Policy Memo

Autonomous vehicles and land use

June 11

To: Scott Haggerty, chair of governing Commission of Bay Area Metropolitan Transportation Commission

From: Shen Qu, Policy Advisor

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RE: How Bay Area should be planning for autonomous vehicles?

Summary

This memo is one of the series of policy analysis about autonomous vehicles for Bay Area. It trys to answer how the autonomous vehicles will affect urban land use, and What the MPO and cities should be planning to seize this opportunity and address the challenges.

Background: the current and projected status of AVs.

Technology: The history of exploring autonomous vehicles can date back to late 1950s (Milakis 2019). Since DARPA ran the Grand Challenge in 2004, the autonomous vehicle technologies entered a "critical juncture." (Docherty, Marsden, and Anable 2018) In the fields of automation control systems, some critical hardwares like processors and sensors are having the ability of undertaking more complex tasks. The improving softwares and algorithm are becoming more fledged. According the definition and taxonomy by SAE-international (2018), the existing technologies are achiving from the Level 3 - Conditional Driving Automation to Level 4 - High Driving Automation.[1]

Industry: Since 2009, Google had conducted a series of tests for AVs over 10 million miles on real-world roads in California, Texas, and other states. Waymo, a company founded by Google, hold the only testing permit for driverless testing by California DMV and committed to providing a ride-hailing services in Arizona in 2018. In 2019, Waymo announced their Level 4 AV will be assembled in Detroit. Almost all big automakers such as Ford, General

[1] SAE defines the concept of AV as ADS-DV (ADS-Dedicated Vehicle), "A vehicle designed to be operated exclusively by a level 4 or level 5 ADS for all trips within its given Operational Design Domain (ODD) limitations." ADS means "The hardware and software that are collectively capable of performing the entire Dynamic Driving Task (DDT) on a sustained basis, regardless of whether it is limited to a specific ODD; this term is used specifically to describe a level 3, 4, or 5 driving automation system."

Motors, Volkswagen, etc., are investing heavily in this field.[Fagnant & kockelman, 2015] The leading transportation network companys (TNC) like Uber and Lyft are making up a term of transportation-as-a-service (Taas) to change current travel modes by AVs.

Academia: Many scholars start working on the reaserch of AVs with lots of energy. Gandia et al. (2019)'s reserch found 10580 published papers in this field from 1945 to 2018. Since 2012, the number of articles have an exponential growth with 39% growth rate while 8-9% average growth rate in science. Although a large amount of the research are from the perspective of systems control, computer science, robotics, engineering, there are more and more articls that start to focus on the AVs' impact on transportation and Land use.

Governavce: In 2011, the Nevada Department of Motor Vehicles issued a first license to google's experimental AVs. Currently, "33 states have passed legislation related to AV." "15 states enacted 18 AV related bills." (State Legislatures n.d.) From 2016 to 2018 the U.S. Department of Transportation (U.S.DOT) and the National Highway and Transportation Safety Administration (NHTSA) published three federal guidences for Automated Driving Systems (ADS is the definition by SAE). The guidances advocate industry, state and local government to support the AVs' development. (Highway and Administration n.d.) California is playing a leading role in this field. Until January 2019, California DMV has issued AV Testing Permits (with a driver) to 62 companies on public roadways.

Changes: unveiling the future

There are some indications that a new era might be dawning. We want to knwow how AVs could influence demand for transportation and land use? This memo will focus on the crutial response for land use. The topic of safety, liability, and other issues will discussed in other memos.

Framwork

While industry, scholars and governments realized the high impact of AV, some research frameworks also imply it is a highly uncertainly evolution rising up some complex issues such as coupling, resonance, or agitation. Milakis, Van Arem, and Van Wee (2017) arrange many substantial implications of autonomous vehicles by a structure of [riple effects], whcih reflected a sequantially spreading process. Land use is placed in the second-order that is affected by the factors in the first-order including travel cost, travel time, vehicle use, capacity, trvael modes, and etc. The flaw of this structure is that the ripple effects model emphasizes the diffusion characteristic of the AV technology and cannot describe the feedback effects, the changes of real estate and land use will influence the travel behavior and traffic in the first-order too. The Diamond of Assembly (Levinson and Krizek 2018 Chapter.12) and the feedback cylce (Wegener and Fürst 2004; adaped by Soteropoulos, Berger, and Ciari 2019) are two helpful complements. These figures can present the relationship between transportation and land use in a more clear manner. AV technology as a exogenous variable will influence travel behaviors in the first ripple, and then is reflected in the change of accessiblity.

Theory:

Muller (2017) introduces the four stages in the spatial evolution of the American metropolitan. Form to , the four-stage model shows that each "break through in movement technology" had reshaped the previous dominated urban form and launched a new era with a "distinctive spatial structure". This history tells us, under the assumption of AV being a breakthrough forces, many previous models, methods, and arguments will fail. We have to review the classical theories before getting some quick answers.

The utility maximization problem: As the core of consumer theory, the supply and demand model explaines the relationship between the price (travel cost) and the quantity (VMT). When price changed or the curve shifted, the market-clearing equilibrium point will reach a new one. In estimating the impact of AV on travel cost and VMT, most of current research based on this theory.[] However, we know this relationship only works in a reasonable range. If the travel cost extend outside the effective range, the previous curve will fail to converge in a new equilibrium point. For example, tend to zero

The bid-rent theroy: this theory derived from supply-demand model and introduced the spatial variables.

Research: Identifies the benefits and costs of these possible outcomes.

focus on Characteristic:

cut off labor cost,

round-the-clock services.

full ridesharing by realtime matching

Time cost (Singleton 2019)

The relevant researches

the impact on land use, wich have short-term and long-term influences. The short-term influences include che change of parking, urban design, affected by travel demand and behavior

The long-term influences include the reconstructure of urban forms and spatial distributions.

Methodology

convergent

high risk in use sufficient principle, and likelihood principle. another option is convariance principle.

Internet, Air Transport system, TNC

inference:

Behavior and land use (Soteropoulos, Berger, and Ciari 2019)

(Hawkins and Nurul Habib 2019)

previous reaserch had give many estimation of the change on road capacities, parking lots, curve space.

use cost and transaction costs - full match

deals fail

The short-term Respose

(Legacy et al. 2019)

Presents policy and planning options for mitigating or otherwise addressing the possible land use effects.

designating pilot area

housing,

parking,

urban design

The strategic planning

long-term effects (Milakis 2019)

Discusses how the MPO and cities may need alter the tools and analyses they use to consider AVs.

Zoning, Division, and partion, not uniform

Conclusion

overestimated and under estimate

from link to node

CA should play a leading role. responsibility

Notes

References

Docherty, Iain, Greg Marsden, and Jillian Anable. 2018. "The Governance of Smart Mobility." *Transportation Research Part A: Policy and Practice* 115. Elsevier: 114–25. https://doi.org/10.1016/j.tra.2017.09.012.

Gandia, Rodrigo Marçal, Fabio Antonialli, Bruna Habib Cavazza, Arthur Miranda Neto, Danilo Alves de Lima, Joel Yutaka Sugano, Isabelle Nicolai, and Andre Luiz Zambalde. 2019. "Autonomous Vehicles: Scientometric and Bibliometric Review." *Transport Reviews* 39 (1). Taylor & Francis: 9–28. https://doi.org/10.1080/01441647.2018.1518937.

Hawkins, Jason, and Khandker Nurul Habib. 2019. "Integrated Models of Land Use and Transportation for the Autonomous Vehicle Revolution." *Transport Reviews* 39 (1). Taylor & Francis: 66–83. https://doi.org/10.1080/01441647.2018.1449033.

Highway, National, and Transportation Safety Administration. n.d. "Automated Driving Systems." Accessed May 27, 2019. https://www.nhtsa.gov/vehicle-manufacturers/automated-driving-systems.

Legacy, Crystal, David Ashmore, Jan Scheurer, John Stone, and Carey Curtis. 2019. "Planning the Driverless City." *Transport Reviews* 39 (1). Taylor & Francis: 84–102. https://doi.org/10.1080/01441647.2018.1466835.

Levinson, David M, and Kevin J Krizek. 2018. *Metropolitan Land Use and Transport: Planning for Place and Plexus*. Routledge. https://doi.org/10.4324/9781315684482.

Milakis, Dimitris. 2019. "Long-Term Implications of Automated Vehicles: An Introduction." Taylor & Francis. https://doi.org/10.1080/01441647.2019.1545286.

Milakis, Dimitris, Bart Van Arem, and Bert Van Wee. 2017. "Policy and Society Related Implications of Automated Driving: A Review of Literature and Directions for Future Research." *Journal of Intelligent Transportation Systems* 21 (4). Taylor & Francis: 324–48. https://doi.org/10.1080/15472450.2017.1291351.

Muller, Peter O. 2017. "Transportation and Urban Form." In *The Geography of Urban Transportation, Fourth Edition*, edited by G. Giuliano and S. Hanson, 57–85. Guilford Publications. https://books.google.com/books?id=J3GnDQAAQBAJ.

SAE-international. 2018. "Taxonomy and Definitions for Terms Related to Driving Automation Systems for on-Road Motor Vehicles." *SAE International,(J3016)*.

Singleton, Patrick A. 2019. "Discussing the 'Positive Utilities' of Autonomous Vehicles: Will Travellers Really Use Their Time Productively?" *Transport Reviews* 39 (1). Taylor & Francis: 50–65. https://doi.org/10.1080/01441647.2018.1470584.

Soteropoulos, Aggelos, Martin Berger, and Francesco Ciari. 2019. "Impacts of Automated Vehicles on Travel Behaviour and Land Use: An International Review of Modelling Studies." *Transport Reviews* 39 (1). Taylor & Francis: 29–49. https://doi.org/10.1080/01441647.2018.1523253.

State Legislatures, National Conference of. n.d. "Autonomous Vehicles | Self-Driving Vehicles Enacted Legislation." Accessed March 19, 2019. http://www.ncsl.org/research/transportation/autonomous-vehicles-self-driving-vehicles-enacted-legislation.aspx.

Wegener, Michael, and Franz Fürst. 2004. "Land-Use Transport Interaction: State of the Art." *Available at SSRN 1434678.*