonomous cars can have a significant impact on the public transport fleet

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	currently incur.		
Changing urban transport policies	Autonomous cars can have different and significant effects on city performance and income generation	It will be noticeable in small cities and suburbs where public transportation is inadequately provided.	Transportation systems consisting of autonomous cars are not efficient and cheap enough to be available as bus lines at all times. Experts also believe that the privatization of public services should not be rushed and the security of this system should be guaranteed first

2-5- Benefits of autonomous vehicles a set of measures to reduce traffic

Regulating the use of urban transportation and encouraging car sharing companies to purchase autonomous vehicles in bulk and changing their service delivery model will help achieve a fundamental improvement in the traffic situation, including factors specific to the urban environment. However, the costs of this type of improvement may turn into other problems. AV can have a different impact on urban forms depending on the type and form of ownership. From the point of view of technological, legal and economic changes, it is the first and the simplest scenario in which a simple car is replaced by an autonomous car. From the point of view of urbanization, the scope of this study shows the need to promote the introduction of the second scenario, which eliminates the private ownership of vehicles and in turn reduces their number. One of the negative consequences of the introduction of AV is the change of urban infrastructure in order to meet the requirements of AV. Transport infrastructure tools should be redesigned with the possibility of greater adaptability and reuse with other functions.

Therefore, based on the theoretical theory presented and researchers' opinions, the development of autonomous cars are classified as described in Table 3:

Table 3. Research theory literature

Row	Title	Year	Researcher	Research method	Goals	Results
1	Environmental impacts of	2022	ÓscarSilva, RubénCordera	Qualitative	Concept of environmental effects relates	Due to the lack of study of some of the environmental results

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	autonomous vehicles: A review of the scientific literature				to many aspects of air pollution, this paper aims to review and present the findings and shortcomings of current research with a broader perspective.	of AVs, it is not possible to draw accurate conclusions about their overall impact, and calls for more comprehensive studies that allow the identification of all necessary measures to achieve a sustainable future.
2	Impact of Driverless Vehicles on Urban Environment and Future Mobility	2020	SerioAgriestibFaustoBreviaPaoloGandini	Descriptive-survey	Purpose of this research is to focus on the way this technology can affect our urban environments and create a basis for policy change at multiple levels.	Planners, policy makers and car manufacturers and other new stakeholders must take a comprehensive and multidisciplinary approach in understanding and evaluating the impact of this technology on our lives and cities.
3	Impact of Automated Vehicles on Urban Form	2022				
4	Smart cars, smart cities and smart sharing: The changing nature of public urban spaces on streets,	2020	Celen Pasalar	Descriptive - library	How these three socio-economic and technological changes may affect the current and future use of urban public space	This chapter addresses the fundamental changes brought about by intelligent vehicles or autonomous AVs. Smart city technologies; And business models and technologies related

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						to urban spaces facilitate the sharing of resources, infrastructure, goods, services, experiences and capabilities.
5	on the path of urban development and sustainable transportation development in the automotive community? Traces of declining car neighborhoods around the world were traced	2020	Cena Selser	Descriptive-analytical	Developing "planning" approaches to reduce the negative effects of car traffic for more sustainable urban development and transportation	Our review shows that the development of car-reduced neighborhoods is (i) consciously embedded in a sustainability context, (ii) characterized by power relations, (iii) as follows. Normative indicators, and iv do not always correspond to lived realities. In sum, the traced narratives of car-depleted neighborhoods are embedded in the general discussion of sustainability, while also revealing society's dependence on the car; Thus, the hegemonic system of the car – although cracking – continues to exist.
6	A design framework for livable streets in the era of	2020	William Riggsa, Bruce Appleyardb and	Qualitative	Possible opportunities for street design in a autonomous	We refuse to let machine-centric thinking dictate the design of our cities again. We need to

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	autonomous vehicles		Michael Johnsonc		future based on taking advantage of the existing situation and eliminating parking	ensure that the physical design of our streets and urban environments keeps pace with rapid advances in automotive technology. While AV is currently being tested in many of our streets, it may take decades for its benefits to be fully realized in our cities. Now is the time to plan, design, and implement flexible street environments to ensure that AVs don't further destroy our cities by putting efficient automation before people. As AV technology continues to advance, cities must stay connected by doing what they've always done best: celebrating people and emphasizing human connection, interaction and commerce.
7	Autonomous driving in structured and unstructured	2006	Kolski, Sascha; Ferguson, Dave; Bellino,	Qualitative	By investigating a hybrid autonomous system that	Our system is able to navigate based on observations from its laser and safely reach a given target while

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	Environments		Mario; Siegwart, Roland		recognizes and exploits structure in the environment with a form of driving lanes, we present.	avoiding obstacles such as curbs and parking cars. We have presented results showing vehicle operation in both structured and unstructured environments. We are currently working on a number of extensions to this approach.
8	Analysis of the influence of spatial design and city architecture on the intra-city transportation system (case study of Neka city)	1400	Mohammadi	Descriptive-survey	Investigating the effect of spatial design and city architecture on the intra-city transportation system of Neka city	Results of this research show that spatial and architectural design including (distribution of architectural plans, distribution of infrastructure in the transportation system, distribution of accesses in urban spaces) has an effect on the intra-city transportation system and the component of accesses distribution in urban spaces with the highest average (22.2) and The distribution of infrastructures in the transportation system has the lowest average (1.86) impact on the intra-city

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						transportation system.
9	Evaluating the impact of urban transportation policies on improving the quality of public spaces in the central part of Tehran, case study: Bazar neighborhood	1400	Salarvandian	Exploratory-Delphi technique		Results of Friedman's comparative test showed that the ecological-environmental, social-cultural, economic and infrastructural-physical dimension respectively received the most influence from traffic policies. The results show that the policy of developing sidewalks with the highest average, i.e. 65.66, development of public transportation. With 63/23, car traffic restriction with 48/72 and parking restriction policy (Mj) with 40/08 have had the greatest impact on the quality of public spaces in the central part of Tehran, respectively.
10	The principles of aspect and landscape control and visual order in urban planning based on	1398	Oveisi	Library studies and review of world literature	Explaining the principles of controlling and maintaining visual order in TOD centers, the components of visual	One of these approaches, whose benefits are known all over the world and is also followed in Iran, is urban development based on TOD public transportation.

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	public transportation				organization in urban planning based on public transportation	
11	The role of urban transportation in the socio-economic development of cities	1395	Soleimani	Descriptive-analytical	The role and importance of transportation in economic-social urban development	After that, through transportation, the role and importance of urban transportation has been addressed, then the effects of this category in urban development from an economic-social point of view have been taken into account. The perspective of the economy of investment in transportation has directly caused the price of agricultural data to decrease and, accordingly, it has reduced production costs. . It has also increased the possibility of access to the market, which has led to the diversification and output of production, and finally, it has provided the tools for the development of non-agricultural sectors in urban areas.

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12	The role of urban space structure in transportation is one of the basic needs of efficient and modern societies.	1395	Ali Sarlak	Descriptive-library	The role of urban space structure in transportation.	Separating the effects of mixed land use and urban design from the effects of density is a difficult task, and the reason for this is due to the qualitative and unmeasurable nature of the variables of mixed use and urban design, and determining its indicators due to their quality should be done either with zero and one virtual variables or with High, medium and low quality indicators are graded, which is very difficult to analyze and quantify, but in contrast to the role of density, its effects can be measured with accurate measurement indicators.

3- Parameters of the impact of autonomous vehicles on the future development of urban space

The impact of autonomous vehicles on the future development of urban space is examined based on several different parameters. The first parameter is the impact on urbanization. Using artificial intelligence systems and advanced sensors, autonomous vehicles are able to continuously monitor the environment and perform driving operations more accurately, which improves urban safety on the streets and reduces accidents. The second parameter is

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economic. Autonomous vehicles can help reduce transportation costs, increase productivity, and reduce traffic, which directly contributes to economic development and urban growth.

The third parameter is the environment. Autonomous vehicles produce less air pollution and greenhouse gas emissions than traditional vehicles because they are more fuel efficient and drive more intelligently. As a result, these vehicles can help improve the air quality of cities and reduce environmental pollution. And finally, the fourth parameter is social. Autonomous vehicles can help increase access to transportation for people with disabilities or the elderly, as well as help create more commuter-friendly and community-friendly cities, as people may use public or private transportation that uses autonomous vehicles more often. which reduces traffic and congestion in cities.

According to the results of the study, three groups of principles of AV influence on the urban form can be highlighted:

First group - impact on urbanization:

It includes factors affecting the structure of the city. The introduction of AV can lead to urban sprawl and reduce building density. On the other hand, AV can increase the density of buildings and make some areas more accessible. (Development and Density)

Second group - impact on road infrastructure:

These principles include effective factors in the use and physical change of the street space. The introduction of AV improves road safety and eliminates the conflict between drivers and pedestrians. The complete replacement of conventional vehicles with AVs not only expands sidewalks, but also completely eliminates the separation of cars and pedestrians on low-traffic streets. Uniform driving speed and synchronized AV actions improve traffic flow without widening roads. Also, the introduction of AV reduces the width of lanes and completely eliminates parking along the side.

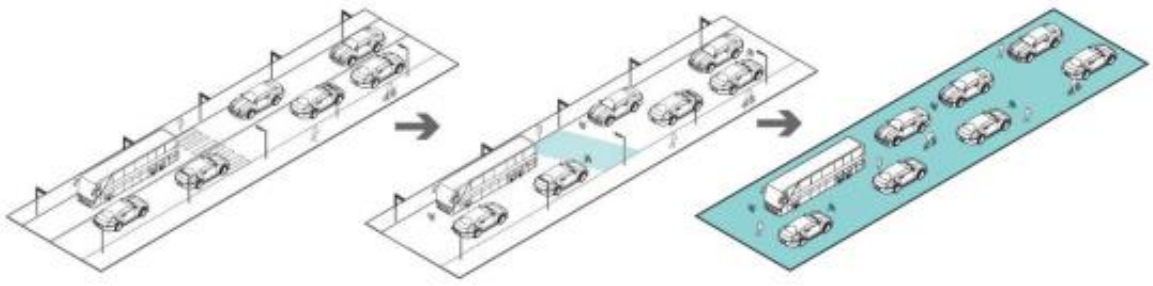

Figure 1. Conversion of walkways and sidewalks in the implementation of AV

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ISSN:1000-3673
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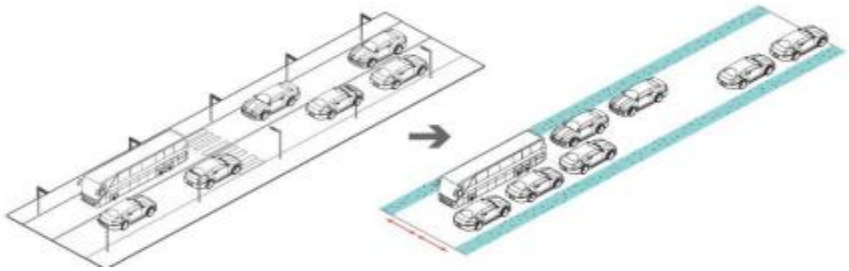

Figure 2. More efficient road use when implementing AV

Third group: influence at local level

This group covers more local changes: the impact on residential development in the city center and suburbs. With the advent of AV to reduce the need for parking, existing parking must be adapted to other functions. Renovation of parking in residential areas increases the density of buildings. In the central areas of the city, parking lots can be converted into offices, housing, retail spaces or recreational spaces. It is necessary to change the infrastructure related to cars: sales halls, car shops. And all kinds of services, gas stations and the emergence of autonomous cars are a reality of the next decade. All over the world, the technical and economic issues of automated technology are being investigated (Corwin S, 2015).

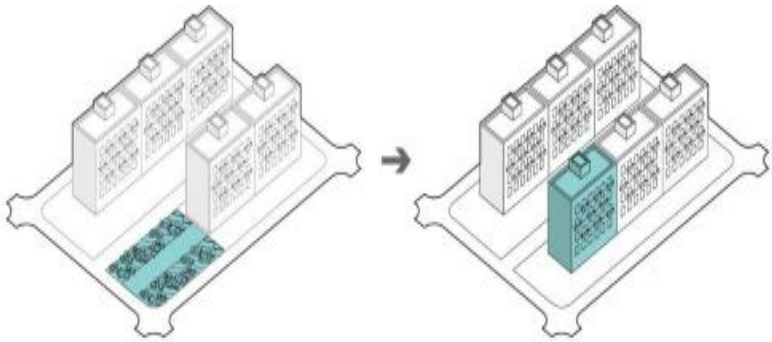

Figure 3. The effect of AV on residential areas

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ISSN:1000-3673
Received: 06-04-2024 Revised: 15-05-2024 Accepted: 28-06-2024

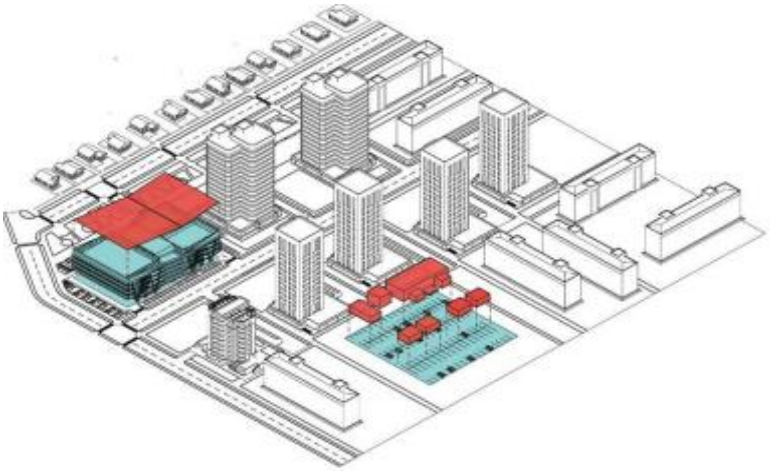

Figure 4. The effect of AV on city center

4- The stages of achieving the parameters of car's impact on urban space

Table 4. Car impact parameters on urban space

Indicators	Sub-indicators (steps)
recession	-Prohibition of using cars over 10 years old - Construction of multi-level parking lots in residential areas and along the third transportation ring -Uniform parking rate for single and multi-level parking in residential areas for local residents - Continued support for car sharing providers - Promoting the development of conventional public transportation services
share	-Registration of personal cars only for people who have a parking space near their home -Paid parking for private cars throughout the city -An increase in tax on private cars or the introduction of a road pricing instrument with a corresponding increase in ownership costs - Separation of parking lots in residential areas based on the type of ownership. Creating parking spaces along the streets for shared vehicles only -Increasing car sharing costs to ensure the attractiveness of regular public transport
Robot making	-Increase in taxes on private cars -Improvement of automatic multi-level parking services in residential areas and along the third transportation ring and gas station services - Municipalities finance the construction of autonomous vehicle infrastructure

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	(5G networks, data processing centers, data protection centers, and dedicated parking lots).
Absolute mobility	-Increasing the vehicle tax on private cars depending on the level of autonomy (the higher the level, the lower the rate) or introducing a road pricing tool with adjustment coefficients for the base rate depending on the level of autonomy of the vehicle. - Providing car sharing services completely throughout the urban area - Municipal budget for autonomous car research

Table 5. Parameters of the impact of autonomous vehicles on the future development of cities

Indicator groups	Aspects studied	Components
Transportation and technology indicators	Transportation and technology indicators Impact on traffic conditions and space requirements, depending on the supply/demand balance for road transport services	-Traffic situation - Reduction of time in traffic - parking place need
Economic indicators	Indirect impact of autonomous technology on city budgets and consumer finances, depending on the balance of supply and demand for road transportation services.	- Development of related infrastructure - Reducing costs and damages caused by traffic accidents -Changes in property value - Transportation productivity
Environmental indicators	environmental effects	- Turning unnecessary parking lots into green areas - Urban transportation that is more environmentally friendly
Social indicators	The impact of autonomous technologies on living conditions in the city and access to these technologies	- Changes in employment structure -Street and road safety - New user participation
Political indicators	transportation policy and regulations	Management of autonomous transportation services

4- The impact of autonomous cars on urban environment

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Autonomous car technology will change the urban environment and the changes will be irreversible. It is important to have an idea about the consequences of its implementation in order to avoid negative developments and try to get the maximum benefit from the introduction of autonomous cars. The purpose of this study is to predict the amount of changes in the quantitative and qualitative characteristics of the urban space as a result of the introduction of autonomous cars. In the work, based on the analysis of scientific and applied literature, certain principles of the impact of autonomous vehicles on the urban form are revealed. Autonomous cars have both advantages and disadvantages. The main benefits include increased mobility, access to areas of cities not currently served by public transport. One of the main advantages of autonomous cars is the increase in safety. Autonomous cars can be used by wider groups of the population, including the elderly and people with disabilities. The widespread introduction of automated vehicles is expected to shorten travel times, as all road users move at a uniform speed; Faster crossing of intersections (due to intellectual coordination of actions), automatic selection of the optimal route using cloud technologies, eliminating the need to find a parking space using public autonomous cars can reduce the need for parking. Also, the introduction of autonomous electric cars significantly reduces the amount of toxic emissions (Heinrichs D, 2016).

There are a number of predictable drawbacks. First, the widespread distribution of autonomous cars and their accessibility by a wider range of the population may reinforce the current trend towards sprawling cities. If autonomous cars are privately owned, increased road traffic will block time-saving movement. Negative impact on human health due to sedentary lifestyle, if driving is preferred over cycling or walking. The introduction of autonomous cars requires a review of professions and infrastructure related to transportation (truck and taxi drivers, gas stations and car shops, traffic police, etc.). Currently, there are several scenarios for the introduction of automatic transportation (Zhu S, 2018).

Depending on the form of ownership, there are basically two scenarios:

The private ownership of the vehicle, to the controls without the external environment and with the help of the automatic system integrated in the public environment and based on urban information.

Public car ownership and division into taxi system and mass network in public transportation system.

These types of autonomous cars will affect the urban environment in different ways, so they will be examined separately in this article. In the first scenario, when cars will continue to be privately owned, global changes are not expected. In a private house, where there is a parking space in a plot near the house, a autonomous car is simply replaced by a conventional car. In

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ISSN:1000-3673
Received: 06-04-2024 Revised: 15-05-2024 Accepted: 28-06-2024

areas with higher density, it can be assumed that communal parking lots will be flooded during the construction of the house, so there will be no need for parking inside the residential building(Vaziri,2024). It will be possible to call the car from the parking lot through the application on the phone. A similar situation will occur with public buildings. Autonomous cars park themselves in a remote parking lot and return. In the second scenario, a new type of mobility appears: an autonomous taxi system. This type can be considered as a logical continuation of a car sharing system. These taxis do not operate on specific schedules or routes, but are focused on demand. In this mode, the machine is working continuously and is more efficient. The next step in this scenario is to integrate such a taxi into the public transport system, thereby solving the "last place" problem. Public transport transports passengers over long distances to Taksim Central Station and a autonomous taxi delivers them to their destination. All this can lead to a fundamental transformation in the public transport system, and in this regard there are different types of ownership of a autonomous taxi: public or private. This use of AV can significantly affect the urban environment. Another issue is the need for a complete reconstruction of the parking lot because the need for parking lots will change in their current form. Parking lots on the side of the streets can be reconstructed into pedestrian spaces or bicycle lanes. In residential areas with denser buildings, there will be no need for parking. After the car reaches the passenger's destination, it moves to the next passenger. A similar situation will occur with public buildings. There will be parking as passenger charging stations on the outskirts of the city. Autonomous taxis can increase group travel. Thanks to the similar structure of public transport, it will be possible to increase access to all areas of the city and increase the density of urban space. Some studies predict that interest in suburban residential areas will increase with the advent of autonomous cars. Autonomous vehicles will provide access to green areas with lower housing prices, but away from the city center, which can lead to urban sprawl and less building density. All this creates additional costs for infrastructure maintenance. (Mearian L,s 2015)

Table 6. The impact of autonomous vehicles on city and residents

scenario	Impact on residents	Impact on urban space
recession	- Reasonable price of private cars - Car maintenance problems in residential areas - Wasting time in traffic - High unit ride costs - Low access to road transport services for people with low mobility and low income	- Constant traffic -Severe lack of car storage - The need to build multi-level parking lots - Reducing the accident rate - Worsening of the environmental situation

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	groups - Loss of transport-related jobs	
share	-Wide access to motor transport services regardless of Wealth and health Low and middle income groups abandon private cars In favor of car sharing - Low travel costs, but more than the general public transportation - A big increase in the cost of owning a car - Mobility increase -Loss of jobs related to transportation	-Reducing the rate of accidents - Improving the environmental situation - Increasing property value in restricted areas - Transportation access - Environmental situation has improved slightly
Robot making	- High attractiveness of owning a autonomous vehicle - Low price of private cars - Big increase in the costs of owning a private car - Increasing the availability of motorized transport services for people with limited mobility -Loss of jobs related to transportation -Less problems in parking and vehicle maintenance	- Permanent traffic without accidents - The need to build automatic parking lots along the ring road in residential areas - Great reduction in the rate of accidents - Increasing property value in areas with limited transportation access - Environmental situation has slightly improved
Absolute mobility		- Reduction of road congestion, very predictable traveling - Reducing to the rate of accidents - Highest improvement in the environment ondition

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6- Results

Autonomous vehicles also offer new opportunities for people with mobility problems, including the elderly (growing population), people with disabilities, and marginalized groups. It is estimated that transportation as a service makes the cost of a ride less than the price of a public transportation ticket, thus helping to break down barriers of inequality and realize social justice. Similarly, the evolution of autonomous vehicles could bring many benefits to society. It can be measured directly and indirectly. Critical indicators for optimizing autonomous vehicle services in urban areas include (1) traffic accidents and traffic volume, (2) transportation costs, (3) parking space, and (4) energy consumption and travel time. A livable city should be safe, clean and with plenty of green spaces. Cars can damage any of these aspects. With the advancement of autonomous technology, road safety and environmental sustainability will greatly increase. The autonomous vehicle revolution could create a future of smoother, more predictable traffic and more efficient public transportation, creating more space for citizens. Also, people can move easily in urban areas, with fewer risks for pedestrians and cyclists. These benefits of autonomous vehicles and smart cities can improve people's quality of life and protect the environment. Therefore, future cities should become smart hubs. The development of smart cities with autonomous vehicles can serve as a guide for long-term urban planning. The main issue is, can autonomous vehicles make cities better places to live? Urban space planning should be designed with the idea that autonomous vehicles do not need parking spaces in city centers, and these spaces can be turned into other facilities that make cities more pleasant places to live.

At the same time, there are challenges such as the difference between the direction in which the automotive sector is moving and the aspirations of cities. But it should be noted that sustainable cities can benefit from better cooperation and sharing in various matters. It also shows that cities still need cars, and it's likely that cars will remain an essential form of transportation. On the other hand, the automobile sector also needs the cooperation of cities, and the adoption of new technologies mainly depends on the policies and desires of cities.

Today, it is safe to say that autonomous vehicle technology will be used in any form in the foreseeable future and will significantly change the approach to transportation and owning a personal car. Autonomous vehicles will lose their fully personal status in favor of the shared model. In addition, autonomous technology can only have a positive impact on the urban environment and transportation if sharing services are developed sufficiently at the same time. Car-sharing and ride-sharing services are expected to grow worldwide over the next decade, with autonomous vehicles making them especially attractive.

Power System Technology
ISSN:1000-3673

Received: 06-04-2024 *Revised: 15-05-2024* *Accepted: 28-06-2024*

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