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Analysis of Social Effects of Autonomous Vehicles

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ABSTRACT. *The intelligent driving characteristics of autonomous vehicles (AVs) have caused widespread concern in society. In order to analyze the possible social effects of autonomous vehicles after application, this paper constructs the social effect analysis framework of autonomous vehicles through four aspects: economic development, energy consumption, social equity and public health. Collecting and analyzing related data through the Q method, the following three social effects (view points) of autonomous vehicles are obtained. First, the advantages of AVs in terms of transportation will help guide people to choose and live in suburbs that are farther away from the city, but this will not cause urbanization in the suburbs; Second, the benefits that AVs bring to life will not be evenly distributed among social groups in the short term. But in the long run, with the advancement of technology and the reduction of the cost of AVs, most people in the society can enjoy the convenience that AVs bring to life; Third, the advantages of AVs in transportation and environmental protection will help to create a good urban business environment to a certain extent and strengthen the radiant role of urban centers. At the end of the paper, we summarized the survey respondents' views on the social effects of AVs and made some suggestions for the development of future AVs.*

KEYWORDS: *autonomous vehicles (AVs), social effect, Q method, view, suggestion*

1. Introduction

With the development of technology, the characteristics of autonomous vehicles in traffic operation, energy consumption and environmental protection have attracted worldwide attention. Autonomous driving technology could replace human drivers to complete vehicle driving operation. When autonomous driving technology applied in society, its impacts on the transportation and social system need to be investigated and studied in order to make a correct and objective evaluation of the development of autonomous vehicles. For example, Brown et al. analyzed the impacts of AVs on energy consumption[1]; Milakis et al. evaluated the accessibility

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impact of autonomous vehicles through land use, traffic, time and individual dimensions [2]; Harper et al. analyzed the effects of AVs on the elderly and people with travel disabilities [3]; Dixit et al. studied the relationship among the incidence rate of AVs, the mileage of autonomous driving and the reaction time of the driver taking over the vehicle in the event of an emergency [4]; Milakis et al. believe it will cause a series of chain reactions when AVs are introduced into society. First, the way people travel will change profoundly. Then it will further cause changes in transportation infrastructure and land use; Finally, AVs will have a comprehensive impact on society which is a huge and complex system [5]. The above researches show that application of AVs will affect all aspects of our society. In order to make AVs serve the society better, it is necessary to analyze and evaluate the possible social effects of AVs.

This paper uses the Q method to analyze the potential social effects of AVs. The reason is that the Q method can better extract and retain the heterogeneity of viewpoints and explore the possible social effects of AVs as much as possible. It is of great significance to the future development and application of AVs. It should be noted that the AVs mentioned in this paper refer to fully autonomous vehicles which are L5 fully autonomous vehicles.

2. Q method

The social effects of AVs are difficult to study through quantitative methods. The Q method can better analyze the possible social effects of AVs using survey data and a method which combination of qualitative and quantitative. The main difference between the Q method and the R method is that the Q method retains the differences in individual viewpoints during the analysis process and reflects the multiple possibilities for the development of things. Its application steps are as follows.

Step 1: Q sample

First, the research goals need to be determined. According to the research goals, opinions need to be collected. Then these opinions will be organized into statements and these statements will form an opinion concourse together. And then appropriate statements in the opinion concourse will be selected to form a sample set -Q sample. Watts et al. consider that it is appropriate to include 30-60 statements in one Q sample [6].

Step 2: Q sort

After the Q sample is formed, respondents will rank the statements in the Q sample according to the degree of approval or opposition. This is a partial ranking. Statements with the same degree of approval or opposition are placed under the same scores. The positive and negative scores correspond to the respondents' approval and opposition to the statement respectively. Respondents' opinions are generally different and the heterogeneity of such opinions can be well reflected in Q sort. The process which respondents rank their statements is also the process which

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respondents express their views. Forced distribution will record the ranking results of respondents. The advantage of Q method is that it allows respondents to place unfamiliar or uncertain options in the middle of the forced distribution table, ensuring consistency of measurement results and opinions.

Step 3: Extracting viewpoints

Q sorted results will be compiled into data. These data will be used to perform factor analysis to extract factors. And the factor loading matrix could show the number of factors. The larger the factor load, the better the factor could explain the viewpoints of the corresponding respondents. Finally, calculating the standard score of statements could help explain the viewpoints.

3. Application of Q method

The research goal of this paper is to analyze the social effects of AVs. The conceptual framework of AVs social effects is mainly derived from the AVs chain effect model proposed by Milakis et al [5]. The paper focuses on the third circle effects in the chain effect model. Construct an analysis framework through economic development, energy consumption, social equity and public health dimensions. Different classic Q method, Q samples are obtained by reading the relevant literature instead of organize relevant experts to exchange and discuss on one issue. Search Papers about social effects of AVs by Elsevier ScienceDirect, Google Scholar and other databases. Search keywords include: autonomous vehicles, safety, risk, social equity, economy, energy and pollution, etc. And these literatures [7-15] are chosen to obtain statements. Finally, 43 statements about the social effects of AVs were screened out to form a Q sample after careful analysis. The Q sample covers four aspects: economic development, energy consumption, social equity and public health.

This survey activity uses the Flash-Q software to sort Q samples. According to wishes, the respondents divided the 43 statements into three categories: approval, neutrality and disapproval. Then respondents selected the two most agree statements in the agreed category and placed them in the space below +5 scores in the forced distribution (Table 1). Similarly, they would select the two most disagree statements in the disapproved category and placed them in the space below -5 scores in the forced distribution. Similarly, they would continue to select three statements in the remaining approval category and placed them in the space below +4 scores in the forced distribution to indicate the second approval. And, they would select three statements in the remaining disapproved category and place them in the space below -4 scores in the forced distribution. The process would not stop until all statements are filled into the forced distribution.

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Table 1 Forced distribution

-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5

In order to accurately analyze the possible social effects of AVs, this survey selected a total of 41 transportation researchers in university. The reason is that researchers have unique sensitivity to new things and will pay attention to changes in the field of transportation in the process of researching various topics. The number of people who responded to the survey was 16 (the feedback rate was 39%). To ensure the validity of the data, the Q ranking results of each feedback was carefully check. Finally, 13 survey data were selected for analysis. Dryzek considers it is appropriate that the number of respondents is between 10 and 40 in the application process of Q method [16]. Although the amount of data in this survey is not very sufficient, the above requirements have been met.

In order to understand the degree of concern of respondents in the ranking process on the economic development, social equity, energy consumption and public health. Sorted data of different respondents were counted. As we all know, these statements which were placed below +/-5 scores or +/-4 scores can represent the clear viewpoints of the respondent relatively. Therefore, the distribution ratio of these clearly statements in four aspects is statistically analyzed. To some extent, the statistical results can indicate the degree of concern of the respondents on AVs in a certain aspect. The degree of attention is shown in Table 2. It can be seen from Table 2 that the average degree of attention of the respondents to economic development is 38%, the average degree of attention to social equity and energy consumption is 22% and the average degree of concern to public health is 19%. This shows that the respondents are most concerned about the impact of AVs on economic development and less on the impact of public health.

Table 2 Degree of attention

Respondent	1	2	3	4	5	6	7	8	9	10	11	12	13	A V(%)
E D(%)	50	30	60	40	30	10	70	0	50	50	50	20	30	38
S E(%)	10	20	0	20	20	30	10	30	20	30	20	40	30	22
E C(%)	10	40	10	30	30	50	10	30	10	0	20	10	30	22
P H(%)	30	10	30	10	20	10	10	40	20	20	10	30	10	19

Note: Economic Development (E D); Social Equity (S E); Energy Consumption (E C); Public Health (P H); Average Value (A V).

This paper adopted factor analysis to explain the social effects of AVs by SPSS 22 software. The data was tested by KMO (Kaiser-Meyer-Olkin) test and Bartlett's

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test. The test results show that the KMO value is 0.622 and the p value is 0. It means that it is appropriate to analyze the data by factor analysis. Considering that Brown et al. believe that each factor needs the support of at least three respondents [17], the factor load matrix after rotation is shown in Table 3.

Table 3 Factor load matrix after varimax rotation

Respondent	Factor		
	I	II	III
1	0.919		
2	0.539		
3	0.786		
4	0.560		
5			0.656
6	0.601		
7	0.482		
8	0.762		
9		0.776	
10		0.692	
11			0.715
12		0.735	
13			0.506

Note: factor loadings>0.48 are selected.

4. Extracting viewpoints

As shown in Table 4, each statement under different factors need to be calculated the standard score. It will help explain the meaning of factors based on standard scores.

4.1 Viewpoint Ⅰ: AVs will guide people's traveling range to expand around the city

AVs can help reduce traffic noise (38), improve passenger comfort (42) and provide more independent private space for passengers (41). In terms of traffic safety, AVs could follow traffic rules better (34). To a certain extent, it will help reduce mortality from traffic accidents (39) and provide passengers with better security than traditional vehicles (26). At the same time, AVs will also reduce the potential safety hazards of vehicles to roadside pedestrians (27). In terms of traffic operation, the application of AVs will improve the capacity of road intersections (30). And it will help effectively alleviate urban traffic congestion (31). Thus, to a certain extent, it could help people reduce anxiety during the trip (37). The benefits of AVs in traffic operations and traffic safety will help people to choose to live farther from the workplace (12). It will increase the value of suburban properties to

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some extent (3). However, it will neither effectively promote the urbanization of suburbs around the city (14), nor help to build more roads between cities and suburbs (9).

In summary, the viewpoint means that the advantages of AVs in terms of travel comfort, safety and convenience will greatly encourage people to choose to live in suburbs farther from the city, but it will not lead to urbanization around the city.

4.2 Viewpoint Ⅱ: Most people in society can enjoy the convenience brought by AVs

Early AVs were expensive (16). In a certain period of time, it will increase the economic cost of traveling of residents (1). AVs can provide passengers with more independent private space (41), reduce the need for on-street parking and make more space available for non-motorized vehicles and pedestrians (24). But the benefits of AVs will not be evenly distributed among different social groups (18), it will lead some people to lose their occupations (6) and provide less employment opportunity than traditional auto industry (8). But in the long run, with the increasing development of society and technology, most people will be able to bear all the expenses required by AVs (23) and could enjoy the convenience brought by AVs (25). AVs could provide more traveling opportunities for those social groups who lack driving ability (20). And AVs can promote the growth of traveling demand (10) and stop the rise in social crime rates (28).

In summary, due to the high cost of manufacturing and operation of AVs, in the short term of application, it may cause some social disadvantages such as leading some people to lose their jobs and so on. However, in the long run, with the advancement of technology and decline of the cost of vehicle manufacturing and operation, AVs will not become the standard for distinguishing social classes (19). People will fully enjoy the convenience that AVs bring to life.

4.3 Viewpoint Ⅲ: The superior transportation and environmental performance of AVs will make the urban business development profitable

AVs will give priority to protecting passengers in AVs in the event of collision with other vehicles and pedestrians (22). To a certain extent, it will weaken the competitiveness of buses in the market (21). The introduction of AVs will reduce the probability of traffic accidents (33) and the number of cars owned per person (7). It could help vehicle reduce emissions of NO_x, CO and other pollutants (36), and improve urban air quality (43).

AVs will increase vehicle traveling speed (35), help reduce fuel prices (15) and save users' parking costs (11). These advantages will further promote the growth of people's traveling demand (10) and effectively stimulate the development of economic activities on both sides of the road (5). To some extent, AVs will not weaken the attractiveness of urban centers (13).

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In summary, the superior performance of AVs in terms of traffic safety and environmental protection will be conducive to the urban business development and strengthen the radiation effect of urban centers.

Table 4 Standardized factor scores

statements		**Factor**	
	Ⅰ	Ⅱ	Ⅲ
Economic Development			
1. AVs will reduce the economic cost of traveling for residents.	-0.90	-1.30	0.51
2. AVs will help reduce the price of commercial housing in urban centers.	-1.15	-1.40	1.06
3. AVs will increase the value of suburban real estate. (the introduction of AVs will make transportation convenient.)	1.16	-1.46	-2.01
4. AVs will balance land value in different areas of the city.	-0.34	-1.12	0.04
5. AVs will stimulate the development of economic activities on both sides of the road. (commercial shops, recreational facilities, housing, etc.)	-0.18	-0.42	0.50
6. AVs will make some people lose their jobs. (such as taxi driver, truck driver, express truck driver, etc.)	1.06	1.28	-1.62
7. The emergence of shared AVs will reduce the number of cars owned per person.	0.04	-0.30	1.82
8. The AVs industry will bring more employment opportunities than the traditional automotive industry. (such as AVs software, hardware systems and job opportunities in related industries.)	-0.03	-0.91	0.56
9. AVs will prompt to build more roads between cities and suburbs.	-1.56	0.95	-0.69
10. AVs will promote to produce more traveling demand.	0.23	1.04	0.25
11. AVs will save users' parking costs.	0.22	-0.65	0.52
12. AVs will help people choose to live far away from workplace.	1.16	-1.22	-1.85
13. AVs will weaken the attraction of urban centers.	-0.47	-0.38	-1.37
14. AVs will promote urbanization in suburbs around the city.	-1.28	-0.62	0.73
15. AVs will help reduce fuel prices. (gasoline, diesel, etc.)	-0.07	-1.40	0.50
16. Early AVs were expensive.	0.11	1.34	1.22
17. AVs will promote economic prosperity and development.	0.10	0.60	-0.11
Social Justice			
18. The benefits of AVs will be evenly distributed among different social groups.	-1.05	-1.32	0.23
19. AVs will become the standard for distinguishing social classes. (such as poverty and wealth.)	-0.31	-0.24	-1.62
20. AVs will provide more traveling opportunities for social groups who lack driving ability. (disabled people, children, elderly people and people without driving licenses.)	0.44	2.58	0.36
21. The introduction of AVs will weaken the competitiveness of buses in the market.	-0.46	-1.19	0.29
22. AVs will give priority to protect passengers in AVs when they collide with other vehicles and pedestrians.	0.26	0.09	0.46
23. Most people have the ability to cover all the costs for AVs.	-1.34	0.48	-0.33
24. The introduction of AVs will reduce the need for on-street parking and produce more space for non-motorized vehicles and pedestrians.	0.18	0.55	-0.95
25. Most people in society can enjoy the convenience brought by AVs.	-0.83	0.98	0.00

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26. AVs will provide better security for passengers than traditional vehicles.	1.72	0.04	-1.18
27. AVs will increase safety risks to roadside pedestrians.	-1.67	0.96	-0.09
28. AVs will lead social crime rate to rise.	-0.60	-1.40	0.71
Energy Consumption			
29. AVs will improve vehicle fuel efficiency. (through route optimization, eco-driving, formation driving and lightweight vehicle.)	1.04	0.93	-0.06
30. AVs will effectively improve traffic capacity at road intersections.	1.24	1.14	0.79
31. AVs will not alleviate urban traffic congestion.	-1.34	0.03	-0.58
32. In the long run, the increase in travel demand caused by AVs will balance the benefits of energy savings.	0.43	-0.58	-0.47
33. The introduction of AVs will increase the probability of happening traffic accidents.	-0.76	-0.05	-1.56
34. AVs will reduce the degree of compliance with traffic rules. (such as overspeed, illegal parking, run the red lights, aggressive driving, etc.)	-1.73	1.11	-1.45
35. The introduction of AVs will improve vehicle traveling speed.	0.44	1.10	1.66
Public Health			
36. AVs will help reduce emissions of NO_x, CO and other pollutants.	0.98	0.23	2.02
37. It will reduce people's anxiety during the trip by using AVs. (such as AVs will increase the reliability of traveling time, etc.)	1.17	0.36	0.71
38. AVs will increase the traffic noise.	-1.20	0.33	0.71
39. AVs will reduce mortality rate caused by traffic accidents.	1.39	-0.86	-0.12
40. AVs will make people more likely to become obese (obesity).	-0.49	1.35	-0.01
41. AVs will provide passengers with more independent private space.	1.10	0.76	-0.85
42. AVs will improve passengers traveling comfort.	1.97	-0.95	0.08
43. AVs will help improve air quality in cities.	1.33	-0.43	1.16

5. Summary and suggestions

In the short term, the high costs of research and development in the early stages of AVs will increase the economic cost of traveling for residents. However, in the long run, the advantages of AVs over traditional vehicles in terms of traffic safety and operation will encourage people to live in suburbs farther from the city, which will help people expand their traveling range. But it will not directly promote the urbanization of the suburbs, nor will it weaken the attraction of urban centers. In contrast, the advantages of AVs in energy conservation and environmental protection make people more willing to use AVs as travel mode. To a certain extent, it has strengthened the role of the city's radiation to the surrounding areas, which is conducive to creating an urban business environment. With the development of science & technology and the progress of society, the manufacturing and operating costs of AVs have been reduced. Most people in the society will enjoy the convenience that AVs bring to life.

Based on the results of the survey, in order to accelerate the application of AVs, this paper provides the following development suggestions. The first suggestion is to strengthen the technical support of AVs. The advantages of AVs in driving safety,

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energy conservation, environmental protection derived from advanced perception, intelligent decision-making and automation technology. Therefore, by accelerating the development of autonomous driving technology can help accelerate the application process of AVs. Second suggestion is scale utility. Only after the application of AVs reaches a certain scale in traffic system, its advantages in environmental protection and traffic operation can gradually emerge. Hence, it needs to further reduce the application cost of AVs so that most people can fully enjoy the benefits brought by AVs. And it will help AVs have a wider development space too.

References

[1] A. Brown, J. Gonder and B. Repac (2014). An analysis of possible energy impacts of automated vehicle. In G. Meyer & S. Beiker (Eds.), Road Vehicle Automation, p.137–153.

[2] D. Milakis, M. Kroesen and B.V. Wee (2018). Implications of automated vehicles for accessibility and location choices: evidence from an expert-based experiment. Journal of Transport Geography, vol.68, p.142-148.

[3] C.D. Harper, C.T. Hendrickson and S. Mangones, et al (2016). Estimating potential increases in travel with autonomous vehicles for the non-driving, elderly and people with travel-restrictive medical conditions. Transportation Research Part C, vol.72, p.1–9.

[4] V.V. Dixit, S. Chand and D.J. Nair (2016). Autonomous vehicles: disengagements, accidents and reaction times. PLOS ONE, vol.11, no.12, p.1-14.

[5] D. Milakis, B.V. Arem and B.V. Wee (2017). Policy and society related implications of automated driving: a review of literature and directions for future research. Journal of Intelligent Transportation Systerms, vol.21, no.4, p.324–348.

[6] S. Watts and P. Stenner (2005). Doing Q methodology: theory, method and interpretation. Qualitative Research in Psychology, vol.2, no.1, p.67-91.

[7] A.R. Palmeiro, S.V.D. Kint and L. Vissers, et al (2018). Interaction between pedestrians and automated vehicles: a wizard of Oz experiment. Transportation Research Part F, vol.58, p.1005–1020.

[8] C. Ross and S. Guhathakurta (2017). Autonomous vehicles and energy impacts: a scenario analysis. Energy Procedia, vol.143, p.47-52.

[9] D.W. Eby, L.J. Molnar and L. Zhang, et al (2016). Use, perceptions, and benefits of automotive technologies among aging drivers. Injury Epidemiology, vol.3, no.28, p.1-20.

[10] D.J. Fagnant and K. Kockelman (2015). Preparing a nation for autonomous vehicles: opportunities, barriers and policy recommendations. Transportation Research Part A, vol.77, p. 167–181.

[11] M.N. Mladenovic and T. McPherson (2016). Engineering social justice into traffic control for self-driving vehicles? Science and Engineering Ethics, vol.22, p.1131-1149.

[12] W. Sun, J.F. Zheng and H.X. Liu (2018). A capacity maximization scheme for intersection management with automated vehicles. Transportation Research Part C, vol.94, p.19–31.

ISSN 2616-5667 Vol.3, Issue 1: 65-74, DOI: 10.25236/AJETS.2020.030109

[13] Z. Wadud, D. MacKenzie and P. Leiby (2016). Help or hindrance? the travel, energy and carbon impacts of highly automated vehicles. Transportation Research Part A, vol.86, p.1–18.
[14] S. Smith (2015). A framework for estimating the transportation system impacts of automated vehicle technologies. U.S. Department of Transportation: Automated Vehicle Symposium.
[15] P. Moriarty and S.J. Wang (2017). Could automated vehicle reduce transport energy? Energy Procedia, vol.142, p.2109-2113.
[16] J.S. Dryzek (2005). Handle with care: the deadly hermeneutics of deliberative instrumentation. Acta Politica, vol.40, p.197–211.
[17] S.R. Brown and W. Stephenson (1980). Political subjectivity: applications of Q methodology in political science. Yale University Press, p.1-351.