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AUTONOMOUS VEHICLES AND URBAN SPACE MANAGEMENT

Summary. Discussions on how urban space would be transformed by the use of autonomous vehicles (AVs) are scarce. This study identifies the impacts caused by the shared use of AVs on urban parking and urban space management. An estimation method was formulated considering the reduction in parking demand, the possible alteration in vehicle ownership, and the reallocation of urban space. A case study was performed in a 673,220 m^2 area through scenarios created by using real data of parking spaces and the results of previous studies. Results showed that parking spaces can be saved with the use of shared AVs, which would allow the reallocation of urban space to new uses (for example, implementation of around 12,000 bike-sharing docking spots, 10 km bike lanes, 7 km additional traffic lane or 140 'parklets'). The results contribute to revealing the positive impacts of AVs.

Keywords: autonomous vehicle, urban space, land use, shared mobility, reshaping cities

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1. INTRODUCTION

As autonomous vehicles (AVs) are under development, analysis of their impacts has become important for understanding how they would affect people and space management. Existing studies [9,14,19-22] focused on formulating models and calculating the reduction in the number of vehicles and parking spaces. However, discussions on how urban space may be transformed were barely made. Therefore, this research focuses on the transformation in urban space generated by the use of AVs considering how changes in number, location and use of parking spaces could save urban space and which new functions could be given to them.

A method was developed to estimate the reduction in demand for parking according to alteration in ownership and the shared use of autonomous vehicles (SAV), as well as to estimate the new uses of the urban space saved according to the priorities of decision makers. In this study, all members of the society that are able to make decisions regarding future changes in the city are considered decision makers. To demonstrate the applicability of the method, a case study was performed in an area in Budapest, Hungary. Different scenarios were created based on previous studies and real data of parking spaces were applied.

This paper is structured as follows: results of relevant literature are revealed in Section 2. The developed estimation method, the scenarios and the collected data are presented in Section 3. The results and findings are discussed in Section 4. This paper is completed by concluding remarks including future research directions.

2. STATE OF THE ART

2.1. Autonomous vehicles in a sharing system

A car is parked approximately 95% of its lifetime [18]. The average car spends about 80% of the time parked at home, is parked elsewhere for about 16% of the time, and thus, only in movement for the remaining 4% [15**Błąd! Nie można odnaleźć źródła odwołania.**]. The main motivation to use private vehicles is work-related, which causes a high parking demand in the daytime, having the overall average parking time of 3.5 hours [15,18]. Nowadays, drivers need to walk to the parking location to pick up their vehicles. Furthermore, cruising for parking spot results in a tremendous amount of excess driving causing air pollution, crashes and traffic congestion [10,11,18,22]. Nevertheless, the access walking distance and cruising for a parking space are not a problem for AV users. There is no need to park the vehicle close to the destination. However, reaching a distant and cheaper parking space can increase the empty runs and vehicle miles travelled, generating additional cost, and consequently, the need for a centralised parking management and control of AVs. Some modelling studies carried in the United States [6,20] and Europe [1,2] show that the use of private AVs increase vehicle miles travelled, reduce public transport use and slow modal shift. Moreover, it leads to a more dispersed urban growth [16,17].

AVs have the potential of becoming a major catalyst for urban transformation (for example, changing urban infrastructure, city design, mobility habits, and time spent during travelling) [5]. It is suggested that the use of SAV fleet could mitigate current issues, such as increasing car ownership, traffic congestions and, subsequently, the time spent travelling daily. To reach the benefits, the social acceptance of AVs is needed, however, technophobia was found as a significant factor against AV use [12].

The impacts of the three types of ownership and market acceptance scenarios that may shape the future demand for parking are [13]:

- Private use: the number of car parking might be the same as today, however, changes in their location might occur as AVs can park far away from the destination.
- Shared use, but single occupancy: fewer parking spaces are expected, the duration of parking would be reduced due to sharing.
- Shared use with multiple occupancy: only a few vehicles need to park, and the location of parking spots is in strategic locations to provide mobility service with minimum waiting time.

Private shared use can be also distinguished if the privately owned vehicle is shared among acquaintances and family members. Moreover, AVs can park more efficiently than humans, the on-street parking spaces might decrease independent of the reduction in vehicle number. Furthermore, on-street parking might be exchanged to off-street parking such as parking garages which could be automatised. Automatisation optimises the available space for its construction as they do not need facilities for human use. In addition, off-street parking may serve as points for charging, cleaning, maintenance and waiting areas for SAVs. Moreover, the multi-row layout could also reduce parking space. A relocation strategy could be used to release barricaded vehicles. The extent of vehicle relocation depends on the layout of the car park; square-shaped car parking spaces can be more effective. The use of AVs can decrease the need for parking space by an average of 62% and a maximum of 87% [7].

Main finding of existing studies regarding the alteration of parking space caused by the different ownership of AVs are summarised in **Błąd! Nie można odnaleźć źródła odwołania.**. The detailed results were used as inputs for the developed method presented in this paper.

Tab. 1

Studies about reduction of parking spaces

Ownership	Study	Study area	Characteristics	Reduction in parking spaces
Private Shared	[20]	Atlanta, USA	SAVs among the members of the same household	-9.5% number of private vehicles, +15 minutes travel time per trip, -12.3% parking space
Shared, single occupancy	[18]	Boston, USA	33% or 100% SAVs	-16% or -48% parking space
	[5]	Atlanta, USA	SAV, 5% market penetration level	-90.3% and -92.4% parking spaces; 1 SAV can remove more than 20 cars; -4.5% in parking land use
	[9]	Lisbon, Portugal	100% or 50% SAVs	-89.3% or -21.2% parking spaces
Shared, multiple occupancy	[14]	Munich, Germany	AV taxi fleet, 0%, 20% or 40% taxi	40% penetration rate, 1 AV taxi can replace 3 conventional cars
	[13]	General	2% of market penetration level	-90% parking spaces with ridesharing
	[9]	Lisbon, Portugal	100% or 50% SAVs	-94.4% or -24.2% parking spaces

Former on-street parking areas could be divided into lanes for bicycles, other micro-vehicles or public transportation services. Consequently, urban space management may be renewed promoting walkability as well as areas focusing on well-being.

2.2. Pick-up and drop-off areas

One of the most important aspects considered in designing the urban space for AVs is the pick-up and drop-off areas, especially in the case of shared use. Designated space is needed to eliminate conflicts with the surrounding roadways and parking spaces.

The aspects to be considered when designing drop-off and pick-up areas are location, style, sign, connection and comfort.

- The *location* of these areas should be close to the entrance of buildings, allowing users to quickly get in or get off. Separated pick-up and drop-off areas are preferable so as to reduce conflict areas and a better flow of users, however, common pick-up/drop-off area could be built if the space is limited.
- The *style* of the areas should represent the functionality to distinguish it from other infrastructure elements.
- The areas should have *signs* indicating their delimitations to support travellers and avoid misuse of it.
- Seamless *connection* should be designed between pick-up and drop-off areas to allow AVs to quickly pick another passenger after dropping-off the previous one.
- A high level of *comfort* is needed during the waiting time (benches, phone charging, lighting, internet, etc). However, the waiting time can be minimised with efficient demand-capacity coordination.

Concluding the results of the state of the art, the alteration in parking management as the consequence of AVs is presented in **Błąd! Nie można odnaleźć źródła odwołania.**. Urban space is composed of private space and public space, such as streets, parking areas, green spaces, parks, and squares. After the introduction of AVs, especially SAVs, the use of urban public space will be altered. The most important impacts are fewer parking spots, off-street parking facilities instead of on-street parking spaces, remote parking, parking close to each other and reallocation of urban spaces.

3. METHODOLOGY

3.1. Estimation method for urban space transformation

The modal share, the type of ownership and parking could cause a significant alteration in public parking space management, which could be transformed into new uses according to the priorities of decision makers. However, the travellers' willingness to walk to take an AV might influence how much of the saved parking spaces would be transformed to pick-up and drop-off areas. To estimate the size of the area allocated for new uses and to assume the type of the new uses (bike lanes, green areas, etc.) after the adoption of SAV fleet, a method was elaborated considering the aspects presented in **Błąd! Nie można odnaleźć źródła odwołania.**.

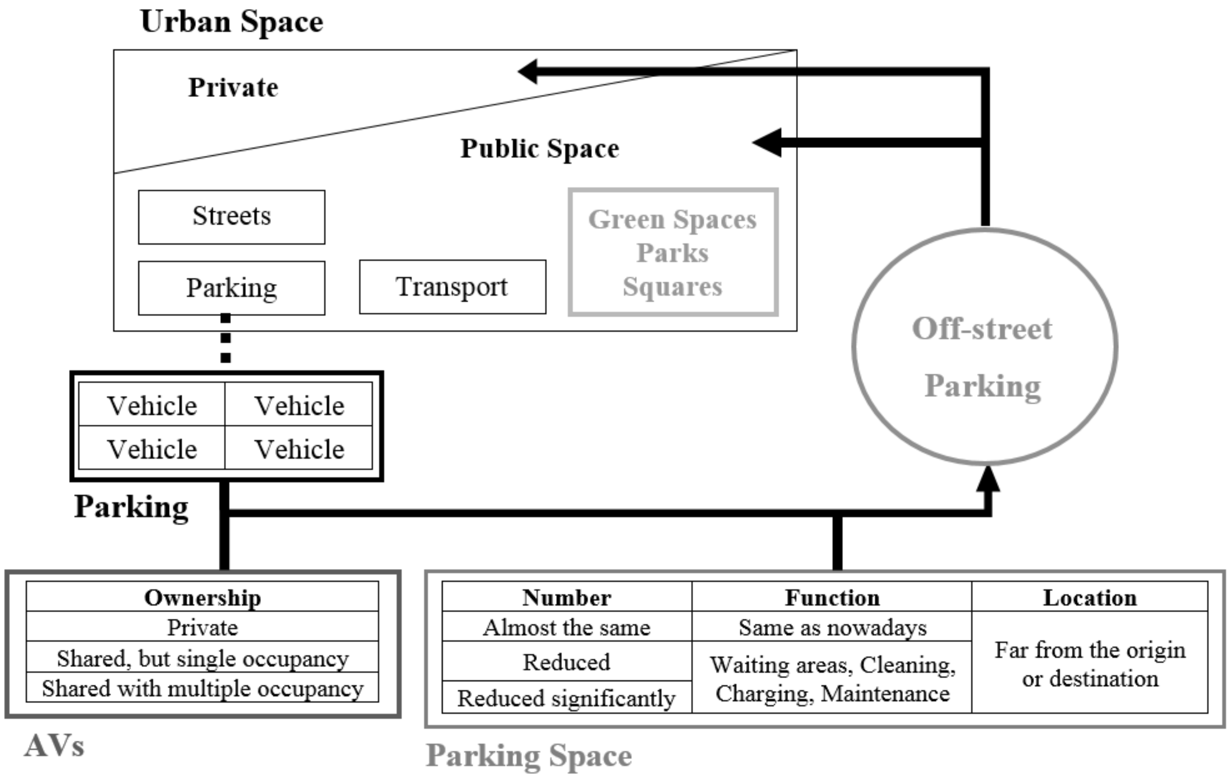


Fig. 1. Urban space in the future with the use of AV

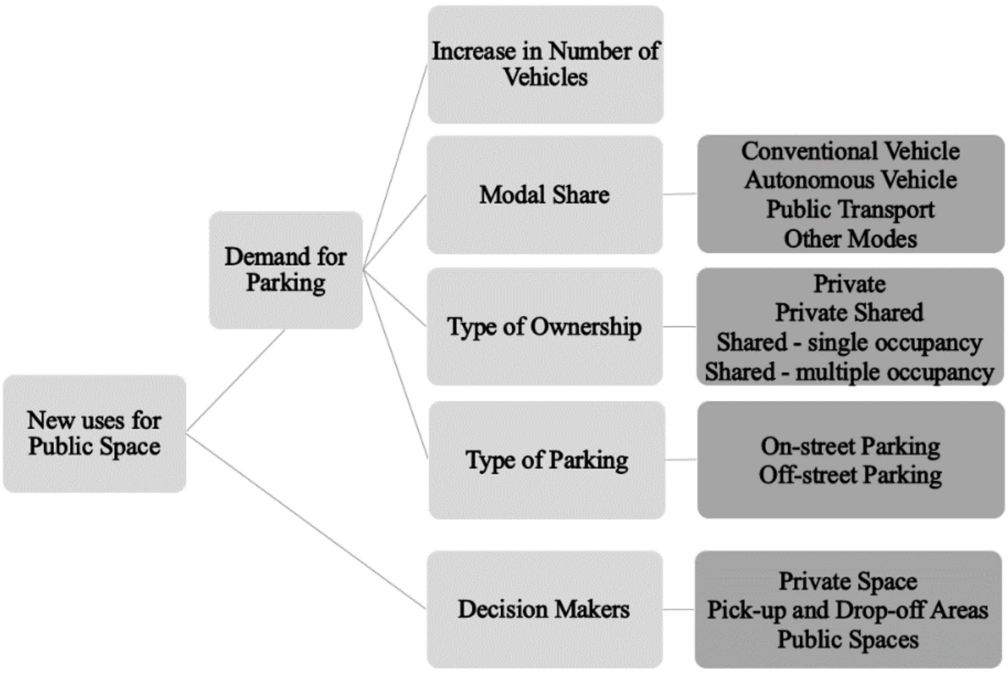


Fig. 2. Aspects considered creating new uses for public space

The annual alteration of urban space and future parking demands are considered due to the expected increase in AV adoption. This method provides predictions regarding changes in urban space management as a tool for city planners. The result of this method is the future parking demand and possible reallocation of urban space. As a limitation, alterations in population and the location of households are not considered. Furthermore, alteration in loading points and charging spots for electric vehicles are neglected. The used indexes are presented in Tab. 2, the variables used during the calculation are introduced in Tab. 3.

Tab. 2

Indexes

Sign	Name	Set of value
k	Parking alignment	*k*=1..z (1: parallel, 2: 45°, 3: 90°, etc.)
j	Type of ownership	*j*=1..m (1: private, 2: private shared, 3: shared with single occupancy, 4: shared with multiple occupancy, etc.)
χ	Type of new use	*x*=1..y (1: public transportation, 2: improving walkability,3: bike-related strategies, 4: additional traffic lane, etc.)

Tab. 3

Variables

Sign	Description
$VI_j^{CO}(t)$	Rate of increase in the number of conventional vehicles in year *t*
$CO_j(t-1)$	Number of conventional vehicles in the year *t*-1 according to *j* ownership
$VI_j^{AV}(t)$	Rate of increase in the number of AVs in the year *t* according to *j* ownership
$AV_j(t \quad 1)$	Number of AVs in the year *t*-1 according to *j* ownership
SP_j^{AV}	Percentage of saved parking space caused by autonomous vehicles according to *j* ownership
OFS	Percentage of off-street parking space from the total parking spaces
Pe_k	Percentage of parking spaces according to *k* arrangement
A_k	Area of each parking space according to *k* arrangement [m^2]
$Rpr(t)$	Rate indicating how many private areas will be created in year *t*
$Pp(t-1)$	Percentage of private area created in the previous year (*t*-1)
$Rpd(t)$	Rate indicating how much pick-up and/or drop-off areas will be created in year *t*
$Pd(t-1)$	Percentage of pick-up and drop-off area created in the previous year (*t*-1)
R_x	Rate of space applied for new use related to *x* new use
$A_x(t-1)$	Area for *x* new use correspondent to the previous year (*t*-1)

Step 1: Number of parking spaces according to demand

The demand for parking in year t ($D(t)$) is calculated according to (1).

$$D(t)=\left[\sum_{j=1}^{m}\sum_{t=1}^{n}\left(1+VI_j^{CO}(t)\right)\cdot CO_j(t-1)+\sum_{j=1}^{m}\sum_{t=1}^{n}\left(1+VI_j^{AV}(t)\right)\cdot AV_j(t-1)\cdot\left(1-SP_j^{AV}\right)\right].\left(1-OFS\right) \quad (1)$$

Step 2: Demand for a parking area

The necessary area for parking in year t ($P(t)$) [m^2] is calculated according to (2).

$$P(t)=D(t)\cdot\sum_{k=1}^{z}(Pe_k\cdot A_k) \quad (2)$$

Step 3: Percentage of saved spaces used for private areas and pick-up and drop-off areas

Saved space is defined as the extra space resulting from the reduction of parking demand caused by the use of SAV fleet. The percentage of it ($Dm(t)$) decided to use for private areas or pick-up and drop-off areas by decision makers is calculated in (3).

$$Dm(t)=(1+Rpr(t))\cdot Pp(t-1)+(1+Rpd(t))\cdot Pd(t-1) \quad (3)$$

Step 4: Area allocated for new uses

The size of the area in the year t ($N(t)$) [m^2] allocated for new uses is calculated according to (4) or (5). The latter considers the combination of areas for new uses, such as an area for cycling or for public transportation, as well as the rates of increment/decrement of this portion of land considering decision makers' priorities.

$$N(t)=\left(P(t-1)-P(t)\right)\cdot\left(1-Dm(t)\right) \quad (4)$$

$$N(t)=\sum_{x=1}^{y}\left(1+R_x\right)\cdot A_x(t-1) \quad (5)$$

3.2. Creation of scenarios

Creation of scenarios represents an important tool to analyse how beneficial the adoption of SAV fleet is for the reduction of parking spaces. Five scenarios were created (Tab. 4) and their characteristics were based on previous studies [9,13,20]. Scenarios simulating the transitional period, when the whole vehicle fleet is not fully composed by AVs, were created to analyse whether AV acceptance in this period would bring significant benefits. It is important to notice that Scenario 4 (transitional) presents private AV fleet and, in Scenario 5 (mix), the fleet is private but shared among members from the same household. It was assumed that population and land use would remain the same, as well as reduction of parking spaces in Scenarios 4 and 5, would happen proportionally to the results obtained from Scenarios 1, 2 and 3 according to the type of ownership. For instance, in Scenario 5, the private SAV fleet would have 9.5% reduction in parking spaces according to the result in Scenario 1.

Tab. 4

Scenarios assumed with the use of AVs

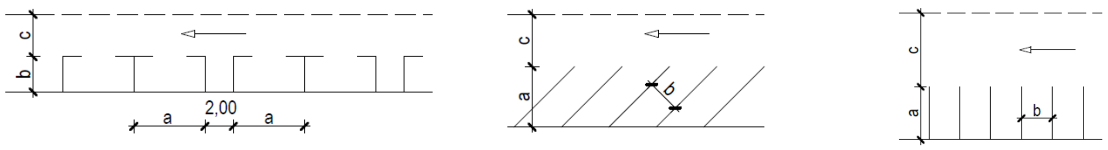
Scenario	Condition	Input Parameters
1	Private ownership	9.5% reduction in private vehicles with private sharing.
2	Shared, single occupancy	89.3% reduction in parking spaces with 100% shared fleet.
3	Shared, multiple occupancy	94.4% reduction in parking spaces with 100% shared fleet.
4	Transitional	AV private fleet: 27%, shared single occupancy fleet: 33%, shared multiple occupancy fleet: 40%.
5	Mix	Private SAV fleet: 10%, shared single occupancy fleet: 50%, shared multiple occupancy fleet: 40%

3.3. Data Collection

The following data should be collected according to the segments (for example, sides of a block):

- the number of parking spaces,
- the location of parking spaces (for example, both sides of the street),
- arrangement of parking spaces (parallel, 45° or 90°),
- whether the parking space takes part of the sidewalk and what the extension of the sidewalk occupancy is,
- characteristics of the surroundings.

The values used for calculation about the occupied area of parking spaces are based on the dimensions according to the type of parking space shown in Fig. 3.



a=5m, b=2.5m, c=3.5m; a=5.2m, b=2.5m, c=3.5m; a=5.5m, b=2.5m, c=5m

Fig. 3. Dimensions of the parking spaces according to the type
(Source: BME, Department of Industrial and Agricultural Building Design, 2013)

To prove the applicability of the developed estimation method, it was applied to an area in the district XI of Budapest, Hungary. It is mainly a residential area, however, it includes a big shopping mall and a university as it is delimited by important public transportation stations with underground and several tram lines. **Błąd! Nie można odnaleźć źródła odwołania.** illustrates the delimitation of the studied area. The district is 33,490,000 m^2 and had 148,517 inhabitants in January 2019 according to the National Statistical Office. The area of study has approximately 673,220 m^2 which would be occupied by around 3,000 inhabitants considering a uniform distribution of population on land. The data regarding parking spaces was collected on field. The area was divided into 120 segments. Photos were taken to support the analysis about how urban space is used.

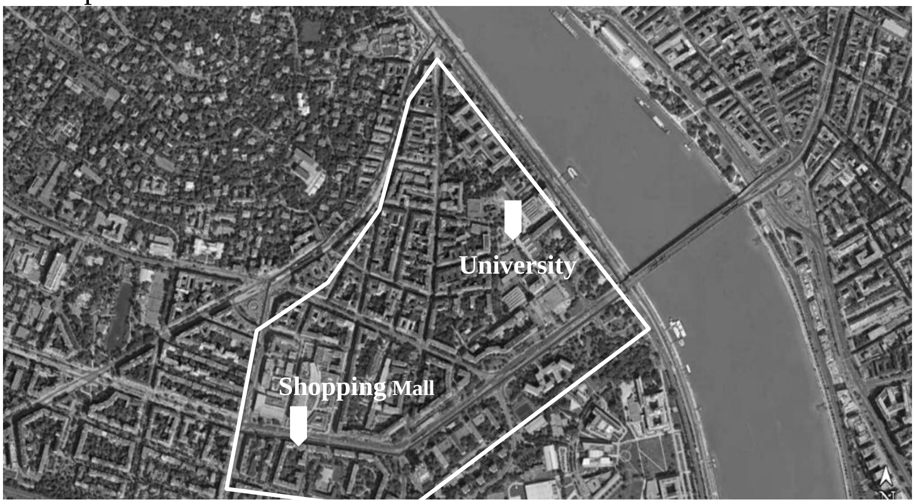


Fig. 4. Delimitation of the studied area (Source: Google Maps)

4. RESULTS AND DISCUSSION

4.1. Situation analysis

In the studied area, mainly on-street parking spaces have been created. This type of parking was considered the easiest solution for managing the increasing parking demand due to the limited number of garages as the buildings are old. As the sidewalks presented large widths, parking was allowed on part of the sidewalks in several cases. In some sidewalks, the entire vehicle is parked on the sidewalk and, in others, part of the vehicle is on the sidewalk. Therefore, sidewalks were shortened and space for pedestrians was reduced.

5% of the total area, 32,016 m^2, is used for parking. **Błąd! Nie można odnaleźć źródła odwołania.** shows the number of parking spaces and the occupied territory according to type of parking.

Tab. 5

Number of vehicles and area of parking

Type of parking space	0°	45°	90°	Total
Number of parking space	1,076	1,279	141	2,496
Area for parking [m^2]	13,450	16,627	1,939	32,016

Two thousand five hundred parking vehicles were counted during the on field measurement. As most of the parking spaces do not have delimitation painted on the floor, excessive space between vehicles may occur. Moreover, additional space needed for opening the doors will not be necessary with the use of AVs.

52% of the original space of the sidewalk was taken, leaving small space for pedestrians. In many situations, the space left is not enough for two people walking side by side. 8% of sidewalks are narrower or equal to 1.20 m, the smallest width is 0.9 m, which coincidently happens in the segment where parking space takes around 85% of the sidewalk. Near popular points of interest where the number of pedestrians is high, pedestrians must squeeze themselves to commute. Furthermore, some drivers park their vehicles taking more space than the delimited parking space, which reduces, even more, the available space for pedestrians and brings irregularities, presenting danger mainly to the disabled people [3,4,8].

4.2. Application of the method

The results considering the determined scenarios are presented in **Błąd! Nie można odnaleźć źródła odwołania.**6. Furthermore, **Błąd! Nie można odnaleźć źródła odwołania.** illustrates the result of multicriteria analysis relating the saved space with the correspondent percentage of the area of study, which allows better visualisation of the benefits. For calculating the saved space, the elimination of parking spaces at 90 and 45° were the priority as more space is occupied than the parking space with arrangement of 0°.

Tab. 6

Saved space in the area of study with use of AVs

Scenario	1	2	3	4	5
Saved parking spaces	238	2,229	2,357	791	948
Saved space [m^2]	3,200	29,083	30,747	10,389	12,430
Saved space [%]	0.47	4.24	4.49	1.54	1.85

Decision makers have an important question to answer regarding how saved space should be used. Considering the ideal scenario for having a more liveable city, decision makers should choose the use of a small percentage of the saved space for building pick-up and drop-off areas, for example, 20%, and the rest for green and open spaces. The possible new uses of the saved spaces are shown in **Błąd! Nie można odnaleźć źródła odwołania.**. The deployment of possible bike lanes, additional traffic lanes, parklets and docking spots in bike-sharing systems instead of parking spaces were examined. Parklets are defined as areas with benches and green spaces implemented in areas previously allocated to parking spaces. Their width has the same dimension as the previous parking space. The parklets were estimated with dimensions of 3.5x50 m, the width of bike lanes was assumed as 2.5 m to benefit the two directions of bike traffic, the width of traffic lane was assumed as 3.5 m and the space occupied per a docking spots was assumed as 1x2 m. During the calculation, the ambitious predictions of the modal shift[4] for 2030 in Budapest (walking: from 9 to 20%, cycling: from 2 to 10%) was considered.

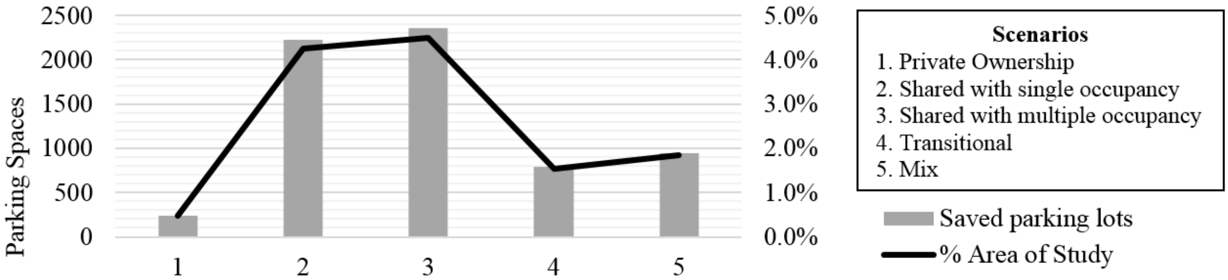


Fig. 5. Saved parking spaces and correspondent percentage according to the determined scenarios

[4] Budapest Transport Development Strategy 2014–2030

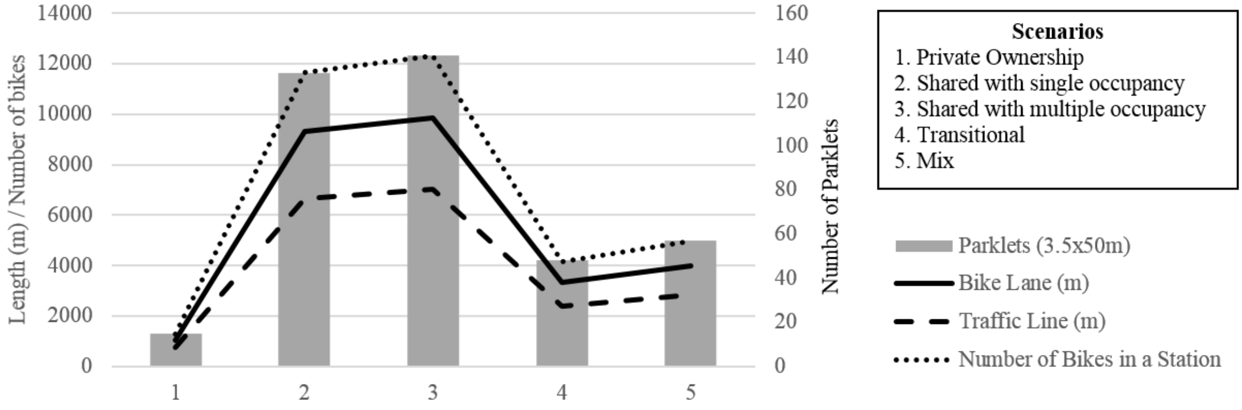


Fig. 6. New uses for the saved parking spaces. (Source: Author)

Besides the gained urban space, all of the saved space could be transformed into green spaces. Additionally, sidewalk expansions could be done, and the estimated length of the traffic lane may be provided for public transportation.

Furthermore, a small number of on-street parking spaces could be left for shared use. These spaces would be used by delivery companies, for loading and unloading, and by electric vehicle users for charging. Smartphone applications for booking a parking space may be very useful to improve the efficiency of the SAV service when planning stops for charging, cleaning and/or maintenance as well as when waiting for a new user.

Finally, the tendency of the presented results was expected. As there is an increase in the number of shared vehicles, there is more possibility of reducing the number of vehicles on the streets, and consequently, the demand for parking spaces. However, different results are brought depending on the city to which the method is applied as the needed parking spaces are influenced by the settlement structure, trip durations and distance travelled.

5. CONCLUSION

The introduction of AVs affects urban space management. However, the caused impacts have not been well known yet. Therefore, this study presented an estimation method for urban space transformation as the main contribution, considering the parking demand, the saved parking space and its reallocation.

It was found that the more SAVs fleet are used, the more savings in parking spaces are achieved which may receive new uses according to decision makers' priorities. Results showed that parking spaces can have new uses, such as the implementation of around 12,000 bike-sharing docking spots, 10 km bike lanes, 7 km additional traffic line or 140 'parklets'. The results presented practical applicability because they can suggest the intensity of changes in urban space management and serve as input in city planning.

The method should be adapted to local characteristics as parking habits, distribution and location of parking spaces may vary from one city to another.

Future research could consider local characteristics relating to the acceptance of AVs and the priorities of decision makers regarding the changes in urban space through a questionnaire survey. Furthermore, changes in population and in the location of households can be included.

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References

1. Boesch P.M., F. Ciari, K.W. Axhausen. 2016. „Autonomous vehicle fleet sizes required to serve different levels of demand”. *Transportation Research Record* 2542(1): 111-119. DOI: https://doi.org/10.3141/2542-13.
2. Correia G., D. Milakis, B. van Arem, R. Hoogendoorn. 2015. “Vehicle automation and transport system performance”. In: *Handbook on transport and urban planning in the developed world*, edited by M. Bliemer, C. Mulley, C.J. Moutou. P. 498-516. Cheltenham: Edward Elgar. ISBN: 978 1 78347 138 6.
3. Czech Piotr. 2017. „Physically disabled pedestrians - road users in terms of road accidents”. In: *Lecture Notes in Networks and Systems* 2: 157-165. DOI: 10.1007/978-3-319-43985-3_14. Edited by: Macioszek E., Sierpinski G. *Contemporary challenges of transport systems and traffic engineering*. 13th Scientific and Technical Conference on Transport Systems. Theory and Practice (TSTP). Katowice, SEP 19-21, 2016.
4. Czech Piotr. 2017. „Underage pedestrian road users in terms of road accidents”. In: *Advances in Intelligent Systems and Computing* 505: 33-44. DOI: 10.1007/978-3-319-43991-4_4. Edited by: Sierpinski G. *Intelligent transport systems and travel behaviour.* 13th Scientific and Technical Conference on Transport Systems. Theory and Practice (TSTP). Katowice, SEP 19-21, 2016.
5. Duarte F., C. Ratti. 2018. „The Impact of Autonomous Vehicles on Cities: A Review”. *Journal of Urban Technology* 25(4): 3-18. DOI: https://doi.org/10.1080/10630732.2018.1493883.
6. Fagnant D., K.M. Kockelman, P. Bansal. 2015. „Operations of shared autonomous vehicle fleet for Austin, Texas, market”. *Transportation Research Record* 2536: 98-106. DOI: https://doi.org/10.3141/2536-12.
7. Heinrichs D. 2016. “Autonomous Driving and Urban Land Use”. In: *Autonomous Driving*, edited by Maurer M., Gerdes J., Lenz B., Winner H. P. 213-231. Germany: Springer, Berlin, Heidelberg. ISBN: 978-3-662-48845-4.
8. Ignaccolo Matteo, Giuseppe Inturri, Nadia Giuffrida, Michela Le Pira, Vincenza Torrisi, Giovanni Calabrò. 2020. “A step towards walkable environments: spatial analysis of pedestrian compatibility in an urban context”. *European Transport \ Trasporti Europei* 76 n. 6. ISSN: 1825-3997.
9. International Transport Forum. 2015. *Urban Mobility System Upgrade - How shared self-driving cars could change city traffic*. Paris: Corporate Partnership Board Report. Available at: https://www.itf-oecd.org/sites/default/files/docs/15cpb_self-drivingcars.pdf.
10. Jacyna M. 1998. “Some aspects of multicriteria evaluation of traffic flow distribution in a multimodal transport corridor”. *Archives of Transport* 10(1-2): 37-52.

11. Jacyna M., J. Merkisz. “Proecological approach to modelling traffic organization in national transport system”. *Archives of Transport* 2(30): 43-56.
12. Koul S., A. Eydgahi. 2020. „The Impact of Social Influence, Technophobia, and Perceived Safety on Autonomous Vehicle Technology Adoption”. *Periodica Polytechnica Transportation Engineering* 48(2): 133-142. DOI: https://doi.org/10.3311/PPtr.11332.
13. KPMG. „Parking demand in the autonomous vehicle era”. Available at: https://home.kpmg/xx/en/home/insights/2017/07/parking-demand-in-the-autonomous-vehicle-era.html.
14. Llorca C., A.T. Moreno, R. Moeckel. 2017. „Effects of Shared Autonomous Vehicles on the Level of Service in the Greater Munich Metropolitan Area”. *International Conference on Intelligent Transport Systems in Theory and Practice.* Munich, Germany. Available at: https://www.bgu.tum.de/fileadmin/w00blj/msm/publications/moeckel/2017_llorca_etal.pdf.
15. RAC Foundation. „Spaced Out - Perspectives on parking policy”. Available at: https://www.racfoundation.org/assets/rac_foundation/content/downloadables/spaced_out-bates_leibling-jul12.pdf.
16. Schmidt Marie, Stefan Voss. 2017. „Advanced systems in public transport”. *Public Transport* 9(1-2) Special Issue: 3-6.
17. Soteropoulos A., M. Berger, F. Ciari. 2019. „Impacts of automated vehicles on travel behaviour and land use: an international review of modelling studies”. *Transport Reviews* 39(1): 29-49. DOI: https://doi.org/10.1080/01441647.2018.1523253.
18. The High Cost of Free Parking by Donald Shoup. Summarized by Tri-State Transportation Campaign. 350 W 31st Street, New York, NY 10001 p: (212) 268-7474 f: (212) 268-7333 www.tstc.org.
19. World Economic Forum. 2018. *Reshaping Urban Mobility with Autonomous Vehicles – Lessons from the City of Boston*. Geneva: World Economic Forum, 2018. Available at: http://www3.weforum.org/docs/WEF_Reshaping_Urban_Mobility_with_Autonomous_Vehicles_2018.pdf.
20. Zhang W., S. Guhathakurta, E.B. Khalil. 2018. „The impact of private autonomous vehicles on vehicle ownership and unoccupied VMT generation”. *Transportation Research Part C: Emerging Technologies* 90: 156-165. DOI: https://doi.org/10.1016/j.trc.2018.03.005.
21. Zhang W., S. Guhathakurta, J. Fang, G. Zhang. 2015. „Exploring the Impact of Shared Autonomous Vehicles on Urban Parking Demand: An Agent-based Simulation Approach”. *Sustainable Cities and Society* 19: 34-45. DOI: https://doi.org/10.1016/j.scs.2015.07.006.
22. Zhang W., S. Guhathakurta. 2017. „Parking Spaces in the Age of Shared Autonomous Vehicles”. *Transportation Research Record: Journal of the Transportation Research Board* 2651: 80-91. DOI: https://doi.org/10.3141/2651-09.

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