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CHANGES IN TRAFFIC INFRASTRUCTURE WITH THE ARRIVAL OF AUTONOMOUS VEHICLES

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Abstract

Autonomous vehicles represent a significant step forward in traffic safety and efficiency. Although it will be quite some time before all vehicles on public roads are autonomous, it is certainly advisable to consider the changes that will need to be introduced to traffic and traffic infrastructure. Autonomous vehicles will significantly increase the efficiency and use of public transportation and car-sharing, which will ultimately mean fewer cars on the roads and less need for parking in urban areas, or their conversion into a type of waiting area. Also, fewer vehicles, whose software has a drastically faster reaction time and much better control of the vehicle, will also mean less traffic jams, greater intersection flow, less need to channel traffic in traffic lanes and will remove traffic lights almost entirely out of use. This paper will look at the form of transport infrastructure and its variants in the case of mixed traffic with autonomous vehicles and drivers, as well as the situation with fully autonomous traffic without people behind the wheel.

Keywords: autonomous vehicles, traffic infrastructure, drivers, AI (Artificial intelligence), car sharing

1 Introduction

Today's transport infrastructure has been developed for hundreds of years in order to adapt to vehicles and the transport of people and goods. With the growth of the economy and society, the need for greater infrastructure is also growing. With the advent of smart vehicles and the development of computer science and its aspects such as artificial intelligence, infrastructure must also take on new and modern features in order not to lag behind. However, the parameters used today in the design of transport infrastructure are oriented to the physical and mental abilities of drivers [1]. With the already mentioned arrival of smart vehicles, the human factor in traffic will be gradually eliminated, and the project parameters will take on new values. This paper will present the current state of road transport infrastructure in which the human factor is dominant, and will also present a variant of road infrastructure in which the human factor does not play a role in driving vehicles (personal and public). Proposed guidelines will be given for the transition period in which traffic will be mixed and where the role of decision-making in traffic will be played in one part by drivers, and in the other part by autonomous systems, i.e. artificial intelligence. In this paper, the focus will be only on the road part of the transport infrastructure.

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2 Overview of the elements of the existing transport infrastructure

Although urban and out-of-town transport infrastructure consists of equal elements, it is noticeable that the urban part of the infrastructure, both transport and others, is significantly more complex. Traffic in urban areas includes many more modalities and it is necessary to take into account pedestrians, people with disabilities, cyclists, cars, trucks, public transport vehicles, tram tracks and the like. It can be said that the urban infrastructure is less subject to strict compliance with the rules, and focuses more on engineering solutions that sufficiently meet the rules and satisfy all traffic participants.

2.1 Urban transport infrastructure

Given multimodality, urban infrastructure consists of many different elements that affect its use and utilization of available space. In addition to roads in urban areas, parking spaces (private, public, as well as garages) play a major role in planning and utilization of space. Existing parking spaces are becoming insufficient for the growth of the number of personal vehicles, and there is a need to increase them [2]. The current dimensions of parking spaces for their comfortable use by drivers are becoming undersized due to the dimension growth of vehicles [3] (Fig. 1), and the current regulations have not been updated with regard to the size of the personal vehicle [4]. Therefore, there is a need to increase the existing parking spaces or to find new locations for them.

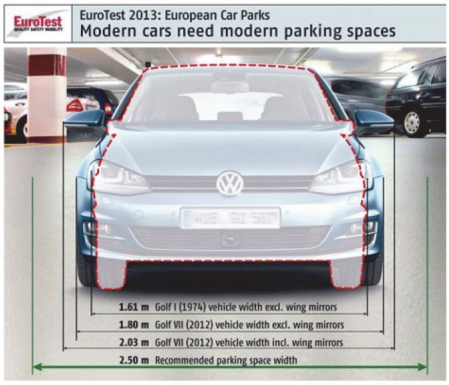

Figure 1 Display of the growth of the dimensions of the same car model over the years in relation to the standard width of the parking space [5]

Intersections in urban areas come in a variety of shapes and sizes and mainly consist of multiple traffic lanes. Such intersections are also guided by significant vertical and traffic lights. It follows from all this that intersections take up a lot of space and that with the growth in the number of personal vehicles, they will potentially require even more space. As most urban areas are extremely limited by free space, the solution for such situations is to remove the surrounding buildings in order to free up space for a larger classical intersection or for a roundabout. Otherwise, over time, there will be increasing traffic jams at intersections that are not designed for such a large number of vehicles. Signalization (horizontal and vertical) is an important factor in traffic management, but it is still there mostly because of people, because of the reduction of the possibility of human error and release from liability in the event of a traffic accident [6].
Another element of urban infrastructure and traffic is public transport. It includes vehicles of different dimensions as well as infrastructure elements such as bus and tram stations that are incorporated into the city network. Although these are additional elements of the urban

environment that are not so much in the out-of-town road network, they are there to reduce traffic congestion and the number of other vehicles on the roads and make the transport of people and goods more accessible and cheaper. Pedestrians and cyclists are also part of the traffic in urban areas and enter the traffic network with pedestrian paths and bicycle paths and lanes. All these elements need to be kept in mind, both when designing urban infrastructure and even more so when participating in traffic in the urban environment. The goal of the designer is to make all elements of the infrastructure as simple, intuitive and understandable as possible, because the people who will use it are prone to mistakes, carelessness, fatigue and similar other characteristics.

2.2 Out-of-town infrastructure

The out-of-town road network consists of motorways and state roads at a higher level and county and local roads at a lower level. At both levels, the existing road network needs to increase capacity due to the increasing number of people [7] traveling by car or intercity, which is reflected in the widening of the cross-section of the road or the use of existing pavements for additional lanes, which means lower traffic speeds. Highways and state roads require a high level of maintenance and equipment. Although they are designed for higher design speeds, their main characteristics derive from the way people use vehicles and from all the aforementioned characteristics of human drivers. Given the higher speeds of movement, it is necessary to ensure larger fields of view on out-of-town roads, both horizontally and vertically. Also, due to the human characteristic of fatigue and deconcentration, certain sections of roads are designed with curves although they could be designed as a straight line [1]. Thus, although out-of-town transport infrastructure is simpler than urban and is not so limited by space and a multitude of transport modalities, most of the design parameters still derive from the anthropocentric design system.

3 Infrastructure for fully autonomous traffic

When we talk about fully autonomous vehicles and fully autonomous traffic, locally or globally, we are talking about the end of an anthropocentric design system in which all elements of infrastructure are subordinate to human. In such traffic where human does not make decisions as a driver and artificial intelligence manages everything, it means that the infrastructure for this traffic no longer has to be understandable to human, does not have to be intuitive and adapted to the human mind to understand it faster and easier. The transport infrastructure should be adapted so that the software and hardware can interpret it as easily as possible. This implies completely new project parameters and significant simplification of the infrastructure and, ultimately, its reduction.

3.1 Urban transport infrastructure

After real estate, in many cases, a personal car is the biggest investment for many people. But despite this, people use cars on average 4 % of the time [8]. During this time, the car loses value and requires additional investment in the form of maintenance and repairs. The market already understands this fact, which has resulted in the establishment of companies with new forms of taxi services. Fleets of such taxi companies are growing, and companies are investing in the development of autonomous vehicles to make their fleet cheaper, safer and more cost-effective. With enough such companies having ever-growing fleets of autonomous vehicles on the roads, car sharing will replace owning a personal car and in the future all cars as well as other vehicles will be autonomous. When the time comes that all vehicles in traffic are autonomous, traffic should become much more efficient, faster, simpler and

cheaper. In that case, the transport infrastructure should be adapted to this and therefore take on a completely new look. Parking spaces will be almost completely eliminated from cities as vehicles will be constantly in operation [9]. Intersections will have a minimum number of lanes and traffic management in this way will no longer be necessary. Vertical signaling will be largely unnecessary, while horizontal signaling will always have to be ideal.
Thus, the transport infrastructure will experience downsizing. It will require enhanced maintenance to avoid errors in communication between the infrastructure and the vehicle. It will be necessary to introduce some new elements just for better communication between the vehicle and the infrastructure, which will mean the removal of traffic lights and traffic signs from use. But as vehicles will not only communicate with the infrastructure, but also with each other, traffic rules will change and the right of way at intersections will be almost unnecessary because every vehicle will know the trajectory and speed of all surrounding vehicles at all times.
When creating future regulations, guidelines, etc., special attention will need to be paid to the points of conflict between autonomous traffic and other participants (pedestrians, cyclists). Participants in traffic outside autonomous vehicles are the most endangered participants in traffic and it is necessary to find the best possible solution how to include them in traffic next to autonomous vehicles and ensure their mobility, which they still have today, while being protected. Artificial intelligence-driven vehicles will be able to anticipate and control conflict situations [10], but pedestrians and the like will have to go through a phase of getting used to and learning how to behave in such traffic. Because of them, traffic signals, although unnecessary for autonomous vehicles themselves, will be a necessity for other road users.

3.2 Out-of-town infrastructure

Although urban infrastructure will experience significant donwsizing, this may not necessarily be the case with the out-of-town road network. The design elements will not change significantly as the vehicles will still be subject to the same laws of physics as today. Radius, widenings, slopes and other elements will remain unchanged. What will change are the need for visibility fields as well as the need for sufficient stopping visibility given that when braking, the drivers reaction time will no longer be a variable. And with V2V (Vehicle to vehicle) communication [11], in case they have to, all vehicles can decelerate at the same time with equal intensity in the convoy. Traffic lanes and road widths will be able to be reduced, as will sidewalks, but as in the case of urban infrastructure, horizontal signage will need to be impeccably maintained and executed.

4 Transition period

As long as people in traffic participate as drivers, the infrastructure will have to be tailored to them as well, no matter how few human drivers there are. But with smart and gradual decisions, it will be possible to adapt the infrastructure to both human drivers and autonomous vehicles, just as it will be possible to motivate people to stop being drivers. If the elements of infrastructure described above are considered and placed in the context of mixed traffic, with an understanding of how autonomous vehicles function and can function, the evolution of these elements can be predicted.
With the growth of autonomous vehicles, personal vehicle ownership will be declining and car sharing on the rise. This means that people will have less need for parking spaces where they will leave their cars. Lower demand for parking spaces will result in less and less supply and in conversion of excess space. In mixed traffic, this will mean that the number of parking spaces needed by human drivers will be retained in urban areas, and if it is assumed that au-

tonomous vehicles (taxis) will be in operation almost constantly and will rarely have to park for long periods, for them there will be no need for parking spaces but certain stations where it will be possible to stay for a shorter time or slow traffic lanes where empty vehicles will be able to circle slowly in the convoy until they are called for use. In larger cities where parking is problematic and where parking buildings have been built, this will also mean relieving traffic and repurposing garage space [9]. Of course, during the night or certain days of the year when movements are declining, autonomous vehicles will also have to be parked somewhere. For such situations, certain areas outside cities can be converted into storage areas for autonomous vehicles. Although this means that the total amount of parking spaces has not decreased significantly and they have only moved from the city center to the outskirts, the occupied area for stationary vehicles will still be smaller if we take into account that autonomous vehicles do not need parking lots of the same dimensions as cars that are human operated. With time and less and less use of personal vehicles, parking spaces will disappear from urban areas [9] and this area will be available for use by pedestrians, cyclists, etc. If we look at intersections in mixed traffic and the same case of the growth of car-sharing and the decline in car ownership, it is possible to suggest steps to adjust the intersection. In the very beginnings of mixed traffic, in a multi-lane intersection, certain lanes can be adapted to be used exclusively by autonomous vehicles as is the case with special lanes for buses and fire trucks in some cities (Fig. 2). With the gradual increase in the number of autonomous vehicles, the number of dedicated lanes may also increase in order to increase the flow of intersections. In addition to lane adjustment, intersections need to be equipped with additional horizontal and vertical signaling and other equipment for I2V (Infrastructure to vehicle) and V2I (Vehicle to infrastructure) communication [11]. Some autonomous vehicles are already used today on some of the busiest roads in the world [13] (Fig. 3).

Figure 2 Example of a lane reserved for buses (taxis and cyclists), which can be used for autonomous vehicle traffic [12]

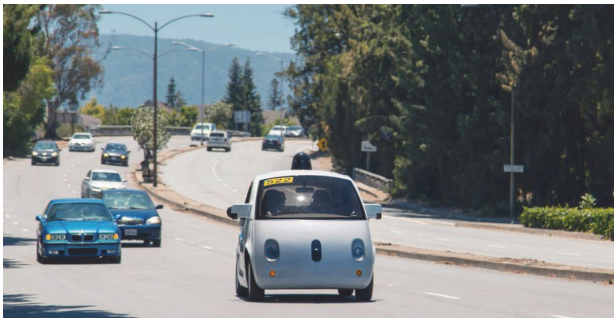

Figure 3 Example of an autonomous vehicle from Waymo LLC without a driver driving on an American road [14]

In the out-of-town part of the road network, the same approach can be used as for intersections. On motorways and other multi-lane roads, one lane can only be used for autonomous vehicles. As the number of these vehicles increase, the number of dedicated lanes may increase, but their characteristics may also change. One autonomous lane will be able to be used only for trucks and the other for smaller passenger vehicles. In another variant, one lane can be used for slow driving and the other for fast driving. In the case of multiple lanes, multiple variants are possible. What will differentiate these autonomous lanes from normal lanes is the ratio of comfort to vehicle volume. Autonomous vehicles will be able to ride in a convoy, very close to each other, like a train wagon. In the case of the human behind the wheel in such a situation, mistakes are almost inevitable and can be fatal. But in the case of autonomous interconnected vehicles in their own lane, errors are reduced to an absolute minimum. The gradual growth in the use of car sharing will gradually change the transport infrastructure, not only for drivers and vehicles, but also for pedestrians and cyclists and for other forms of personal mobility that do not include road traffic. The removal of parking spaces will mean larger pedestrian and bicycle corridors, and will even open up places to build tram tracks in city centers. Ways in which infrastructure can be gradually adapted to mixed traffic and autonomous traffic, include increased maintenance of roads and road equipment, introduction of new infrastructure elements and elimination of some existing elements, as well as redistribution and redesign of certain elements.

5 Conclusion

Although autonomous vehicles are already relevant today, it will be many more years before they fully assume a human role in traffic. This mostly depends on the change of business models of existing large car manufacturers and on the acceptance and testing of such vehicles by the market. This gives infrastructure designers a certain advantage because the future is predictable and it is possible to prepare well for major changes in traffic. However, the problem of the construction sector and infrastructure is very low agility and poor ability to progress and adapt quickly, as well as the fact that investments in infrastructure are large and demanding. While on the other hand there are car manufacturers that are much more agile in adapting to new market demands and the IT sector which is extremely agile and changing on an almost daily basis. Therefore, it is clear that autonomous vehicles will get on the roads long before the infrastructure is ready for it. In order to avoid late adjustments to such traffic and, if possible, to speed up the arrival of such traffic on public roads, it is in everyone's best interest for infrastructure designers to work closely together with the automotive industry and the IT sector. Given that autonomous vehicles are already used today on some of the busiest roads in the world, it is evident that significant infrastructural adjustments are not currently necessary for autonomous vehicles operating in traffic. But in the case of cooperation of the mentioned sectors, the infrastructure could experience rapid and economically viable changes that would significantly facilitate the work of the IT and automotive sectors to develop autonomous vehicles and put them on the market faster. Those sectors should be the ones to instruct infrastructure designers on how to design the infrastructure so that vehicles can use it in the best and safest way.

References

[1] Korlaet, Ž.: Uvod u projektiranje i građenje cesta, Građevinski fakultet Sveučilišta u Zagrebu, Zagreb, 1995.

[2] Eger, R.: Critical desing parameters for garages, Građevinar, 65 (2013) 6 pp. 547-552, doi:10.14256/JCE.806.2012

[3] Jato.com, https://www.jato.com/suv-registrations-set-record-accounting-1-4-cars-sold-europe-2016/, 20.05.2020

[4] Republic of Croatia: Pravilnik o prometnim znakovima, signalizaciji i opremi na cestama, Narodne novine, NN 92/2019.

[5] Eurotest 2013, European car parks, https://www.thelocal.es/userdata/images/1392291994_Untitled-1.jpg, 20.05.2020.

[6] Cerovac, V.: Tehnika i sigurnost prometa, Fakultet prometnih znanosti, Zagreb, 2001.

[7] Croatian Bureau of Statistics, Registered road vehicles and road traffic accidents, 2019, https://www.dzs.hr/Hrv_Eng/publication/2020/05-01-04_01_2020.htm, 16.04.2020.

[8] Bates, J., Leilbing, D.: Space Out - Perspective on parking policy, London, RAC Foundation, 2012.

[9] Millard-Ball, A.: The Autonomous Vehicle Parking Problem, Transport policy, 75 (2019), pp. 99-108

[10] Science Alert: Tesla's Autopilot Predicts a Crash Freakishly Early, https://www.sciencealert.com/watch-tesla-s-autopilot-predicts-a-crash-freakishly-early, 20.05.2020.

[11] Steyn, W.J.vdM, Maina, J.W.: Guidelines for the use of accelerated pavement testing data in autonomous vehicle infratructure research, Journal of traffic and transportation engineering, 6 (2019) 3, pp. 273-281, doi: https://doi.org/10.1016/j.jtte.2019.05.001

[12] Hawlisch, M.: Bus lane, 2006. https://simple.wikipedia.org/wiki/Bus_lane#/media/File:Busspur_und_Haltestelle_in_Mannheim_100_9128.jpg, 20.05.2020.

[13] aDigitalNomad.net: Tesla autopilot 2019.16.2 vs New York City heavy traffic, https://www.youtube.com/watch?v=hNKBfeHmGjI, 27.05.2020.

[14] dw.com: https://www.dw.com/image/39629871_403.jpg, 20.05.2020.