Exploring the effects of autonomous vehicle on residential location choice behavior

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1. Introduction

The development of autonomous vehicles (AVs) has been progressing in recent years. It has been pointed out that the introduction of the AVs has a great influence on social systems as well as transportation systems. Milakis et al. (2017)[1)] classifies the effects of introducing AV into the following three stages. The first stage is the influence on the transportation system. It is inferred that transportation mode choice, travel cost, and traffic congestion pattern would change. The second stage is assumed to be the impact of the secondary ripple effect on the broader social system such as land use, employment, infrastructure development. The third stage is a tertiary ripple effect such as energy consumption, public health, safety, equality economy. This research focused on the change of the residential location which is the secondary ripple effect.

When a fully automated operation system is realized, the system will perform all diving tasks. Hence, it becomes unnecessary for human beings to drive, thus it is possible to execute various activities inside the car. Travel time and travel expenditure to the workplace, land price and so on are taken as a traditional factor of choosing a residential location, whereas feasible activities inside the vehicle can be additional factors that affect the residential location choice behavior after introducing automated cars. If other activities can be carried out in the car while traveling, there is a possibility that activities executed in a daily life is substituted in the car. It is inferred that individuals with more in-car activities that can perform during travel have less influence on where to live than the individuals who are not so. Moreover, it is thought that it varies depending on the mode of autonomous cars such as ride-sharing in which individuals share the ownership with others and private possession; it is owned like an existing car by an individual.

2. Stated preference (SP) survey

In this research, a web-based stated preference survey was conducted to evaluate the impact of in-car activities that would be feasible after introduction of automatic driving technology on residence location choice. The number of respondents for the survey was 615 people who commuted to work by car in Hiroshima or Fukuoka. On the premise that travel time, traveling expense and land price were the same as the present situation, the survey was designed to sorely evaluate the impacts of AVs on the secondary activities in the car. In the SP survey, respondents were asked to choose a rental house from two alternatives (rental house A and B). the attributes shown in the SP survey include travel time to the workplace, housing cost, occupied area, travel distance to the nearest supermarket, station and bus stop. To make the choice context realistic for the respondents, respondents were asked to answer the current travel behavior including travel time to the workplace, housing cost, occupied area, travel distance to the nearest supermarket, station and bus stop. These revealed preference attributes were used as a baseline in the SP survey: the value of each attribute was made by randomly increasing or decreasing the baseline to -30%, -10%, 0%, +10%, +30%. Each respondent was asked to choose one of the alternatives in the following three cases: (i) conventional car, (ii) AV (ride-sharing) and (iii) AV (private ownership).

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3. Methodology

The residential location choice behavior is represented by using a Panel Binary Mixed Logit Model which considers the random effect as bellow,

$$P_{1nt} = \int_{b_n} \frac{exp(V_{1nt}+b_n)}{exp(V_{1nt}+b_n)+ exp(V_{0nt})} f(b_n)db_n \quad (1)$$

where P_{1nt} is a probability of choosing rental house A at the t-th time of individual n, V_{1nt} is deterministic or observable portion of the utility at the t-th time of individual n, b_n is random effect expressing unobservable individual-specific effects. In this model, it is assumed that b_n follows Normal distribution $f(b_n)$.

In addition, as Figure 1 shows, respondents were classified based on a cluster analysis into two groups as follows: (i) individuals who have a low possibility of executing in-car activities [in minutes] and (ii) individuals who have a high possibility of executing in-car activities [in minutes]. Each group is incorporated as the explanatory variable of travel time to the workplace as dummy variables.

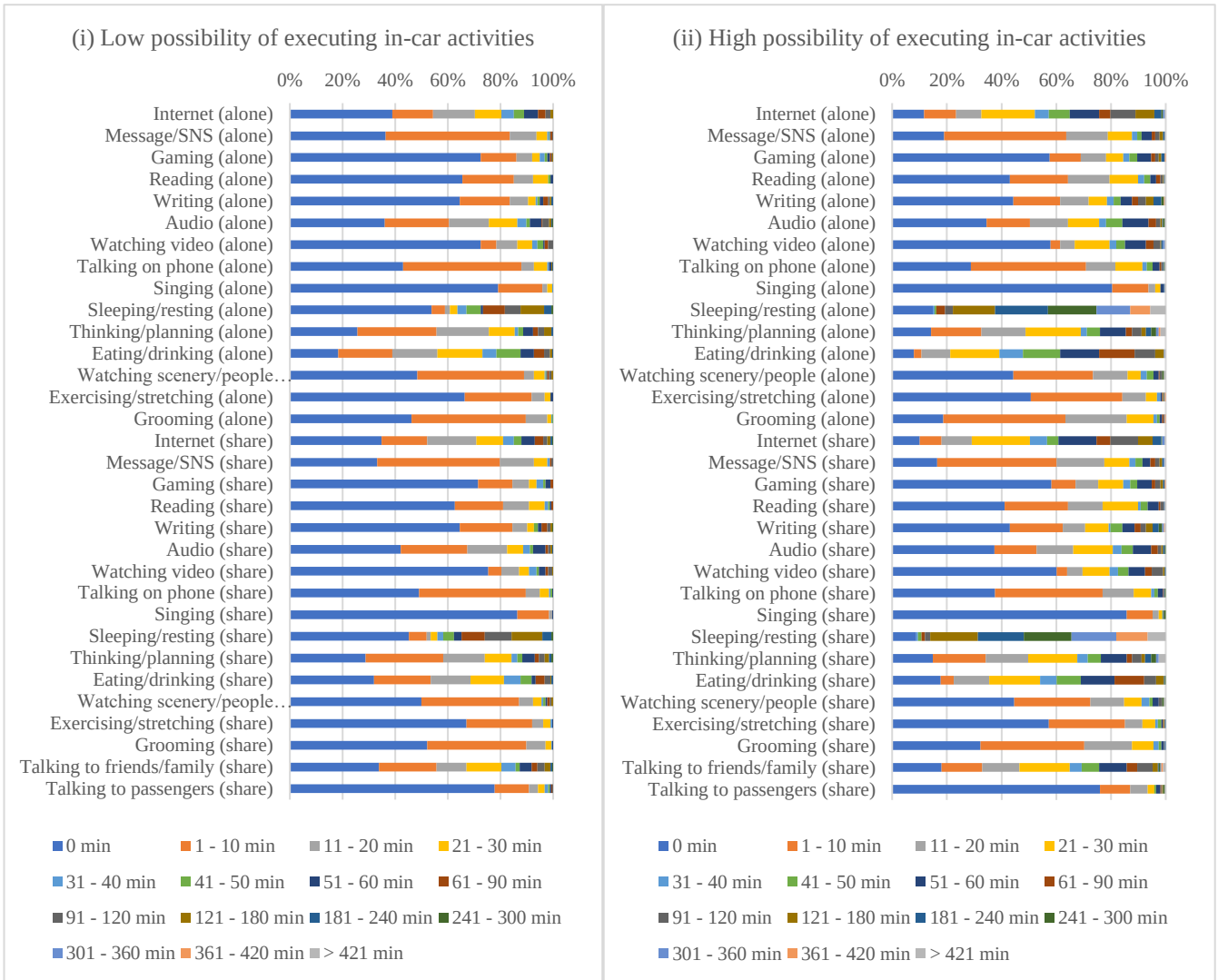

Figure 1. Possibility of executing in-car activities in two groups

4. Estimation results

The obtained outcomes are shown in Table 1 and Table 2. All parameters of housing cost, occupied area and travel distance

to the nearest supermarket were statistically significant. The parameters of travel time to the workplace were statistically significant apart from two parameters. For these results, the willingness to pay for housing cost for the shortening of travel time to the workplace in three cases are derived as Table 3 shows.

Table 1. Model estimation results without in-car activities variables

Explanatory variable	Conventional car			AV (ride-sharing)			AV (private ownership)		
	Parameter	z-value		Parameter	z-value		Parameter	z-value	
Travel time to the workplace (min)	-0.01553	-3.033	**	-0.01515	-2.994	**	-0.01195	-2.350	*
Housing cost (10,000 yen)	-0.3519	-15.251	***	-0.3427	-15.102	***	-0.3741	-16.010	***
Occupied area (m^2/ 100)	2.0905	12.374	***	1.8122	11.115	***	1.6476	11.692	***
Travel distance to the nearest supermarket (*km*)	-0.3283	-2.409	*	-0.2904	-2.168	*	-0.2898	-2.136	*
Travel distance to the nearest station (*km*)	0.01096	0.1710		-0.01772	-0.279		0.009407	0.147	
Travel distance to the nearest bus stop (*km*)	-0.2460	0.2012		-0.05715	-0.297		-0.1622	-0.839	
Random parameter (variance of b_n)	0.07194			0.05437			0.04703		
Initial log-likelihood	-1576.9			-1577.3			-1580.1		
Final log-likelihood	-1356.0			-1380.4			-1355.4		
Likelihood ratio	0.1401			0.1248			0.1422		

*: significant at 5% level, **: significant at 1% level, ***: significant at 0.1% level

Table 2. Model estimation results with in-car activities variables

Explanatory variable	Conventional car			AV (ride-sharing)			AV (private ownership)		
	Parameter	z-value		Parameter	z-value		Parameter	z-value	
Travel time to the workplace for individuals who have a low possibility of executing in-car activities (min)	-0.01062	-1.496		-0.01679	-2.367	*	-0.11959	-1.684	+
Travel time to the workplace for individuals who have a high possibility of executing in-car activities (min)	-0.02080	-2.807	**	-0.01343	-1.852	+	-0.11949	-1.635	
Housing cost (10,000 yen)	-0.3517	-15.245	***	-0.3428	-15.102	***	-0.3741	-16.008	***
Occupied area (m^2/ 100)	2.0953	12.397	***	1.8109	11.103	***	1.9476	11.688	***
Travel distance to the nearest supermarket (*km*)	-0.3247	-2.380	*	-0.2916	-2.176	*	-0.2898	-2.135	*
Travel distance to the nearest station (*km*)	0.01288	0.201		-0.01839	-0.290		0.009399	0.147	
Travel distance to the nearest bus stop (*km*)	-0.2467	-1.283		-0.05677	-0.295		-0.1622	-0.839	
Random parameter (variance of b_n)	0.07327			0.04669			0.05438		
Initial log-likelihood	-1576.9			-1577.3			-1580.1		
Final log-likelihood	-1355.5			-1380.3			-1355.4		
Likelihood ratio	0.1404			0.1249			0.1422		

+: significant at 10% level, *: significant at 5% level, **: significant at 1% level, ***: significant at 0.1% level

Table 3. Willingness to pay for housing cost for the shortening of travel time to the workplace

	Willingness to pay for housing cost for the shortening of travel time to the workplace		
	No distinction of possibility of executing in-car activities	Low possibility of executing in-car activities	High possibility of executing in-car activities
Conventional car	54.65 yen per minute	30.19 yen per minute	59.13 yen per minute
AV (ride-sharing)	51.92 yen per minute	48.98 yen per minute	39.18 yen per minute
AV (private ownership)	30.19 yen per minute	31.97 yen per minute	31.94 yen per minute

5. Conclusion

It is confirmed that individuals who can execute activities in an AV tend to accept longer commuting time, although the degree depends on the mode of AVs (i.e., shared or unshared uses). The results indicate that further urban sprawl could happen if unshared AV becomes widely used. Such negative impacts on urban form, however, would be substantially small when shared AV is introduced under ride-sharing scheme.

Reference

1) Milakis, D., van Arem, B., van Wee, B. (2017) Policy and society related implications of automated driving: A review of literature and directions for future research, Journal of Intelligent Transportation Systems, Journal of Intelligent Transportation Systems, 21(4), 324-248