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# THE HISTORY OF THE TRANSPORT SYSTEM DEVELOPMENT AND FUTURE WITH SHARING AND AUTONOMOUS SYSTEMS

*The world today is rapidly changing with the spread of automation. Moreover, urban life is more and more common and the number of inhabitants is rapidly growing. This time is the renaissance of bicycle-based vehicles, especially of electric power assisted bicycles. Vehicle sharing is also getting more popular. These progresses will have a crucial effect on traditional transportation networks. Moreover, the traffic volume, parking facilities and public space usage can be drastically modified. A research data is introduced from Paris and Lisbon, which helps to forecast the effect of the autonomous and sharing systems. This evolution can be advantageous, but it can also bring some disadvantages. In this article, these changes are summarized in the mirror of history, especially the Futurama concept and the transport system changes in Los Angeles. This overview will be a good basis for further research and for the development of a routing algorithm.*

**Keywords:** smart city, multimodal, autonomous, sharing

## 1 Introduction

Autonomous development is more and more in the focus of all the developers in the transportation industry. Tesla [1] and Google [2] are the biggest from the IT sector, but conventional car builders also invested a lot in this research area. Not just the automotive sector, but train [3] and aircraft [4] manufacturing companies also take part in this improvement, and their aim is to achieve the biggest available cost savings. This can be realized by cutting down operational costs and by reducing the probability of accidents. Moreover, in the case of the rail industry the infrastructure optimization is also a key factor [5]. Furthermore, the smart city concept can also be effective and be a part of these developments. The evolution of the smart city concept was in the highlight of a study, with the intent to summarize and determine the content of the concept [6]. The outcome was that the definition is still forming, the content is expanding and 'smart city' trends cover the environmental, the digital and the social part of the life, as well. This also has an effect on Urban planning which was examined by Koryagin [7]. Moreover, the smart city conception can affect the transportation performance. These characteristics and the possible changes are also determinative [8].

In the case of a passenger transport in a multimodal transport chain, the level of comfort and available parking spots are the most important factors. This was researched and three scenarios were modeled in [9]. The three alternatives are the following: the first is traveling only with a private car; the second is that the decision can be made between using a private car or using the public transport

with a P+R facility and the third alternative considered the personal comfort additionally. This area was also examined by Kirchler [10]. The effect on the environment was also examined from the viewpoint of parking [11].

The environmental impact must be taken into account, as well, regarding the level of pollution and the resources used by the transportation. This, especially the CO<sub>2</sub> emission was in the main focus of a study made at Altau University [12]. The effect on environment was also examined from the viewpoint of parking [13]. One should not forget the economic aspects [14]. Furthermore, the special case of logistics has to be taken in account, as well [15].

Regarding autonomous operation, the acceptance by the society is also a key factor. A wide range survey was made in 2014, which focused on opinion of the common people [16]. Moreover, ethical questions cannot be neglected, either [17]. Furthermore, the testing procedure is also a key factor in this case [18]. In other studies, some predictions were made to sum up the possible advantages and disadvantages of the role of autonomous transportation [19-20]. In addition, the traffic distribution need to be considered, as well [21]. With the usage of the autonomous systems, the door-to-door transport can be made easier. A review was made to summarize the accessibility of the public transport [22].

This article is an extension of a conference paper [23]. That paper focused only on the role of autonomous cars. In this article, their effect on the public transport and the possible function of autonomous vehicles in public transport is presented. One of the inspirations to widen our study was a presentation about the trends and opportunities in the future cities [24].

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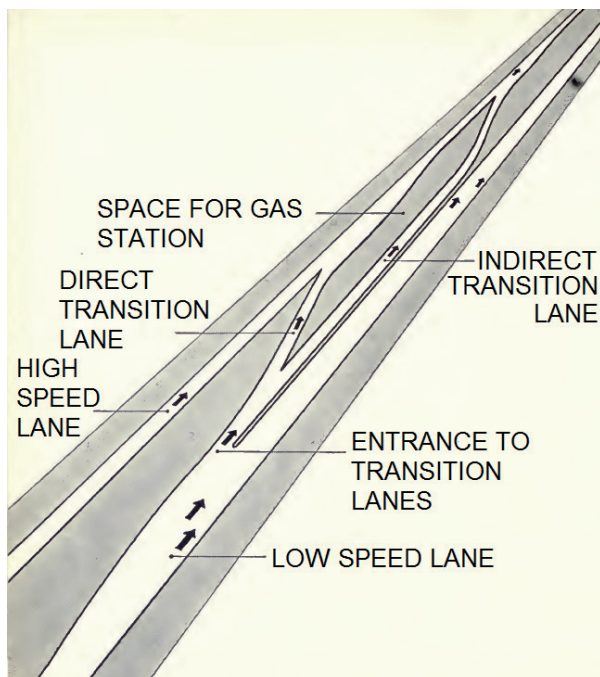
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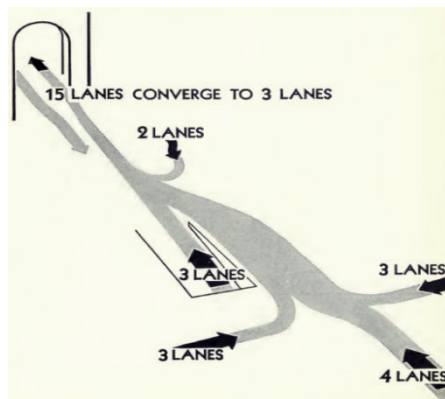
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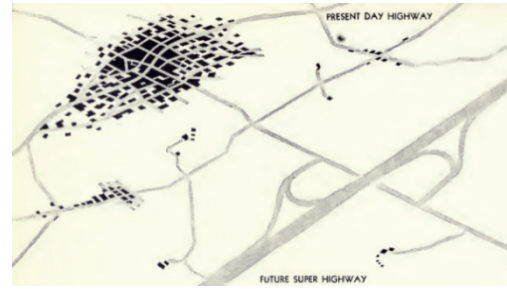
**Figure 1** Safe (in the arm of Jesus) [27]



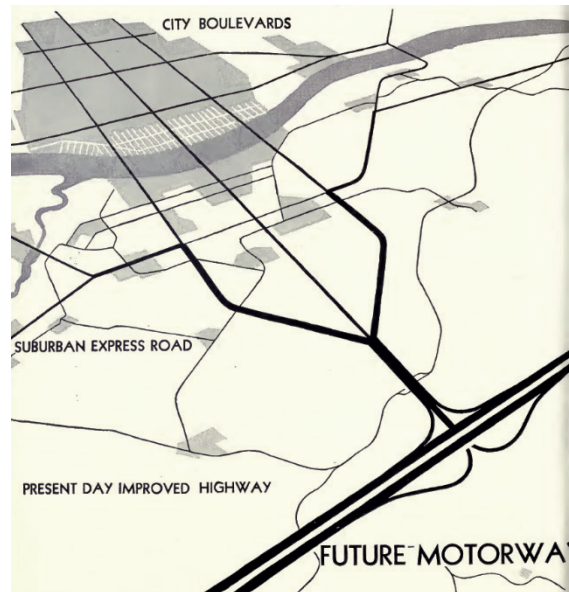
**Figure 2** Transit from one speed to another [27]



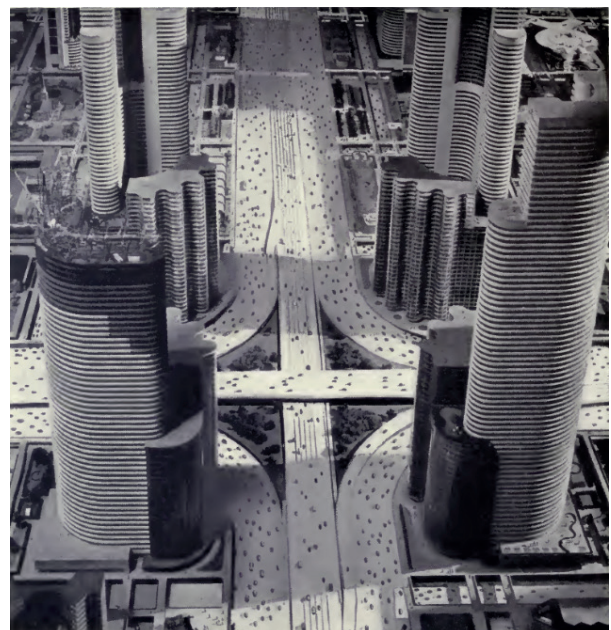
**Figure 3** George Washington bridge approach problem [27]



**Figure 4** Motorway feeders from farm and village [27]



**Figure 5** Motorway feeder to city [27]



**Figure 6** Express boulevards are the main arteries for the through city traffic [27]

Regarding the research listed above, there is an active discussion to find some solutions for the problems caused by urbanization. There are several possible answers, such as the smart city concept, the autonomous driving and

the Futurama concept - even though it is quite old. The hypothesis is that autonomous vehicles alone cannot solve the traffic congestion problems.



Figure 7 Commuting radius extension

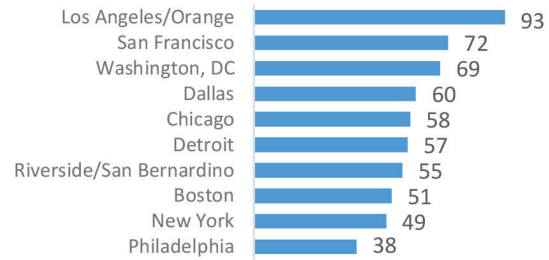


Figure 9 Annual hours of delay per Traveler by Metropolitan Area, 2003 [30]

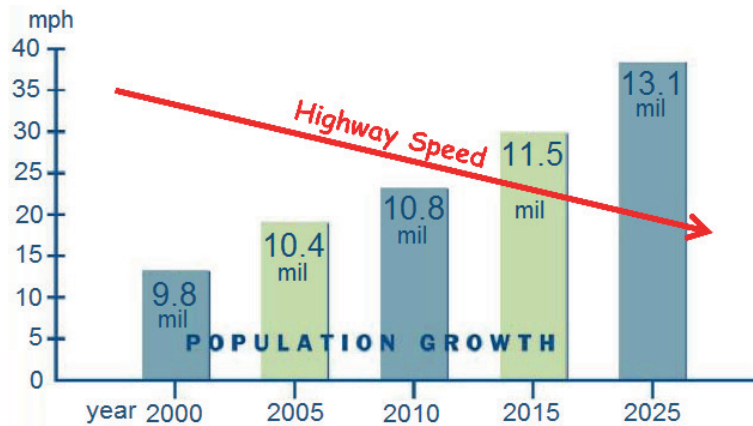


Figure 8 Comparison of population growth and highway speed [28]

## 2 The Futurama concept

In 1939, a new approach was presented in connection with transportation at the New York World's Fair [25-27]. The expo's aim was to predict the trends of the next 20 years. One of the main sponsors of the event was General Motors Corporation. Norman Bel Geddes collected his thoughts about this future in a book [27]. He saw the future in automation. One of the main reasons was to avoid accidents (Figure 1). This is still the core basis of autonomous development.

In this book, the answer for the safety, comfort, speed and economy questions was the concept of highways in and out of cities. The concept of changing between different travel speeds is depicted in Figure 2.

The identified core problem was the change (decrease) of number of lanes, which caused a bottleneck effect (Figure 3).

The connection concept of the smaller cities was the following (Figure 4).

In the case of bigger cities, the following model was proposed (Figure 5).

Image of the city center is presented in Figure 6.

A prediction for the commuter traffic was that the commuting radius can extend 6 times with this concept (Figure 7).

## 3 The effect of the Futurama

This concept had the most impact on the city of Los Angeles (LA). Therefore, the transportation changes are

summarized according to the Futurama with the history of LA.

The Transportation Research Library & Archive made a great collection of the milestones of the developments of transportation in LA [28].

The milestones, according to Barrett, were the following: in 1870s, a horse-drawn system was installed in the city. In the next decade, cable cars replaced the horse power, which was needed due to the rapid growth of the population and transit. This system was highly unreliable because of the dirt in the cable tubes, which caused freezing during operation. Therefore, this system was changed in the 1890s to electrically powered cars. This caused a rapid expand in the network.

Some decades later, a slow degradation was starting. The principles of business started to change before and after the Second World War. The maintenance costs of the network - such as the replacement of old vehicles, the renewal of the stations and tracks - became a priority problem to the local and federal governments. The fares were artificially kept low due to political interests. Additionally, the car became a status symbol. Moreover, General Motors began to sell air-conditioned and air-suspended buses with 45 seats. Operators predicted that the freeway system would accommodate and speed up the buses. As a result of these processes, the last rail line was closed in 1963.

In the following decades, the bus was the core of public transport although a public discussion focused on a monorail and metro system. Those times were also characterized by innovative and special solutions that were intended to sustain public transport without a high capacity

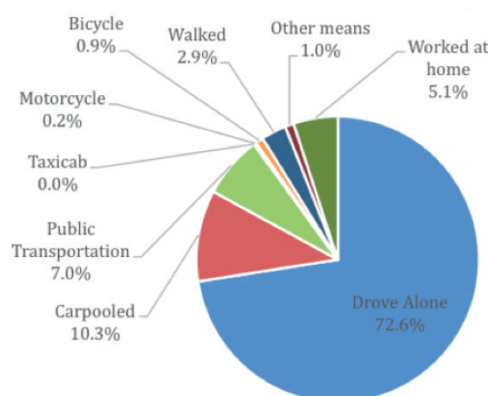
**Table 1** Modal-split in 2005 in Los Angeles [30]

Subject	Total	Male	Female
Workers 16 years and over	1,662,238	954,410	707,828
MEANS OF TRANSPORTATION TO WORK			
Car, truck or van	79.50%	81.00%	77.50%
Drove alone	67.80%	68.90%	66.40%
Carpooled	11.70%	12.10%	11.10%
In 2-person carpool	9.00%	9.20%	8.70%
In 3-person carpool	1.70%	1.90%	1.50%
In 4-or-more person carpool	0.90%	1.00%	0.90%
Workers per car, truck or van	1.37	1.34	1.4
Public transportation (excluding taxicab)	10.30%	9.30%	11.70%
Walked	3.20%	2.90%	3.50%
Bicycle	0.60%	0.90%	0.20%
Taxicab, motorcycle, or other means	1.70%	1.80%	1.50%
Worked at home	4.70%	4.00%	5.70%

**Table 2** Fleet size for different TaxiBot and AutoVot scenarios (% of current Lisbon car fleet, 24-hour weekday average) [33]

			Fleet size	% of baseline
Baseline			203 000	
100% shared self-driving fleet	Ride sharing (TaxiBot)	No high-capacity public transport	25 917	12.8
		With high-capacity public transport	21 120	10.4
	Car sharing (AutoVot)	No high-capacity public transport	46 249	22.8
		With high-capacity public transport	34 082	16.8
50% private car use for motorized trips	Ride sharing (TaxiBot)	No high-capacity public transport	13 265+194 537*	102.4
		With high-capacity public transport	10 900+147 767*	78.2
	Car sharing (AutoVot)	No high-capacity public transport	22 887+194 275*	107.0
		With high-capacity public transport	18 358+148 050*	82.0

\* = shared + private cars



**Figure 10** Modal-split in 2015 in Los Angeles [31]

core network. After several public vote fails, the first high capacity light rail line was opened in 1990 [29] and since then the network has been rapidly expanding.

Due to the high mobility and motorization, the highway speed was constantly decreasing along with the population

growth (Figure 8) and the time spent in traffic jams was also increasing (Figure 9).

In 2005, a Census was made and data was also evaluated in connection with transportation (Table 1). Ten

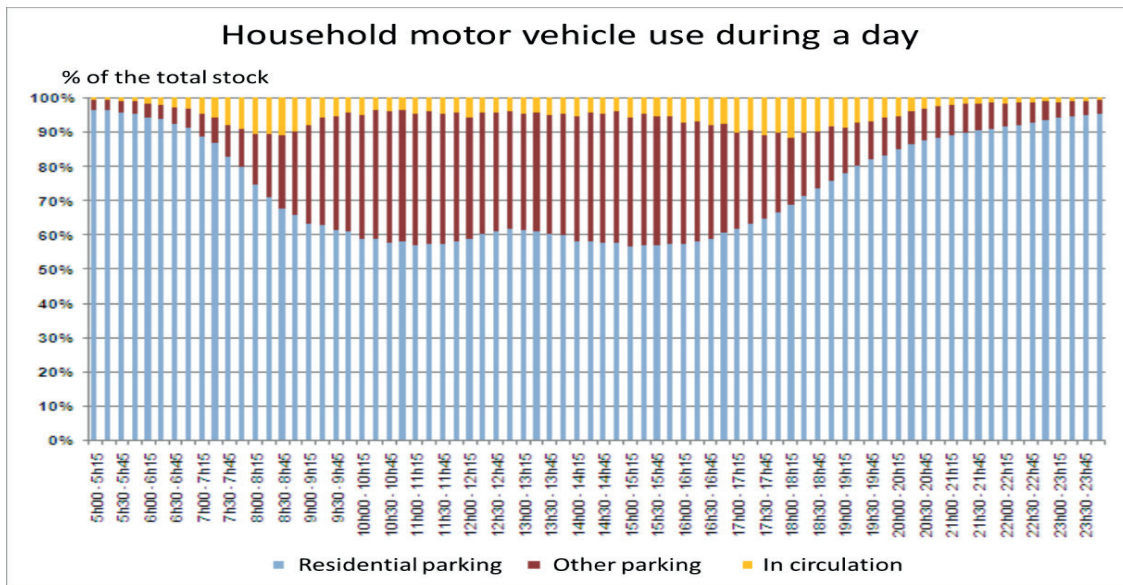


Figure 11 An average car is parked approximately 23 hours a day [32]

Table 3 The Automated levels for driving (SAE 2014) [19]

	SAE level	Name	Execution of steering and acceleration / deceleration	Monitoring of driving environment	Fallback performance of dynamic driving task	System capability (driving modes)
Human driver monitors the driving environment	0	No automation	Human driver	Human driver	Human driver	n/a
	1	Driver assistant	Human driver and system	Human driver	Human driver	Some driving modes
Automated driving system monitors the driving environment	2	Partial automation	System	Human driver	Human driver	Some driving modes
	3	Conditional automation	System	System	Human driver	Some driving modes
	4	High automation	System	System	System	Some driving modes
	5	Full automation	System	System	System	All driving modes

Table 4 Possible autonomous vehicle usage [19]

	Advantages	Disadvantages	Potential group of users
Personal autonomous vehicles - self-driving vehicles in private ownership.	Continuous availability. The private property can be stored in the vehicle.	A vehicle that meets the travel aim cannot be chosen for each trip. High costs.	Frequent travelers on a daily base, and/or the car is used as a storage for private property.
Shared autonomous vehicles - Self-driving taxis, door-to-door service for the users.	A vehicle for the actual need can be chosen. Door-to-door service.	Waiting for a car is possible. No personal staff (driver). The car can be dirty after the previous user.	Not so frequent travelers.
Shared autonomous rides - Self-driving vans (micro-transit) take passengers to or near destinations. Supplementary service for public transport systems.	The cost will probably be the lowest.	The comfort level will be the lowest, the travel time probably will be higher.	Occasional trips.

years later, driving alone was getting more common (Figure 10).

The Futurama concept had the highest impact on the transportation methods of the USA, but the rest of the world

was also concerned. A survey was made about the daily car usage in Paris (Figure 11).



Figure 12 In Seattle, parking spaces were designated for dockless bikes [34]



Figure 13 Singapore is still improving its dockless bike-sharing regulation [35]

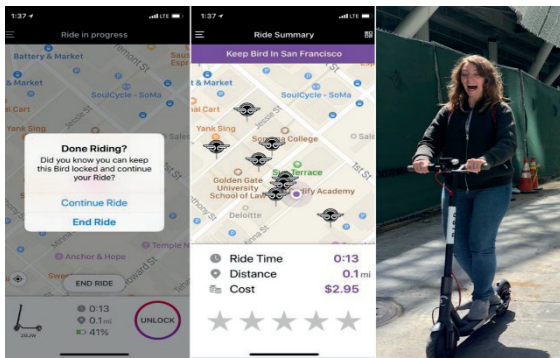


Figure 14 Bird electric scooters are taking over San Francisco [36]

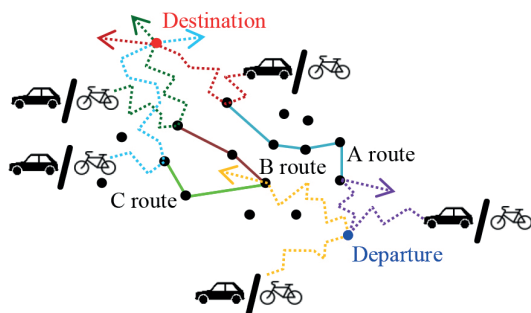


Figure 15 Traditional public transport with the new age solution

Based on this survey, only 10% of the vehicles are in the traffic flow in peak hours and 90% are parking mainly at home or other locations, especially at the working place.

According to this, only 10% of the cars are causing the traffic jams. In 2015, the International Transportation Forum published a report about the shared self-driving cars [33]. This study was based on experiences of the Autonomous taxi system for New Jersey and the taxi

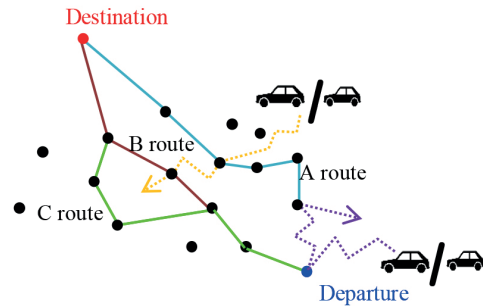


Figure 16 Traditional public transport with the new age solution during the trip

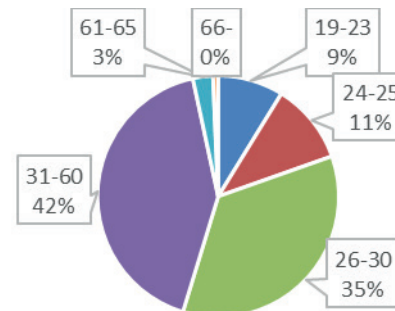


Figure 17 Age distribution

### Importance of punctuality

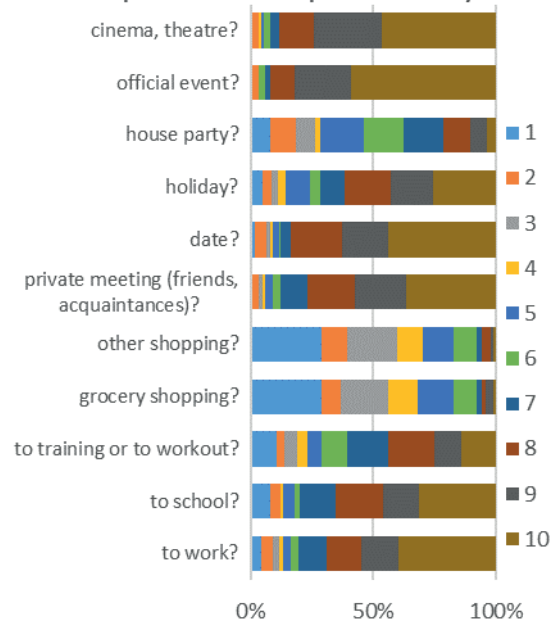


Figure 18 Importance of punctuality

pooling for New York City. The subject of the research was the city of Lisbon.

Based on Table 2, in the case of the 100% shared self-driving fleet with a high-capacity public transport, the actual car fleet size can be reduced by 90%. In the light of the car usage survey [32], this - in general - can cause elimination of the actually not used (parking) cars, but there will be no significant effect on traffic jams and road capacity. Based on

**Table 5** *Employment status*

Status	Percent
Employee	70.55%
Entrepreneur	0.68%
Middle manager	13.01%
Pensioner	0.68%
Volunteer	0.68%
Student and part time employee	1.36%
Student	13.01%

this, autonomous cars cannot replace, but only supplement the high-capacity public transport.

## 4 Supplement transportation

### 4.1 Autonomous vehicles

Definition of autonomous transport was created based on the Society of Automotive Engineers (SAE) classification [19], this is presented in Table 3 and the possible role of the car is summarized in Table 4.

According to data presented in Table 3, only level 5 is suitable for use of autonomous service.

The most effective solution for society is the shared autonomous ride that requires much less parking facilities, but the economic effect, especially for car producers, can be negative due to decrease in the number of sold cars.

### 4.2 Bike, scooter share

Traditional bike sharing systems are used worldwide nowadays. They are usually based on a fix docking network. This type of system is working properly, but it usually serves only the high density areas in the cities, if the operation costs and effectiveness are taken into consideration. Moreover, the docking stations mean a restriction for users. Therefore, some operators started to develop dockless solutions.

The greatest advantage of the dockless system is that the user can leave the bicycle anywhere. On the other hand, this can cause a mess in the cityscape. Therefore, parking places for bikes were created as a solution in Seattle (Figure 12) and in Singapore (Figure 13).

In addition to electric bikes, a new solution is underway. This is the electric scooter, which reduces the required space and gives more flexibility to the user. A service was started in San Francisco (Figure 14).

## 5 Public transport and the new age transport solutions

Considering the possible cooperation between traditional public transport, different sharing solutions and the autonomous vehicles based on the Futurama

experiences and the research outcomes, it can be concluded that the public transport can only be supplemented with these solutions and cannot be fully replaced by them. Therefore, the low density areas can be served by the autonomous solution, but bike and scooter sharing systems are the best solutions for the high density city center. A schematic model is created to demonstrate this (Figure 15).

Those solutions cannot be used only to take the so-called last mile, but also to change between the high capacity transportation lines (Figure 16).

In this case, the autonomous vehicle operates as a taxi and the bike/scooter sharing system as a dockless solution.

## 6 Survey data

In 2017, a preliminary survey was made to examine the people's relationship with travelling. This survey distinguished between commuters and those going on leisure trips. A part of the results is published in another article [37]. The aim of this survey was to measure the effect of different factors on the user decisions according to the travel mode and the route planning. Due to the preliminary nature of the survey, the outcome was not representative. In order to complete the survey, one required internet connection and the questionnaires were shared via e-mail and Facebook. Even so, 146 participants submitted their answers. Those were basically submitted from Budapest and respondents were mainly people with higher education. Regarding the research of Smith [38] and the Pew Research Center [39], the spread of smartphones and internet usage are higher where the population density and the per capita income are higher. Based on this, the probability of the new techniques (e.g.: autonomous car, shared economy, ...) usage is higher. Moreover, the commuting and traffic problems appearance is presumably higher, as well. Based on this, result of this survey can be used as good preliminary data for further research. The age distribution of the respondents is presented in Figure 17.

The participants' employment status is given in Table 5.

Regarding the data presented in Figure 9, the importance of punctuality could have a significant role, which helps to understand the effect of delay on travelers. The following diagram summarizes the results regarding punctuality (Figure 18).

In this diagram, “1” represents the least important and “10” represents the most important factor. It clearly demonstrates that punctuality is a key factor if the event's starting time is fixed, and it is not as important in the case of categories concerning leisure time. In the light of the traffic distribution (Figure 11) and delays (Figure 9) caused by traffic jams, the predictability of commuting is of great importance.

## 7 Summary

In this article, the Futurama concept and its effect to the world (with the example of Los Angeles) were summarized. The history of LA's public transport is presented in more detail.

Two important researches were presented in connection with autonomous cars. The outcome of a survey made in Paris on distribution of car usage showed that only 10% of the cars are causing the traffic jams. Another research on

autonomous car usage was based on a simulation of Lisbon's traffic change in the case of presence of autonomous taxis; this study predicted that the number of cars can be reduced to approximately 10%, only if there is a well-functioning, high-capacity public transport. Based on this finding, autonomous transportation cannot replace the traditional public transport systems, it can only supplement them.

Classification of the autonomous systems was also done. Furthermore, the new age bike sharing systems were introduced. These also might have a significant effect on public transport systems and autonomous transportation.

Based on the presented survey data, punctuality is a key factor for travelers. Regarding the delays, caused by the traffic jams and the research data, the autonomous car cannot be the only solution for traffic problems. Based on this, the hypothesis of the article is considered to be supported.

This overview can be a good starting point for future research. As a next step, the routing algorithm needs to be implemented as described in Section 5.

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