# MULTI-TASKING BEHAVIOR IN AUTONOMOUS VEHICLE AND ITS IMPACTS ON RESIDENTIAL LOCATION CHOICE BEHAVIOR

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A multi-tasking behavior can be executed in the car after the introduction of autonomous vehicle (AV). Because of this, people could accept longer travel times, possibly resulting in living in a place far from their workplace in the long term. In addition, the influence may differ depending on whether the AV is used individually or with others (i.e., ride-sharing), and the type and amount of activities carried out in the car. Therefore, in this research, the influence of introduction form of AV (shared or individual use) and the difference in-vehicle activities on residential location choice behavior are evaluated through a stated preference survey on residential location choice under three different scinarios (existing car, shared AV, privately owned AV). The results indicate that respondents tend to choose residences distant from the workplace especially when unshared AVs spread, and its influence is greater for individuals who can conduct more daily activities inside the car.

***Key Words :*** *autonomous vehicle, residential location choice behavior, multi-tasking behavior*

## 1. INTRODUCTION

In recent years, the development of autonomous vehicles (AVs) has been progressing. According to the Ministry of Land, Infrastructure, Transport and Tourism (MLIT)[1)], the introduction of AVs is expected to reduce traffic accidents, resolve and alleviate traffic congestion, respond to the declining birthrate and aging population, improve productivity, and strengthen international competitiveness. Milakis et al. (2017)[2)] classifies the effects of introducing AVs 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 is the impact of AV on the broader social system such as land use, employment, infrastructure development (secondary ripple effects). The third is the impacts of AV on effect such as energy consumption, public health, safety, equality and economy (tertiary ripple effects). This research focuses on the change of the residential location which is one of the secondary ripple effects.

When a fully automated operation system is realized, the system will perform all driving tasks. Hence, it becomes unnecessary for human beings to drive. It is possible to execute multi-tasking activities inside the car. Travel time, 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 AVs. 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. Individuals who can perform more in-car activities during travel may not need to live close to the workplace. The impacts may also depend on the form of AV (shared or individual use), since the type and amount of in-car activities would depend on whether the AV is individually used or shared with others.

## 2. LITERATURE REVIEW

According to Fagnant and Kockelman[3], it was estimated that the vehicle miles traveled would increase by 20% when the market share of the AV reached 90%. This estimation was based on a comparison with an induced demand caused by an increase in a traffic capacity after expanding a traffic infrastructure.

Zmud et al.[4] surveyed at Austin, United States. The majority responded that the vehicle miles traveled would not be changed even if they would use AVs. This is because habits, traffic routes, activities and residences would not be changed, whereas 25% of the respondents answered that the vehicle miles traveled would increase because it would add long distance travels, leisures, and local trips to the current travel pattern.

Lamondia et al.[5] focused on a potential modal shift from existing cars owned by individuals and airplanes to automated cars in Michigan state in the USA as a case study. The model estimation resulted in a modal shift of up to 36.7% from existing cars and up to 34.9% from airplanes to AVs when traveling less than 500 miles. In case of traveling over 500 miles, a modal shift at a rate of roughly 20% from existing cars to AVs was estimated while a modal shift from airplanes to AVs was suppressed compared to existing cars, which was between 9.3% and 19.9%.

Thalys International[6] conducted a comparison of travel expences and travel time in Thalys, a high speed international railway, and airplanes and investigated the impact of being able to exercise highly productive activities inside the car on travel mode choice. Facilities such as the Internet environment, electrical outlet, meal, taxi reservation are installed in the Thalys vehicle. According to the survey results, 97% of respondents commuting by Thalys worked in the car while traveling. Besides, about 50% of respondents said that they could spend more than half of the time in the car to work. They estimated the factors of affecting mode choice were travel expenses (53%), distance (5%), travel time (29%), productivity in the car (13%). For the results, it was suggested that the travel time should be reevaluated considering the productivity in the vehicle.

Malokin et al.[7] implemented a survey on northern California in the US to find the influence of the activities carried out during commuting on the utility for transportation choice and movement. In this study, "Technological (activity involving information and communication technology)," "Recreational (relaxed activity)," "Productive (writing, reading and other things)," "Traditional (activity not using digital technology)," "Maintenance (activity related to self-maintenance)" in-vehicle activities are analyzed by factor analysis. Under the hypothesis that the "Productive" in-vehicle activities had the most influence on the mode choice, "Productive" was incorporated into the explanatory variable and the model estimation was carried out. The results show that the utility increased as perceived "Productive" in-vehicle activities increased. The modal shift from other transportation to "shared ride" and "driving alone" was also confirmed in a presupposed scenario, where the extent of activites in the automated driving vehicle is assumed to be equivalent to that in "Commuter rail."

Few studies have been conducted on the impacts of increasing multi-tasking activities on residential location chice behavior although changes in vehicle miles traveled and changes in multi-tasking activities after the introduction of driverless cars have been studied.

## 3. STATED PREFERENCE SURVEY

In this research, a web-based stated preference (SP) survey was conducted to evaluate the impact of a multi-tasking behavior that would be feasible after introduction of automatic driving technology on residential location choice. The number of respondents for the survey was 615 individuals who regularly commute to work by car in Hiroshima or Fukuoka, Japan. On the premise that travel time, travel cost 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 rental house 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 reveled 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). Each respondent answered the SP question four times with different attribute levels.

## 4. METHODOLOGY

### (1) Panel Binary Mixed Logit Model

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

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

where $P_{1n}$ is a probability of choosing a rental house A for individual $n$, $V_{1n}$ is a deterministic or observable portion of the utility for individual $n$, $b_n$ is a random effect expressing unobservable individual-specific effects.

In this model, it is assumed that $b_n$ follows the normal distribution $f(b_n)$.

### (2) Cluster Analysis

As **Fig.1** shows, respondents were classified based on a cluster analysis into two groups as follows: (i) individuals who have a low possibility of executing a multi-tasking behavior in the car, and (ii) individuals who have a high possibility of executing a multi-tasking behavior in the car. The Ward's method was adopted for the clustering. We assume that the sensitivity to travel time to the workplace is different between these two groups.

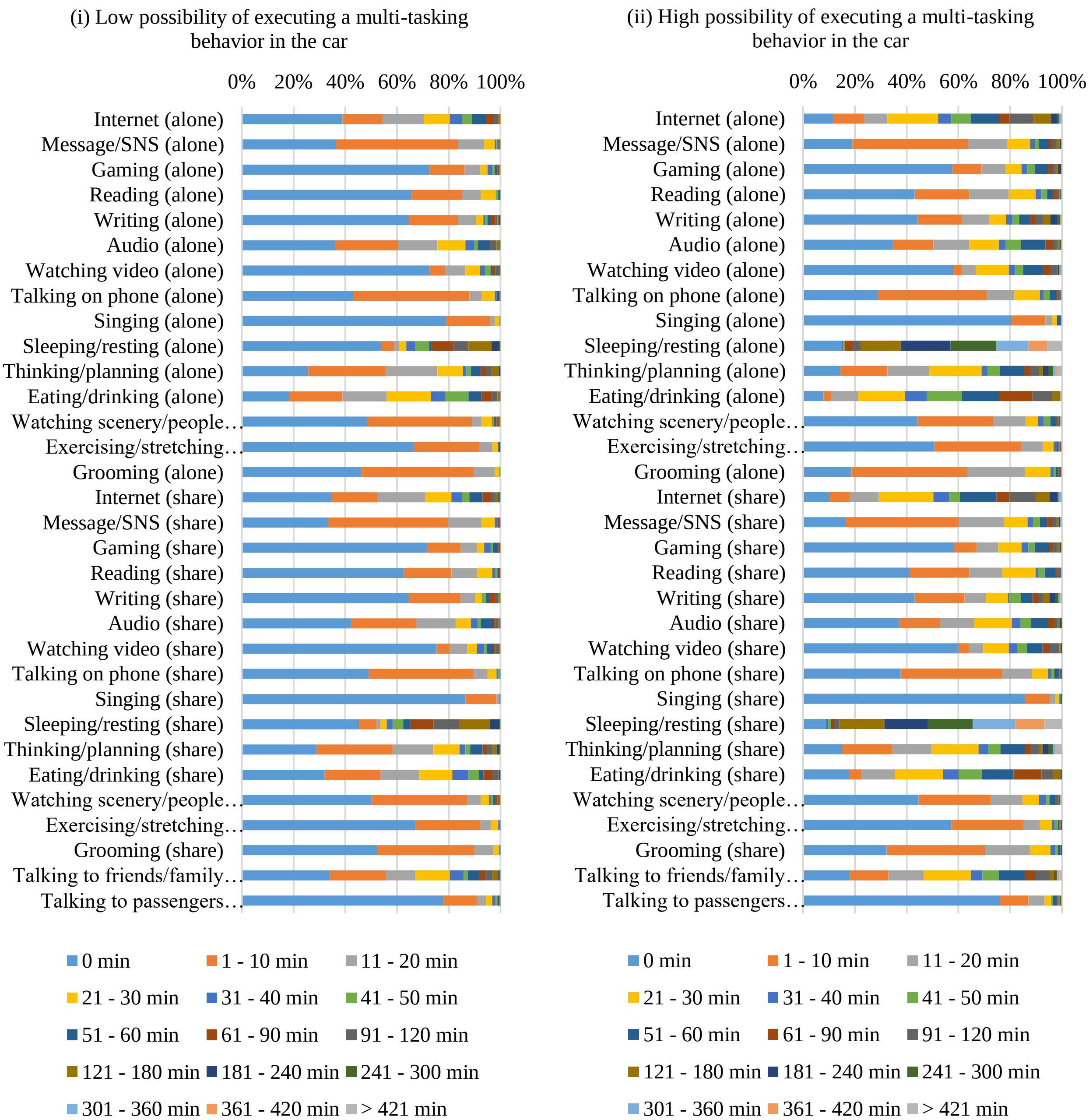


**Fig.1** Possibility of executing a multi-tasking behavior in the car in two group

## 5. ESTIMATION RESULTS

The model estimation results 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. The parameters of travel distance to the nearest station and bus stop are not significant in any cases at any levels. It means that these do not affect residential location choice behavior. Based on the results, we caluculate the willingness to pay for housing cost to shorten travel time to the workplace in three cases as shown in **Table 3**. It is found that there is a possibility of progressing further sprawl phenomena when privately owned AV becomes popular although the impact on urban structure or distribution of residence would be small if shared AV becomes widespread. The results also show that individuals who can replace more daily activities tend to have lower traveling resistance although the degree depends on the mode of introduction of AVs.

**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) | -0.016 | -3.03 | ** | -0.015 | -2.99 | ** | -0.012 | -2.35 | * |
| Housing cost (10,000 yen) | -0.352 | -15.25 | *** | -0.343 | -15.10 | *** | -0.374 | -16.01 | *** |
| Occupied area ($m^2$/ 100) | 2.091 | 12.37 | *** | 1.812 | 11.12 | *** | 1.648 | 11.69 | *** |
| Travel distance to the nearest supermarket (*km*) | -0.328 | -2.41 | * | -0.290 | -2.17 | * | -0.290 | -2.14 | * |
| Travel distance to the nearest station (*km*) | 0.011 | 0.17 | | -0.018 | -0.28 | | 0.009 | 0.15 | |
| Travel distance to the nearest bus stop (*km*) | -0.246 | 0.20 | | -0.057 | -0.30 | | -0.162 | -0.84 | |
| Random parameter (variance of $b_n$) | 0.072 | | | 0.054 | | | 0.047 | | |
| Initial log-likelihood | -1576.9 | | | -1577.3 | | | -1580.1 | | |
| Final log-likelihood | -1356.0 | | | -1380.4 | | | -1355.4 | | |
| Likelihood ratio | 0.140 | | | 0.125 | | | 0.142 | | |

*: 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 a multi-tasking behavior in the car (min) | -0.011 | -1.50 | | -0.017 | -2.37 | * | -0.012 | -1.68 | + |
| Travel time to the workplace for individuals who have a high possibility of executing a multi-tsking behavior in the car (min) | -0.021 | -2.81 | ** | -0.013 | -1.85 | + | -0.012 | -1.64 | |
| Housing cost (10,000 yen) | -0.352 | -15.25 | *** | -0.343 | -15.10 | *** | -0.374 | -16.01 | *** |
| Occupied area ($m^2$/ 100) | 2.095 | 12.40 | *** | 1.811 | 11.10 | *** | 1.948 | 11.69 | *** |
| Travel distance to the nearest supermarket (*km*) | -0.325 | -2.38 | * | -0.292 | -2.18 | * | -0.290 | -2.14 | * |
| Travel distance to the nearest station (*km*) | 0.013 | 0.20 | | -0.018 | -0.29 | | 0.009 | 0.15 | |
| Travel distance to the nearest bus stop (*km*) | -0.247 | -1.28 | | -0.057 | -0.30 | | -0.162 | -0.84 | |
| Random parameter (variance of $b_n$) | 0.073 | | | 0.047 | | | 0.054 | | |
| Initial log-likelihood | -1576.9 | | | -1577.3 | | | -1580.1 | | |
| Final log-likelihood | -1355.5 | | | -1380.3 | | | -1355.4 | | |
| Likelihood ratio | 0.140 | | | 0.125 | | | 0.142 | | |

+: 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 to shorten travel time to the workplace

| | Willingness to pay for housing cost to shorten travel time to the workplace | | |
|---|---|---|---|
| | Without in-car activities variables | Low possibility of executing a multi-tasking behavior | High possibility of executing a multi-tasking behavior |
| Conventional car | 441 yen per minute | 302 yen per minute | 591 yen per minute |
| AV (ride-sharing) | 442 yen per minute | 490 yen per minute | 392 yen per minute |
| AV (private ownership) | 319 yen per minute | 320 yen per minute | 319 yen per minute |

## 6. CONCLUSION AND FUTURE WORK

It was 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 indiocate 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.

In this research, a web-based survey was performed under the assumption that the travel time, travel cost and land price do not change from the present situation though, the survey must be considered a possibility that it will change by introducing AVs. In addition, the residential status as well as the residential location might change due to the introduction of AVs. Hence, there is a probability that the model employed in this study cannot represent a proper residential location choice behavior.

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## REFERENCES

1) Ministry of Land, Infrastructure, Transport and Tourism. (2016). Reference 3-1, The First Meeting, Retreved February 5, 2018 via: http://www.mlit.go.jp/jidosha/jidosha_tk7_000018.html
2) Milakis, D., Van Arem, B., and Vanwee, B. (2017). Policy and society related implications of automated driving: A review of literature and directions for future research. *Journal of Intelligent Transportation systems: Technology, Planning, and Operations*, Vol. 21, No, 4, 324-348.
3) Fagnant, D. J., and Kockelman, K. M. (2015). Preparing a nation for autonomous vehicles: opportunities, barrers and policy recommendations for capitalizing on self-driven vehicles. *Transportation Research Part A: Policy and Practice*, Vol. 77, pp. 167-181.
4) Zmud, J., Sener, I. N., and Wagner, J. (2016). Self-Driving Vehicles Determinants of Adoption and Conditions of Usage. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2665, pp. 57-64.
5) Lamondia, J. J., Fagnant, D. J., Qu, H., Barret, J., Kockelman, K. (2016). Shifts in Long-Distance Travel Mode Due to Automated Vehicles Statewide Mode-Shift Simulation Experiment and Travel Survey Analysis. *Transportation Research Record: Journal of the Transportation Research Board*, No. 2566, pp. 1-10.
6) Thalys International. (2012). Travel Time Efficiency, Retrieved February 5, 2018 via: https://www.thalys.com/img/pdf/b2b/etude/Etude_Travel_Time_Efficiency_en.pdf
7) Malokin, A, Circella, G., and Kokhtarian, P. L. (2015). How Do Activities Conducted While Commuting Influence Mode Choice? *TRB 94th Annual Meeting*, Vol. 733, pp. 1-23.

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