SELF-DRIVING VEHICLES IN URBAN ENVIRONMENTS

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Abstract

The future of cities includes self-driving vehicles. Every new car generation offers several autonomous features that contributes to the development of these systems. Autonomous vehicles (AVs) include many benefits for the city and its inhabitants. Moreover, security aspects rise as well as the complexity of the system itself. Therefore, cities need a framework to develop, test and deploy this ground-breaking technology. Then, the aim of this paper is to propose an autonomous vehicle cluster map that allows cities to develop AV systems. The research investigates cities and their current self-driving technology development. It determines variables of these current systems and it develops an assessment. The research finding shows that the automobile industry has an important role in the implementation but there are other stakeholders in the urban context. These findings facilitate the creation of a cluster map. It offers reference for the development and implementation of autonomous systems. The paper implements the cluster map in Prague as an example of its applicability.

Key words: self-driving, autonomous vehicles, driverless technology, cluster, city mobility

JEL Code: O14, O18, R49

Introduction

The introduction of self-driving vehicles on the roads will have an impact not only on the future of the automotive industry, but also on the urban environments in terms of mobility and road safety (McKinsey&Company and Bloomberg, 2016). The desired outcome of driverless technology is to eliminate human error and thus to increase road safety (Dameri, 2017). However, current users of autonomous vehicles (AVs) experiment a false sense of security. This phenomenon resulted in self-driving fatal accidents, the first one happening in Tesla Model S in May 2016. In the wake of the recent crash of Uber in Arizona, the citizens' security on roads and smart mobility became an important issue discussed by many city governments around the world. Therefore, cities need to develop, test and deploy this ground-breaking technology with the automobile industry and other stakeholders in the urban environments context.

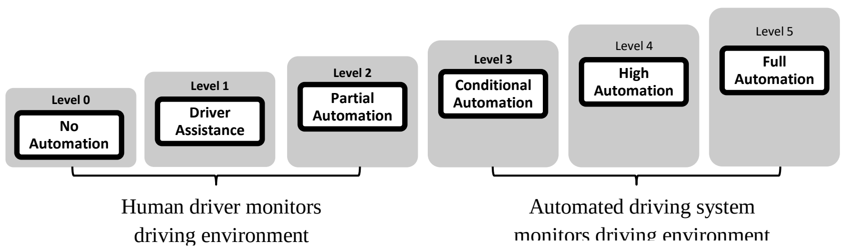
The new mobility plays a crucial role in our lives (commuting to work, home, hobbies, shops, etc.) but also in business (logistics). Local authorities must therefore wisely prepare cities to undertake this change. They need to collaborate and co-develop driverless technology with key stakeholders, which are automakers, technology companies, universities and policy makers. In this context, the main objective of this paper is to examine current cities' AV approaches in order to propose a reference cluster how to develop AVs. The research implements the cluster map in Prague as an evidence of its applicability.

1 Theoretical background

Major urban planning changes will have to be conducted to ensure successful self-driving deployment by key stakeholders (city governments, technology companies, universities, OEMs and suppliers). Therefore, there are two main knowledge backgrounds to explore in order to develop the AV city cluster. The first knowledge is about the specifics on driverless concept. The second knowledge refers to the cluster theory.

Self-driving vehicles, autonomous vehicles or robo-cars are vehicles driven by a software system without human input. In practice, before reaching a fully autonomous vehicle technology, there are preceding levels of automation. The Society of Automotive Engineers (SAE) defines standardized automation levels. The higher level, the higher automation and less human interaction is required during the driving tasks as seen in Figure 1 (SAE, 2016).

Fig. 1: Autonomous driving levels



Source: SAE, 2016

Defence Advanced Research Projects Agency (DARPA) has stimulated the AV development with Grand challenges from 2004. Researchers competed in number of miles driven with their unmanned vehicles; firstly, in the U.S. deserts, then on public roads (Urmson et al., 2008). The main motive for them was to develop revolutionary technology and win a prize. However, today's main benefit and motive for self-driving vehicles' deployment is to increase road safety due to lower numbers of accidents. The US National Highway Traffic Safety Administration Study (NHTSA, US DOT, 2015) estimated that 94% of road accidents are caused by human error. Another benefit is to offer new mobility to people who cannot otherwise drive, i.e. handicapped people, children or elderly. If AVs would be used efficiently (car-sharing, car-pooling or as shared robo-taxis), traffic will improve thanks to lower number of vehicles (private cars). That is why, fuel consumption could also reduce thanks to optimized automated driving systems, which will work efficiently and cut CO2 emissions. Self-driving automakers also prepare in-car entertainment to fill up the new passengers' free time since passengers will have the possibility to do other activities than driving while commuting (relax, read a book, work or even sleep).

Nevertheless, the challenges for self-driving vehicles increase. These are technical, legal and challenges related to the consumers' point of view. The technical core refers to the readiness of the whole AV ecosystem (i.e. fast data transmission, software, high-resolution maps, sensors, infrastructure and prevention against cyber-security, etc.). Currently, due to insufficient technical readiness, the legal aspects play an important role in AV discussion. Current AV regulation is inconsistent and unsatisfactory because the main liability and other legal issues are not yet resolved (Favaro et al., 2018). Therefore, researchers suggest that in the future, insurance business models will be transformed, shifting from individual to OEM's insurance for all models. In addition, some also hypothesize about the ethical dilemmas of the software, which needs to be well programmed to understand the moral issues and context to act accordingly, as for example deciding who will live or die (Calo, 2015). Consequently, the AV success and mass deployment depend on the consumers' trust and acceptance.

Cluster theory facilitates the understanding of the complex AV environment and its stakeholders. There are many definitions of clusters in the field of economics. From Marshall's industrial districts to Porterian clusters, the term cluster has changed but it still usually refers to geographic concentration of interconnected companies (service, product or knowledge suppliers, associated institutions and customers) in specific industry (Belussi & Caldari, 2009; Delgado et al., 2014). This regrouping and subsequent concentration of similar and related businesses can bring advantages of such geographic proximity: know-how spill-overs, easier collaboration, decrease in transfer costs and access to specialised labour (Lagendijk, 2001). Moreover, the cluster effect of having competitors nearby stimulates competition and drives innovation, technology progress and testing. Examples of prosperous clusters are Silicon Valley in California (high-tech), the City of London (financial centre) or Hollywood (films).

2 Methodology

The theoretical knowledge about the AV systems facilitates the analysis of current AV development in cities worldwide. This analysis confirms key stakeholders from theory and determine current best practices. Cluster mapping allows stakeholders integration from best practices and it also facilitates the design of the cluster map proposal for Prague.

2.1 Pre-selection of cities

There is a vast number of worldwide cities involved in developing or testing autonomous vehicles and there are rankings, which have undertaken different concepts. Then, this research paper implements structural and eliminatory approach in order to choose cities with best practices elements. The results enable the creation of the reference cluster for AV development.

The paper investigates agglomerations in terms of population (one million inhabitants and more). Macroeconomic factors such as population, GDP and other relevant statistical data enable the identification of the appropriate urban agglomerations for AVs. The identification derives from arguments of researchers and automakers. They predict the first introduction of AVs will be in developed and wealthy cities. Larger cities are complex (e.g. high number of intersections), therefore AVs need to make more manoeuvres and sort the occurrence of more difficult situations (McKinsey&Company & Bloomberg, 2016; Vogt, 2017). Consequently, the selection for multi-scorecard analysis includes agglomerations with both significant population number and high GDP per capita.

2.2 Multi-scorecard analysis

The implementation of multi-criteria scoring model determines cities with AV relevance (Table 1). The criteria for this model include existing AV initiatives in the urban agglomeration, current city infrastructure level, availability of renowned technical universities, current traffic congestion level, safety need for AV and involvement in smart city projects. Likert scale facilitates the factor assessment.

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Tab. 1: Multi-scorecard criteria model

Criteria	Value in total scoring	Measurement	Evaluation	Source
AV initiatives scoring	40%	Consumer acceptance of AV	1 = the lowest acceptance, 5 = the highest acceptance	Autonomous Vehicles Readiness Index
		AV demonstrations	0 = no testing of autonomous cars, 1 = simple pilot, 2 = more number pilots	Press search, other reports
		Dedicated AV test base	0 = not designated place, 1 = dedicated place to try (street, area on public roads), 2 = open a specific AV base	Press search, other reports
		AV regulation	0 = not developed, 1 = regulation discussed, 2 = regulation put in place	Government websites, press search, other reports
		AV subsidies	0 = no subsidies, 1 = subsidies to AI, V2V (R&D in general), 2 = subsidies to AV (testing)	Government websites, press search, other reports
		AV city strategy	0 = not developed, 1 = designated city strategy	Government websites, press search, other reports
		Autonomous metro	0 = not developed, 1 = autonomous metro put in place	Press search, local transportation websites, other reports
		5G development	0 = not developed, 1 = tested and developed	Press search, other reports
		Developing/testing connected vehicles (V2X) technologies	0 = not developed, 1 = tested	Press search, other reports
		AI R&D for AVs	0 = no AI development, 1 = AI development	Press search, other reports
Safety need for AV	20%	Number of road fatalities per 100 000	5 = highest need of AV (3,5 fatalities + vision zero goal) 4 = vision zero strategy and lower than 3,5 fatalities 3 = no vision zero, high fatalities rate (more than 8) 2 = no vision zero, fatalities rate between 6 - 8 1 = lowest need for AV, no vision zero, lower fatalities rate (below 6)	WHO Report (data per country), Vision Zero statistic, National Security Council, Stat Japan, Chinese Statistics (NCBI)
		Availability of Vision zero strategy		Press search, city websites, city reports/strategies
Congestion level	10%	XX hours average time lost in traffic per year	5 = largest hours lost (more than 170h), most congested 4 = between 150-170 3 = average hours lost (120-150) 2 = between 100-120 1 = least hours lost (less than 100), least congested	TomTom Traffic Index
Tech universities (R&D)	10%	Best technical universities ranking	5 = World best universities for engineering in the city (close neighbourhood) 3 = Great universities in the country/state for the USA 0 = Average engineering universities	The Times Higher Education World University Rankings
City infrastructure	10%	City infrastructure development ranking	5 = the best infrastructure (95-100 ranking) 4 = (90-95) 3 = (85-90) 2 = (70-85) 1 = the worse infrastructure (below 70)	Infrastructure ranking from EIU Global Liveability ranking
Smart city	10%	Smart city ranking	5 = the highest score (up to 10 in the ranking) 4 = high score (between 10-25) 3 = average score (between 25 and 50) 2 = low score (between 50 – 85) 1 = the lowest score (more than 85)	IESE Cities in Motion Index
Total city AV scoring	100%	∑ (Value of critera$_1$*scoring$_1$ + value of critera$_2$*scoring$_2$ + ...)	5 = best possible score, 1 = lowest possible score	

Source: Authors

2.3 Clustering

The implementation of cluster mapping tools develops the proposal for Prague's AV cluster map. Cluster mapping facilitates the development of a graphical tool to understand the cluster. Literature includes several techniques for cluster mapping representation. However, neither of them claims to be the common standard. Moreover, a cluster mapping is a representation of the relationships within the cluster. Therefore, the selection of the relationship map tool facilitates the required description (Damelio, 2011).

The results from multi-score analysis determine specific cities. Then, the research develops an in-depth analysis of AV initiatives, key stakeholders and their relations with the selected cities. Then, it creates the respective cluster maps to illustrate research findings. The main stakeholders (suppliers, R&D players, academic institutions, public organizations and financing firms) obtain a score. This score facilitates the comparison by number of players in each category and their relations (operational partnership or strategic relationship). Finally, similarities and differences determine the elements to include in the proposal for the future cluster map in Prague.

3 Findings

A dataset of 569 biggest agglomerations is analysed based on population and GDP per capita. Out of these agglomerations, 20 are selected for multi-scorecard analysis. These selected agglomerations for this analysis are mainly from US, China, Japan and Europe. The multi-score model determines five cities with the highest scores. These cities are Singapore (4,7), London (4,5), San Francisco (4,4), Tokyo (4,2) and New York (4,1).

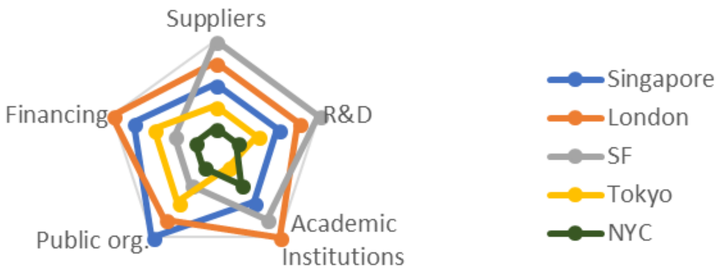
The leading city is Singapore with its Singapore Autonomous Vehicle Initiative (SAVI), which coordinates the whole process of testing and research projects in Singapore. Moreover, it has created a specific consortium (Smart Mobility) and a committee (CARTS) for autonomous driving development. That is why, Singapore is considered as a pioneer in autonomous driving and is also predicted to deploy the first autonomous driving vehicles on public roads. The reason is the high growth of population, which drives the government to push and take part in smart mobility projects, including offering self-driving public transportation, on-demand services through robo-taxis or using self-driving trucks.

Secondly, London and national government fund various AV research and testing projects through Innovate UK program (Centre for Connected and Autonomous Vehicles, CCAV). The most important projects, e.g. GATEway, DRIVEN consortium or MOVE_UK, serve as best practice globally, because they managed to bring together OEMs, R&D players as well as insurers and local government. Compared to Singapore, the government seeks prestige, strives to be at the forefront of AV developing, but has a laissez-faire approach.

Scoring third, San Francisco is the epicentre of AV thanks to Silicon Valley and Californian state government setting the clearest AV regulatory guidelines. High network through AV consortiums is located around top universities such as Stanford and Berkeley. Tokyo and the Japanese government are passionate about AVs and wish to demonstrate it during the 2020 Olympics in Tokyo. Japan wants to prove its technological power and resolve its population-ageing phenomenon. The last selected city is New York, lacking behind others, but being proactive in AV development and it prognoses to have AV technologies soon to meet regulatory pressures concerning vehicle emissions and to ease city transport congestion.

Based on the cluster analysis through cluster mapping tools of the selected five cities, the paper scored and benchmarked the key five cluster roles as seen in the Figure 2 below.

Fig. 2: Cluster comparison



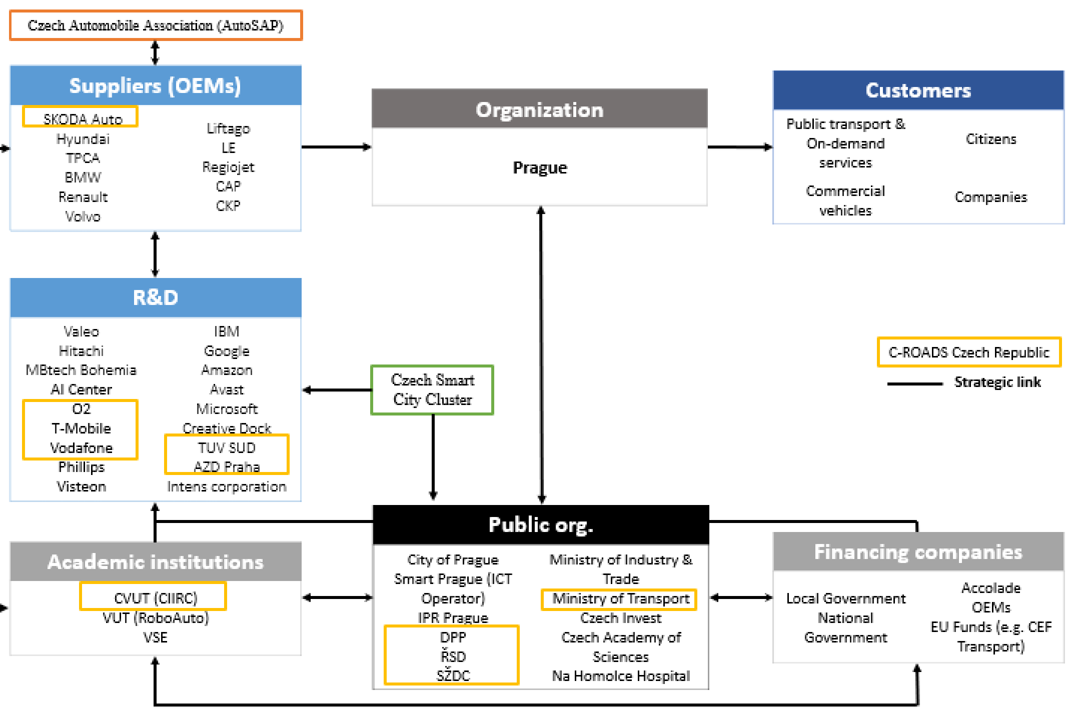
Source: Authors

4. Proposed future cluster map and recommendations

The assessment of current AV situation of Prague and its surroundings determines a score of 2.0 points for the city. Nevertheless, the score is driven down mainly by lower intensity of issues (safety need and congestion level) compared to other cities. However, in terms of level of action (AV initiatives, smart city, city infrastructure and R&D), Prague should improve in all respective categories. Firstly, regarding the main category (AV initiatives), Prague misses AV strategy on the city level, which prevents from AV investments and also testing since city is not ready to clock in AVs. Yet, Czech Republic is active in testing V2X communication and 5G on highways around Czechia under programme C-ROADS Czech Republic. Secondly, compared to the best practice from London, Prague does not offer financial incentives to develop AV technology, which is alarming in the country where automotive sector plays a pivotal role for the economy. Czech government stated in Vision of Autonomous Mobility Transport (Ministry of Transport, 2017) that the determination of required financial means for AV development and infrastruture is not possible now due to current lack of requirements of AV operation. This statement makes the future of Czech AV ecosystem more unclear and not supportive. Finally, the Czech consumer acceptance of AVs determinates the future demand (even public one) of self-driving vehicles in Prague. Since according to the Goodyear-LSE research, Czech drivers are sceptical to autonomous cars (68% would avoid using autonomous cars). The other categories play also vital roles in attracting investors, key suppliers and technological companies to test and develop AV technologies in Prague. Nowadays, the initiatives were pushed mainly by the stakeholders (bottom-up cluster approach), but Prague should start to be involved in the AV development too to avoid negative externalities and coordinate AV activities (top-down cluster approach).

After in-depth analysis of five chosen AV clusters, the city of Prague together with the Czech government (mainly Ministry of Transport) should bring to discussions and create Prague AV cluster with these selected public and academic institutions, technology companies as well as suppliers as can be seen in Figure 3.

Fig. 3: Proposed cluster for Prague



Source: Authors

Conclusion

Self-driving vehicles represent a new technology, which will disrupt not only the automobile industry, but also lives in the urban environments. However, autonomous vehicles also bring many unknowns that must be further explored (legal background, security and technology issues or consumer acceptance). This paper confirms the importance of developing plans to introduce and develop AV systems. The complexity of the issue includes several stakeholders besides the automakers. The analysis of the current best practices in AV systems confirms that strong relationships among these stakeholders facilitates the AV implementation.

The current body of knowledge presents AV rankings but it lacks standardization. The paper creates and implements a methodology that assess current AV development in cities. This approach contributes with the discussion on AV measurement for cities. The proposal for an AV cluster in Prague summarises the stakeholders and their relationships in a city. All these actors need specific evolution to include new technologies but the coordination of that evolution within a cluster facilitates their individual development. The Prague AV cluster illustrates these interactions and it offers a reference for other cities willing to develop their own AV cluster.

The long Czech automobile tradition is an excellent input to develop the AV cluster in Prague. Nevertheless, it also entails increasing Czech competitiveness by higher involvement in AV development. Maybe now it is the right time to start to change the perception of Czech Republic as a “car manufacturer” country to an “AV solutions” provider for cities.

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