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Consumer Demand for Fully Automated Driving Technology: Evidence from Japan*

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Abstract

Automated driving technology is one of the most important applications of advanced artificial intelligence technology, which is being extensively incorporated into transportation worldwide. Policymakers expect the introduction of fully automated vehicles (FAV) to significantly reduce the number of accidents that are due to human error and road congestion. Using originally collected large-sample survey data from 2015, this paper evaluates current consumer demand in terms of purchase intention (PI) and willingness to pay (WTP) for FAV in Japan. On average, consumers expect FAV to be available for purchase in approximately 13 years, and 47% of respondents report positive PI. Average WTP was approximately 190,000 yen ($1,650) and 290,000 yen ($2,520) for respondents with positive PI. Using regression analysis, we also analyze the determinants of PI and WTP, such as the subjective merits and demerits of FAV as well as other household and city characteristics.

Keywords: Automated driving, Consumer demand, Purchase intension, Willingness to pay (WTP), Consumer survey, Japan
JEL classification: R41, R42, D12

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1. Introduction

Artificial intelligence (AI) technology has advanced exponentially in recent years, and technologies such as 'Siri' and 'pepper'[1] have been installed in the machines that consumers use daily. AI technology is also used in automotive industries to develop fully automated vehicles (FAV), which enable people to use cars without driving. Automated driving technology has already been tested or used in public transportation systems and on freeways in different countries. For example, in 2012, Spain conducted a successful platooning experiment with FAV on public roads. The U.K. government and several relevant industries are jointly planning to introduce FAV for use in public transportation, which will connect Heathrow airport with Bristol, London, Milton Keynes and Coventry by 2017.[2] In Japan, globally recognized vehicle companies such as *TOYOTA* and *NISSAN* have been testing their automated driving technologies on freeways and local roads. Additionally, the Japanese government plans to introduce FAV on selected roads by 2020. It is likely that drivers will begin to see FAV on ordinary roads sooner than expected.

Automated driving (AD) offers a variety of benefits. According to an official report on the AD trend by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) (2015)[3], accident reduction and traffic mitigation are two of its major advantages. For example, 96% of traffic accidents on freeways in Japan are due to human errors such as mishandling, carelessness, and misjudgments by drivers; it is expected that automated driving technology will eliminate these accidents. Additionally, approximately 60% of Japan's traffic congestion

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1 Siri is a computer program developed by Apple that serves as an intelligent assistant. Pepper is a humanoid robot with a dialog system; it was developed by Softbank, which is a Japanese Mobile Phone Company.

2 'Pods' are driverless vehicles that move on tracks and have already been tested at Heathrow airport. They are used as a prototype of an automated vehicle that would eventually be used on normal roads without tracks.

3 "*kentou kadai no seiri*" https://www.mlit.go.jp/road/ir/ir-council/autopilot/pdf/05/2.pdf

occurs at sag sections of roads, and another 20% occurs at tunnel entrances. Financial loss from traffic congestion in Japan is estimated at approximately 12 trillion yen per year[4] (10.4 billion USD[5]). FAV are expected to contribute significantly to reductions in road congestion. Furthermore, almost 40% of Japanese drivers are elderly, and their mishandling of vehicles is a frequent cause of fatal accidents. In recent years, these incidents have been reported regularly in the media and have raised concerns among the public.

Despite the promise of FAV, their introduction also raises concerns about additional purchasing and maintenance costs and possible information leakages from their software, as the recording of private information may contribute to various crimes. Moreover, there are on-going debates about policy issues related to road regulation. The introduction of AD technology will largely be determined by the decisions made by policy makers. Additionally, insurance regulation is an important issue, as the definition of accidents would change with FAV on the road.

There is widespread interest in FAV from consumers, policymakers and related businesses. Surveys have been used to study consumer demand for AD, focusing mainly on their largest potential markets: the U.S., the EU, China, India, Australia, and Japan. Bekiaris (1996) provided one of the earliest studies on FAV demand using data on 407 respondents from 9 countries. The study found that people were in favor of driving assist systems, which urge drivers to pay attention to their driving, but the respondents showed concern and disapproval regarding FAV. Other surveys have been conducted more recently. Google tested automated driving in 2012, by which time the HAVE it project and SARTRE project had also been

4 MLIT(2015) https://www.mlit.go.jp/road/ir/ir-perform/h18/07.pdf
5 We use the exchange rate of 1USD=115 yen throughout this paper.

conducted; thus, later surveys were conducted under the circumstances where fully AD seemed more realistic to consumers, and acceptability was also significantly increased compared to a few decades earlier. J.D. Power (2012) used data collected from 17,400 car owners in the U.S. and found that approximately 37% responded that they ‘will purchase’ or ‘will probably purchase’ FAV. However, when respondents were asked the same question about purchase intention (PI) assuming an additional cost of 3,000USD, only 20% had a positive PI. Hence, consumers’ PI is conditional on the expected cost of AD technology.

There are several surveys that contain Japanese samples: Continental (2013), Aucnet (2014), and BCG (2015). Continental (2013) collected approximately 1,200 consumer samples in Germany, China, Japan, and the U.S. According to the data, the recognition rates for AD were 67%, 64%, 29% and 50% in Germany, China, Japan, and the U.S., respectively. On the other hand, the shares of people who wanted AD to be available were 19%, 44%, 39%, and 23% in Germany, China, Japan, and the U.S. Additionally, the shares of respondents with positive expectations of using automated vehicles on a freeway were 17%, 36%, 39%, and 28% in Germany, China, Japan, and the U.S., respectively. These results showed significantly low recognition of AD in Japan. The survey also asked about expectations regarding the locations where AD would be used. Among sampled countries, the Japanese have shown relatively high acceptance of AD. Moreover, while 61% of Japanese respondents answered that they were `more inclined to agree that automated driving is a useful advancement,’ 43% of Japanese respondents answered that they `don’t believe that automated driving will function reliably’. Thus, Japanese consumers do think AD would enhance their daily lives, but they also have concerns about the reliability of the related technology.

Aucnet (2014) and BCG (2015) have conducted consumer surveys about AD and

FAV in Japan. Aucnet collected 1,119 samples through the Internet, and the results show that 16% of respondents ‘would like to purchase’, 34% ‘would probably like to purchase’, 7% ‘would not want to purchase’, 6.9% ‘will not purchase’, and 36.6% ‘do not know’ about purchasing FAV. In sum, approximately 70% of respondents had a positive attitude toward automated driving. BCG (2015) also conducted an Internet survey and received 1,583 responses from Japanese consumers who intended to purchase a car or had recently bought one at the time of the survey. The data suggested that between 40% and 50% of respondents were inclined to purchase FAV. The report suggested that consumers’ main reasons for being interested in purchasing FAV were ‘utility from automated driving on a freeway and during traffic congestion’, ‘increased safety for elders who drive and being ‘attracted to newly state-of-the-art technology’. Furthermore, the survey asked about willingness to pay (WTP) for partial and fully automated driving systems (FADS) and showed that WTP for each system was approximately 100,000 yen (870USD) and 200,000 yen (1,740USD), respectively.

Previous surveys and reports on AD and FAV provide basic information on the demand for these technologies. However, the results and analyses of previous studies do not provide details about consumers’ anticipated benefits and concerns with regard to AD and FAV becoming a standard presence on the road. Moreover, there are limited studies examining the determinants of consumers’ demand for AD and FAV. The study by Payre et al. (2014) is one of the few to have examined the factors affecting perceptions of AD; it found that consumers who owned cars with driving assistance systems, such as adaptive cruise control (ACC) or a lane keeping system (LKS), were more likely to be positive about purchasing FAV.

Our study provides deeper insight into consumer demand by surveying the subjective advantages and disadvantages of AD. We analyze the determinants of purchase intention (PI) and WTP for FADS using originally collected Japanese household survey data obtained in 2015. To our knowledge, our survey provides the most recent and largest consumer dataset related to AD. Our analysis combines objective area data such as population density and traffic accident data with survey data. In addition, we also provide analysis at the municipality level, combining aggregated individual-level survey data and city-level objective data.

The rest of this paper is organized as follows. Section 2 provides details on the data and describes the variables. Section 3 provides descriptive statistics. Section 4 presents the estimation model and Section 5 provides estimation results and discusses the results. Section 6 concludes.

2. Data and variables

This study uses an original Internet survey conducted in November and December 2015, which received 246,642 responses. Our survey builds on previous related surveys and offers significantly expanded coverage of questions on consumers' perceptions of AD and FAV; it also includes individual and household characteristics. An Internet survey has the advantage of avoiding the interviewer bias caused by arbitrary factors – such as the appearance or gender of interviewers – when responding to sensitive questions such as household income, employment status and WTP (Welsch and Kühling, 2009). Moreover, given the extensive accessibility of the Internet in Japan, it is a relatively time- and cost-efficient method of collecting data from a large sample compared to a face-to-face survey.

The survey contained several main questions regarding consumer demand for AD and FAV: 1) the expected time frame in which FAV would be available for purchase, 2) the purchase intention of FAV when they become available, and 3) the additional amount the respondent would be willing to pay for FADS. We asked 'when do you think FAV will be available in the market?' and respondents were given several time range options.

To assess PI of FAV, respondents were given 4 options: 1) will purchase, 2) will consider purchasing, 3) will not purchase, and 4) do not know. We constructed 3 dummy variables for purchase intention (PI) using responses to (1) ~ (3) and dropped those respondents who had chosen (4) from the regression analyses. Additionally, respondents were asked to choose a range of WTP for FADS from 21 options, which ranged from 0 to 3 million yen (approximately 26,000 USD). Then, we eliminated the respondents who replied that they did not know their WTP for FADS.

We use several categories of variables that could be determinants of consumer demand for FAV or FADS. As main explanatory variables, we use dummy variables constructed from the merits and demerits associated with AD. We provide a full list of merit and demerit options in Table 1 and Table 2. These tables provide the share of respondents who selected each option, and the results are further described in the next section. We also use factor analysis to create combined indices of the merits and demerits of FAV. As shown in Table 3, we found three factors per merit and demerit with eigenvalues larger than 1.

[Table 1-3 about here]

We also construct mobility-related variables that may be related to the demand for FAV or FADS: the number of car trips per day and average driving time per trip, purpose of car trips, commuting time, driver's license dummy, reasons for car ownership, and reasons for not owning a car. We also ask about dissatisfactions with the traffic environment and about where the respondents expect to use FAV, with the options of general roads, freeways and inner cities. In addition, we use individual and household characteristics such as respondents' age, gender, marital status, number of household members and number of children in a household, education by university graduation, household income, occupations and subjective health evaluation.

Furthermore, we use citizen identification information from the '2015 Basic Resident Register' to construct municipality-level variables, including population density, number of annual traffic accidents, and injuries /deaths related to traffic accidents. We also use another data source, CASBEE (Comprehensive Assessment System for Built Environment Efficiency), to obtain municipality averages of taxable household income and the share of households with elders. Finally, we use prefecture dummies to control for unobservable regional characteristics that may affect respondents' demand for FAV.

Out of 246,642 respondents, we eliminated 6,085 respondents without valid postal codes and for which we could not merge objective municipality level data from alternative sources. We also dropped 98 observations from municipalities that lacked traffic accident data and population density data, and we dropped 412 respondents who resided in municipalities without data on taxable household income. We were left with 240,054 responses. Furthermore, we dropped 49,717 respondents who did not provide household income. Finally, we eliminated respondents who answered that they 'do not know' their WTP (51,965 samples) or PI (51,701 samples) of FADS; 188,089 and 136,388 samples were used for WTP and PI analyses, respectively. Table A1 (See Appendix) provides summary statistics of all variables used in the analyses for the full samples and sub-samples used for the PI and WTP analyses.

3. Descriptive analysis

3.1. Timeframe of FAV availability in the consumer market

Figure 1 shows the results of consumers' perceptions regarding the timing of FAV becoming available in the market. On average, respondents anticipated that FAV would be available for purchase in approximately 13 years.[6] This is rather consistent with their predicted actual availability according to the Automated Vehicle Symposium (2014), which indicated that FAV would be available for purchase in 2030. Hence, our average time frame matches the general expectation. In our survey, 53% of respondents answered that they expect AD to be on the market within 15 years. This is somewhat higher than the 37% of respondents in the survey of Mobility (2013) who stated that AD technology would be available on the consumer market within 15 years. While the mean is approximately 13 years, the most popular time range was 6-10 years, with almost 40% of respondents choosing this option. On the other hand, approximately one quarter of respondents answered that they 'don't know' the timeframe in which AD would be available.

[Figure 1 and 2 about here]

Figure 2 shows the distribution of expected time ranges of FAV availability in the market by age group. The result implies that older generations expect that FAV will be available sooner compared to younger generations. In particular, there is a visible difference between respondents above and below the age of 50. This trend may reflect elders' higher anticipation that FAV will be available soon; it differs from the results of Aucnet (2014), which found that elders had negative views of AD. This difference may be because Aucnet's survey had only slightly more than 60 samples in total, and given the sample size of our data, our result seems more reliable.

3.2. Perceptions about the merits and demerits of automatic driving

Table 1 and Table 2 show the results of the merit and demerit options selected by the respondents.[7] The respondents were given 17 merit options and 12 demerit options. Then, they were allowed to choose unlimited options, and the results are provided in the *multiple* columns. If they had chosen more than 3 options, the respondents were also asked to choose the top 3 merits or demerits, and the results are provided in the top 3 columns. While the average share per option is lower in the top 3 columns, we see very little change in the rankings between *multiple* and the top 3 columns.

The results of the merit options in Table 1 indicate that consumers have high expectations of FAV being a useful tool in the mitigation of mobility problems and accidents related to elderly drivers. Almost half of the respondents chose this option, and it was also ranked first in the question on the top 3 merits. Additionally, reduced traffic accidents and options related to improving the comfort and convenience of driving were also popular options. On the other hand, options such as 'children can ride on their own' and 'having FAV to raise status and reputation' were rarely chosen. Additionally, people do not seem to regard FAV as a mobility tool that can expand their current mobility.

We have compared the selection rate of children's independent mobility as a merit of FAV in the full sample and the sub-sample of respondents with children (N: 30,774) and have

[7] Out of 246,642 samples, there were 47,406 and 39,883 respondents who did not choose merits and demerits, respectively. Also, there were 33,159 respondents who chose neither a merit nor a demerit.

found little difference in the rates. However, we found a significant difference between full samples and sub-samples of respondents without a drivers' license (N: 23,150) in the selection rate of the option 'will not need driver's license' with FAV; approximately 12% of the full sample and 29% of the sub-sample chose that option. Moreover, approximately 19% of respondents without licenses chose this option as one of their top 3 merit options, while only 4% of the entire sample chose this as one of their top 3 merit options. This result clearly reflects the different expectations between drivers and people without licenses.

Table 2 shows the respondents' selection rates of the 12 demerits. Overall, the results indicate consumers' strong concerns regarding the technological dependability and safety of FAV, as well as their concerns about the additional cost of this new and not-yet-available technology. These concerns are in accordance with the findings of BCG (2015). Although the MLIT considers the possibility of information leakage a serious issue, cost and the robustness of technology seem to be consumers' main concerns. Nevertheless, information security is an important issue, and, as the introduction of FAV on public roads becomes more realistic, there will be increased scrutiny of software issues, including the possible malfunctioning and mishandling of stored information.

We also use the merit and demerit categories identified by factor analyses. As shown in Table 3, the merit and demerit options each had three factors with eigenvalues larger than 1. Three merit factors are 1) reduced driving burden; 2) automatic driving to designated destinations and automatic parking; and 3) non-requirement of driver's license. The first category of burden reduction had high weight loadings among the merit options with high selection rates, as shown in Table 1. A study by BCG (2015) showed that U.S. consumers highly valued 'increased safety with FAV', 'reduction of insurance cost', and 'improved productivity due to efficient usage of time' as major benefits of FAV. Japanese consumers also value the safety and increased productivity associated with AD. On the other hand, the three factors from the demerit options are as follows: 1) uncertainties of AD, 2) concerns about information security, and 3) restrictions on driving speed.

3.3 Purchase Intention and WTP for FAV or FADS

Figure 3 shows that approximately 12% of respondents answered that they 'will purchase' and 35% of respondents answered that they 'will consider purchasing' FAV or FADS. A near-majority of respondents are inclined to purchase FAV or FADS. Approximately 20% of respondents answered that they 'will not purchase' these technologies. This share is similar to the figure in BCG's (2015) report. Additionally, 32% respondents answered that they 'do not know'. One of the reasons for this relatively large size of the agnostic group may be lack of interest and information about AD. PI per sub-sample groups indicate that men are somewhat more inclined to purchase, but PI does not seem to significantly vary with age. Additionally, the result shows that respondents who do not own a car or do not have a drivers' license have lower PI compared to car owners but more often respond that they 'do not know' their PI. As shown in Figure 4, we observe, overall, that the municipalities with the highest PI are located in the Hokkaido region and in the non-coastal inner areas of Japan, where cars play a relatively more important role in daily mobility.

[Figure 3 and 4 about here]

Figure 5 shows the result of WTP for FADS by consumer characteristics. The sub-sample of respondents without a driver's license seems to have a relatively lower PI, but they are willing to pay relatively more for FAV. This result seems to imply that respondents without a driver's license are polarized: either they are uninterested in technology and unwilling to pay for it or very interested in purchasing FADS and willing to pay much more than average drivers. Additionally, similarly to PI, men have a higher WTP than women. However, in contrast to the results of PI, elders' WTP is significantly higher than average. This result may be partly due to elders' high expectations of the benefits of AD and their relatively high household incomes.

[Figure 5 about here]

We present two maps of WTP distribution: Figure 6 is the map of WTP distribution of all respondents except for those who answered that they do not know their WTP. Figure 7 maps the WTP of respondents who answered that they will purchase FADS. The comparison of these maps indicates a strong correlation between the WTP and PI of consumers.

[Figure 6 and 7 about here]

4. Estimation model

To examine the determinants of consumer demand for FAV and FADS, we use OLS regression analysis for WTP and an ordered logistic regression analysis for PI. The estimation equation is as follows:

$$WTP_i = Constant + [A_i] \cdot [Merits] + [B_i] \cdot [Demerits] + [\Gamma_i] \cdot [transfer\ \ preferences] + \sum (\delta_i \cdot Individual\ \ attributions) + Error_i$$

A_i, B_i, Γ_i, and δ_i are coefficients and [・] are a matrix of variables.

We run two estimation equations for WTP, one with separate merit and demerit dummies and the other with merit and demerit factors.

The estimation equation using an ordered logit model for PI is as follows:

$$\ln\left(\frac{PI_k}{1 - PI_k}\right)_i = Constant + [A_i] \cdot [Merits] + [B_i] \cdot [Demerits] + [\Gamma_i] \cdot [Transfer\ \ preferences] + \sum (\delta_i \cdot Indevidual\ \ attributions) + Error_i$$

We also run two estimations for PI with separate sets of merit and demerit factors, similar to the WTP analyses.

Furthermore, we use aggregate data at the municipality level combined with socioeconomic data. We use the following estimation models for WTP and PI.

$$WTP_i = Constant + [A_i] \cdot [Merit\ \ rates] + [B_i] \cdot [Demerit\ \ rates] + [\Gamma_i] \cdot [Transfer\ \ preference\ \ rates] + \sum (\delta_i \cdot Regional\ \ attributions) + Error_i$$

$$\ln\left(\frac{PI\ \ on\ \ average_k}{1-\ \ PI\ \ on\ \ average_k}\right)_i$$

$$= Constant + [A_i] \cdot [Merit\ \ rates] + [B_i] \cdot [Demerit\ \ rates] + [\Gamma_i]$$

$$\cdot [Transfer\ \ preference\ \ rates] + \sum (\delta_i \cdot Regional\ \ attributions)$$

$$+ Error_i$$

5. Results and discussion

5.1. Individual-level analysis

Table 4 shows four regression results: For each WTP and PI, we provide the results with separate merit and demerit options, and with the factors of the merits and demerits calculated using factor analysis. The results suggest that the following merit options positively affect consumer demand for FADS: supporting the elderly, reducing traffic accidents, and reducing the burden of driving. On the other hand, demerit options such as an increase in initial and maintenance costs, information leakage to third parties, and possible malfunctions were found to negatively affect consumer demand. In particular, the merit of FAV in improving elders' driving has a positive and relatively large impact on WTP. The expected improvement in mobility with FAVS, as well as the expected reduction in traffic accidents, also had relatively large positive coefficients.

Two demerits, 'the possibility of malfunction or accident' and 'unclear responsibility when a traffic accident happens,' had negative effects on PI but positive effects on WTP. This result may reflect consumers' perception that taking measures against malfunctioning and setting clear regulations about responsibility for traffic accidents would increase their willingness to purchase and make FADS more valuable. According to the calculation with coefficients in Table 4, the monetary benefit per capita of fully removing technical malfunctions is approximately 8,500 yen (74USD), and the benefit of clarifying regulations and understanding responsibility for traffic accidents is approximately 7,500 yen (65USD). Additionally, per capita loss from uncertainty regarding information leakage to third parties is approximately 4,000 yen (35USD).

[Table 4 about here]

The results of other mobility-related variables indicate that consumers are willing to pay more for safety and the avoidance of congestion by purchasing FADS. Additionally, consumers who regularly drive long-distances have relatively higher PI and WTP. On the other hand, people who 'prefer to go out alone ' or 'prefer to go out without specific purposes' had relatively lower PI and WTP. Moreover, people who 'make a plan beforehand when going out,' 'want to follow plans when going out', and 'want to shorten the time spent on the road' also had relatively lower PI and WTP. The results also indicate that a one-minute reduction in driving time would increase respondents' WTP by an average of 170 yen (1.5 USD), which would add up to 10,000 yen (87 USD) per hour.

In addition, we find that expectations of AD on general roads and freeways both have positive effects on PI; however, they do not affect WTP. On the other hand, people in urban areas have lower PI but relatively higher WTP. Considering consumer characteristics, 'having children' and 'not having a driver's license' positively affect both PI and WTP. Meanwhile, 'not owning cars' positively affects PI; however, it hardly affects WTP. Respondents who expect that automated vehicles will enter the market earlier are inclined to purchase FAV but to pay lower fees for them. As for household income, an increase of one million yen leads to an increase in WTP of 6,500 yen (57USD). Given that WTP for FAD is, on average, approximately 200,000 yen (1,740USD), WTP is equal to 240,000 yen (2,087USD) when household income is 10 million yen (8,700USD). Household income affects WTP positively, but the impact per unit is so small that it is almost irrelevant. Overall life satisfaction has a positive effect on WTP but a negative effect on PI.

Regarding objective data variables, population density does not affect WTP, but accidents-per-capita by municipality has a positive effect on PI. In addition, the variable of the difference between personal assessment of municipal administration services and municipality average also had a positive impact on PI. This result implies that people who are more satisfied with their municipality's services have a higher PI of FADS. Given that the introduction of FAV would require the coordination of regulators and local policy makers, consumers who trust their local policy makers may expect a smoother transition to FAV-based road and traffic regulations.

5.2. Municipality-level analysis

The municipality analysis indicates that the rate of car ownership has a positive effect on PI. However, it does not have a significant effect on PI. Additionally, the convenience of dropping off and parking cars has the same effect. Also, municipalities with a higher share of people who regard expanded accessibility as a benefit of FADS seem to have a higher average PI. In addition, concern about the malfunctioning of FADS negatively affects both the average PI and average WTP. This result indicates that public relations activities concerning the possible safety issues of FADS need to be managed to improve the acceptability of FAV.

[Table 5 about here]

Consumers seem to expect major accident reductions from the introduction of FAV, and we found a positive effect of this expectation on their PI. However, the positive impact of the expectation of accident reduction is smaller than the negative impact of people’s concerns regarding the malfunctioning of FADS. Other city-specific variables, such as average taxed income, the ratio of elders, number of traffic accidents, and average subjective assessment of municipal administration services, and average subjective life satisfaction did not have statistically significant impacts on the average WTP for FAV. Thus, the acceptability of FAV would be affected by individual characteristics rather than by city specific characteristics.

6. Conclusion

As AD technology advances rapidly and receives more media coverage, public consumers are increasingly exposed to this new technology and are developing expectations. Policy makers are assisting with the investment in both hard and soft technologies related to AD and are preparing for the full introduction of FAV in the consumer market and on public roads by debating optimal regulatory policies. Nonetheless, as with any technology, understanding consumer demand and perception is essential to predicting the near-future market and to grasping barriers to the introduction of FADS as common consumer goods.

Our survey data indicates that Japanese consumers expect that FAV will enter the market in approximately 13 years, and 47% of consumers are inclined to purchase FAV. The majority of consumers expect to use AD technology on freeways and also on general roads. Also according to the survey data, WTP for FADS is approximately 0.19 million yen (1,650 USD). We see a strong correlation between PI and WTP. The respondents who answered that they 'will purchase' FADS when available have an average WTP of 285,000 yen (2,480USD), and respondents who would 'consider purchasing' would pay 225,000 yen (1,960 USD) on average. On the other hand, the WTP of respondents who 'will NOT purchase' FADS was 134,000 yen (1,165USD). Thus, consumers with the strongest PI have a WTP double that of consumers with no interest in purchasing FADS. As for these WTPs, given the price of partial ADS and FADS, BCG (2015) estimated prices for partial AD vehicles and FADS at approximately 2,000~5,700 USD and approximately 9,800 USD, respectively. Hence, there seems to be a significant gap between the WTP and predicted prices.

The major merits of FAD are as follows: eliminating concerns of elders, automatic destination arrival and parking, reducing the burden of driving, and reduction in traffic accidents. These merits can be classified into the following three categories: 1) reducing the burden of driving, 2) getting in and out of the car at designated locations and automatic parking, and 3) not needing a driver's license. On the other hand, accidents due to malfunctions, unclear responsibility for accidents, and initial costs and maintenance costs are the majority demerits of FAD. These demerits can be classified into the following three categories: 1) anxieties about the unfamiliarity of automated driving, 2) leakage of information, and 3) restrictions on cars' availability. We find that elderly people are highly interested in FAD, as they selected more merit and demerit options than other groups.

The results of regressions indicated that merits mainly positively affect acceptability and demerits mainly negatively affect acceptability. Considering that people who do not have cars or drivers' licenses are more willing to accept automated driving than people who do have cars and drivers' licenses, we anticipate the expansion of usage for people without cars.

Our municipality-level analysis found that municipality level variables such as averaged tax income, the share of elders, and average ratings of municipal services as well as average life satisfaction ratings do not affect consumer demand for FADS. The variables that show significant effects on both individual analysis and regional analysis are related to traffic accidents. Furthermore, using individual data, we performed a multiple regression analysis of the expansion of accessible areas, which is one of the major benefits of automated driving. As a result, it is clear that inner-city areas, particularly in Tokyo, show higher acceptability of AD than other areas.

There are several issues that can be addressed in future studies to further our understanding of consumer demand for AD: 1) closing the gap between the price that firms expect and the price that consumers are willing to pay; 2) addressing the issue of possible technical malfunction, and 3) information security. The first problem may be resolved through subsidies either to the industry or to consumers, and also by an increase in investment to lower production costs. As for issues (2) and (3), investment in the field of technological development would be useful, but sharing information about technological advancements and the merits of AD with consumers may also be an effective strategy.

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Tables and Figures

Tables

Table 1. The results of selected merits (multiple selections and top 3 selections)

Rank	Merit options	Multiple	Top3
1	Mitigating transportation problems involving elders	45.44%	29.92%
2	Getting off at designated places, and automatic parking	37.25%	21.01%
3	Overall reduction of the burden from driving	36.42%	18.92%
4	Automatically braking in the cases of danger	35.54%	14.66%
5	Reducing traffic accidents due to human errors	32.43%	18.38%
6	Burden reduction from long trips	32.32%	13.39%
7	Getting on at designated places	31.67%	14.31%
8	Able to switch between automatic and manual drive	28.60%	7.91%
9	Can effectively use traveling time	23.95%	8.20%
10	Automatic starting according to signals	22.19%	2.55%
11	Automatic lane change, overtaking, and merging	20.85%	3.14%
12	Automated transportation of goods	18.12%	5.44%
13	Will not need the driver's license	12.18%	4.36%
14	Accident would not be the driver's responsibility	11.72%	4.31%
15	Extended accessibility	10.72%	2.08%
16	Children can ride without supervision	4.01%	0.57%
17	The status of having automated vehicles	2.02%	0.24%

Table 2. The results of selected demerits (multiple selections and top 3 selections)

Rank	Demerit options	Multiple	Top3
1	Possible traffic accidents by technical malfunctions	53.76%	43.48%
2	The obscurity of responsibility in the accidents	48.63%	31.43%
3	Increase in Initial costs and maintenance costs	42.37%	25.26%
4	Children may misuse the car without supervision	40.08%	22.56%
5	The third party can miuse the car	35.37%	18.58%
6	Increased traffic quantities	27.23%	9.36%
7	Reaching wrong destinations due to system malfunctions	25.63%	7.85%
8	Needs to learn new operative system	20.40%	8.97%
9	Recording of all routes and destinations	13.24%	4.38%
10	Possible leakage of private information	11.83%	3.09%
11	Cannot drive over speed limit	9.50%	2.99%
12	Difficult to remodel the cars	3.88%	0.75%

Table 3. The results of Factor Analyses: Merit and demerit factors

Factors	Options with high weight loading for a given factor	Factor description
Merit 1	Mitigating transportation problems involving elders Burden reduction from long trips Overall reduction of the burden from driving Switching between automatic and manual drive Reducing traffic accidents due to human errors Automatic braking in the cases of danger Automatic starting according to signals Automatic lane changes, overtaking, and merging	Burden reduction from driving
Merit 2	1: Getting off at designated places, automatic parking 2: Getting on at designated places 3: Automated transportation of goods	Automatic arrival and parking at designated destinations
Merit 3	7: Will not need the driver's license 9: Children can ride without supervision 11: Accident would not be the driver's responsibility	Do not need driver's license
Demerit 1	3: Children may misuse the car without supervision 6: The third party can miuse the car 7: Possible traffic accidents by technical malfunctions 10: The obscurity of responsibility in the accidents 11: Increased traffic quantities 12: Reaching wrong destinations due to system malfunctions	Uncertainties and risk of AD and FAVS
Demerit 2	4: Recording of all routes and destinations 5: Possible leakage of private information	Concerns regarding information security
Demerit 3	1: Needs to learn new operative system 8: Cannot drive over speed limit 9: Difficult to remodeling the cars	Restrictions

Table 4. Determinants of consumer demand of FAV and FADS (individual level analysis)

Variables	WTP (1)	WTP (2)	PI (1)	PI (2)
Merit options				
Getting off at designated places, and automatic parking	0.306	1.754***		
Mitigating transportation problems involving elders	1.823***	1.174***		
Burden reduction from long trips	0.417*	1.379***		
Overall reduction of the burden from driving	1.668***	1.279***		
Reducing traffic accidents due to human errors	1.557***	1.182***		
Extended accessibility	1.472***	1.389***		
Automatic braking in the cases of danger	1.016***	1.101***		
Demerit options				
Increase in Initial costs and maintenance costs	-0.915***	0.865***		
Recording of all routes and destinations	-0.976***	0.948***		
The possibility of traffic accidents by malfunctions	0.858***	0.704***		
The obscurity of responsibility in the accidents	0.747***	0.772***		
Merit factors				
Burden reduction from driving			2.285***	1.382***
Automatic arrival and parking at designated destinations			0.927***	1.586***
Will not need the driver's license			0.198*	1.051***
Demerit factors				
Uncertainties and risk of AD and FAVS			0.251*	0.663***
Concerns regarding information security			-0.426***	0.953***
Restrictions of AD			-0.917***	1.027***
Preference regarding travel and mobility				
Likes traveling	-0.136	1.016	-0.150	1.025**
Prefer to make a plan when going out	0.316	0.935***	0.309	0.923***
Prefer to go out alone	0.367	0.869***	0.397*	0.863***
Don't mind paying extra cost for safety	3.791***	1.197***	3.817***	1.223***
Prefer to follow plans when going out	0.208	0.983	0.234	0.994
Want to shorten traveling time	-0.748***	1.000	-0.699***	0.997
Don't mind paying extra cost to avoid congestions	2.541***	1.111***	2.598***	1.097***
Prefer to go out without plans	0.287	0.917***	0.325	0.908***
Automatic Driving				
On general roads	-1.042***	1.610***	-1.193***	1.629***
On a freeway	-0.376	1.426***	-0.432*	1.375***
Inner city streets	1.169***	0.951***	1.223***	0.938***
Individual attributes				

Age	-0.952***	1.023***	-0.951***	1.020***
Household income	0.657***	1.012***	0.657***	1.012***
Childr(en) in household	2.151***	1.056***	2.127***	1.054***
Car owner	0.644	0.458***	0.692	0.449***
Diver's license	-3.340***	0.702***	-3.478***	0.674***
Average driving time	0.0168***	1.001***	0.0169***	1.001***
Population density of a municipality	-4.64e-05	1.000	-4.82e-05	1.000
Accidents per capita of a municipality	-372.4	2.777e+29**	-400.6	1.519e+30**
Difference between personal evaluation and municipality average of municipality evaluation	1.345***	1.106***	1.325***	1.114***
Life satisfaction	0.792***	0.988*	0.817***	0.988*
Observations	188,089	136,388	188,089	136,388
R-squared	0.044	.	0.044	.
pseudo R2	.	0.0989	.	0.0984

Note: *** p<0.01, ** p<0.05, * p<0.1

Table 5. Determinants of consumer demand of FAV and FADS (municipality level analysis)

Variables	WTP (1)	WTP (2)	PI (1)	PI (2)
Merit options				
Getting off at designated places, and automatic parking	-4.727		1.359***	
Automated transportation of goods	-0.480		1.116	
Burden reduction from long trips	-4.777		1.224*	
Will not need the driver's license	-4.898		0.952	
Accident would not be the driver's responsibility	4.103		1.334*	
Reducing traffic accidents due to human errors	11.70**		0.868	
Extended accessibility	16.79**		1.222	
Demerit options				
Needs to learn new operative system	5.887		1.128	
Increase in Initial costs and maintenance costs	5.412		0.941	
Making a record of all tracks	9.307		1.114	
The third party can miuse the car	1.801		0.899	
The possibility of traffic accidents by malfunctions	-14.33***		0.777***	
Increased traffic quantities	-1.994		0.965	
Reaching wrong destinations due to system malfunctions	2.146		0.777**	
Merit factors				
Burden reduction from driving		7.284**		1.012
Automatic arrival and parking at designated destinations		-2.832		1.271***
Will not need the driver's license		3.748		1.139***
Demerit factors				
Uncertainties and risk of AD and FAVS		-3.557		0.754***
Concerns regarding information security		-0.233		0.981
Restrictions of AD		0.162		1.039
Regional attributes				
Average age	0.167	0.0944	1.003	1.002
The share of car owners	-0.330	-0.0608	0.825***	0.839***
Car accidents per capita	75.26	104.9	5.858	4.779
Taxable income per capita	0.438**	0.461**	1.001	1.002
Average municipal evaluation	-0.745	0.166	1.022	1.004
Average life satisfaction measures	-2.062	-2.330	1.003	1.003
Hokkaido	-1.210*	-1.298*	0.952***	0.953***
Tohoku	-0.792	-0.602	0.986	0.987
Chubu	-0.380	-0.332	0.987	0.990
Kinki	-0.510	-0.293	0.994	0.998
Chugoku	-0.227	-0.0496	0.971**	0.966***

Shikoku	1.239	1.332	0.986	0.988
Kyushu	-1.270**	-1.162*	0.985	0.988
Observations	405	405	405	405
R-squared	0.150	0.118	0.456	0.459

*** p<0.01, ** p<0.05, * p<0.1

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Figures

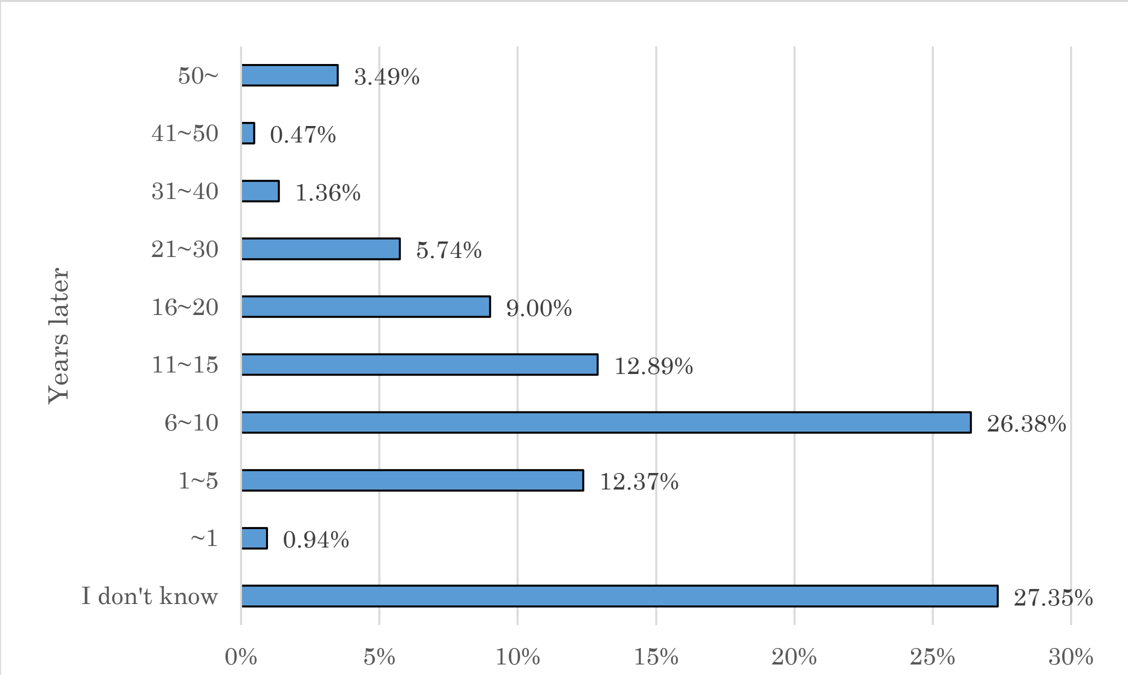

Figure 1. When would FAV be available in the market?

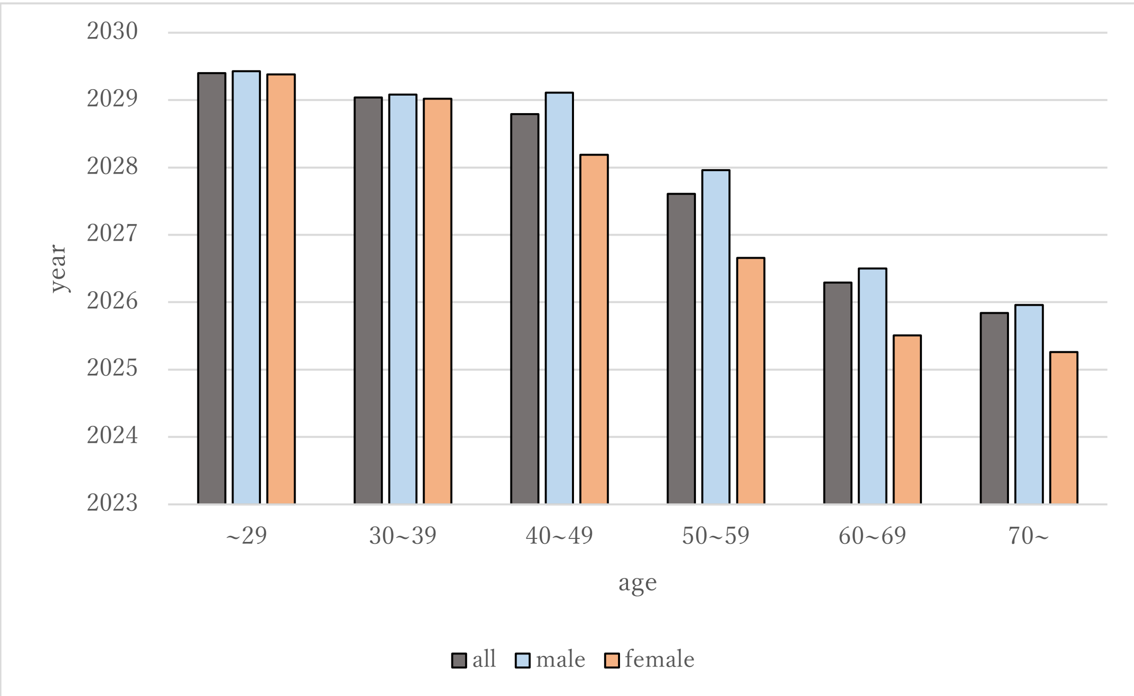

Figure 2. When would FAV be available in the market? (by age groups)

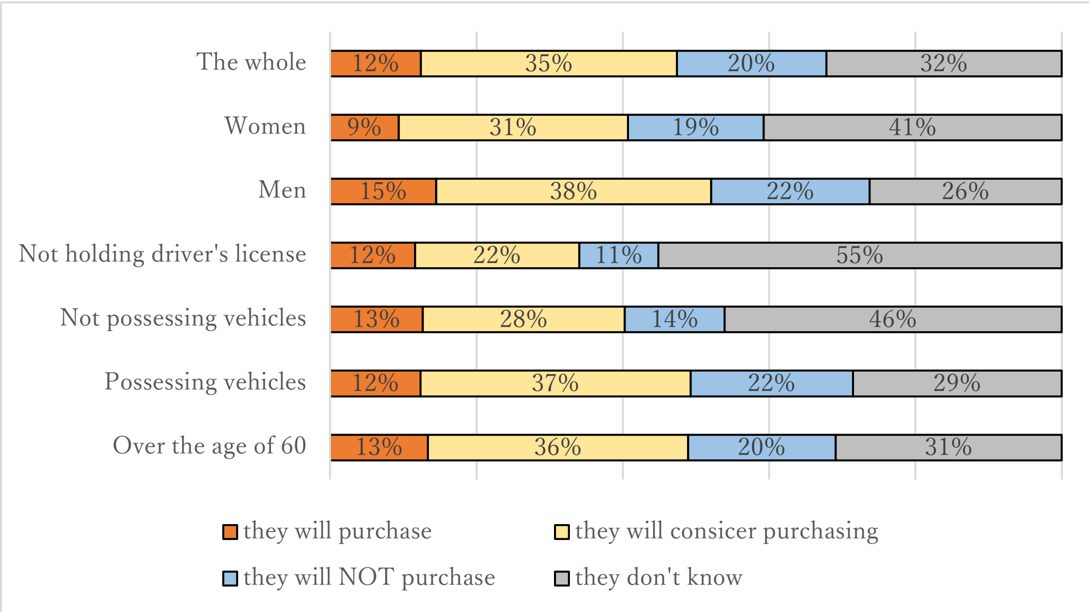

Figure 3. Purchase Intention for FADS by consumer characteristics（N: 246,642）

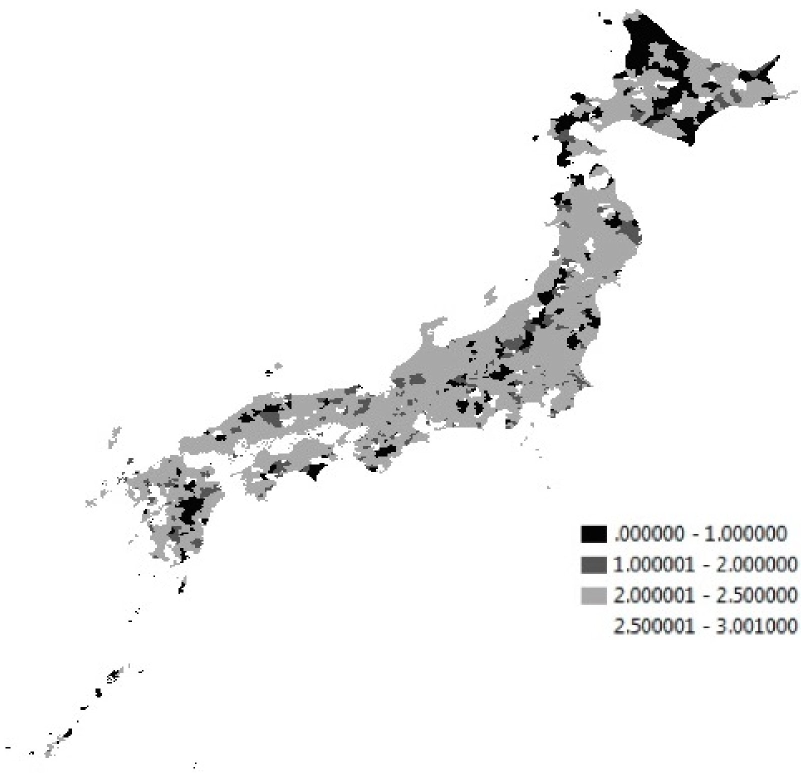

Figure 4. Distribution of Purchase Intention at municipality level

*1-will purchase, 2-will consider purchase, 3-will not purchase.

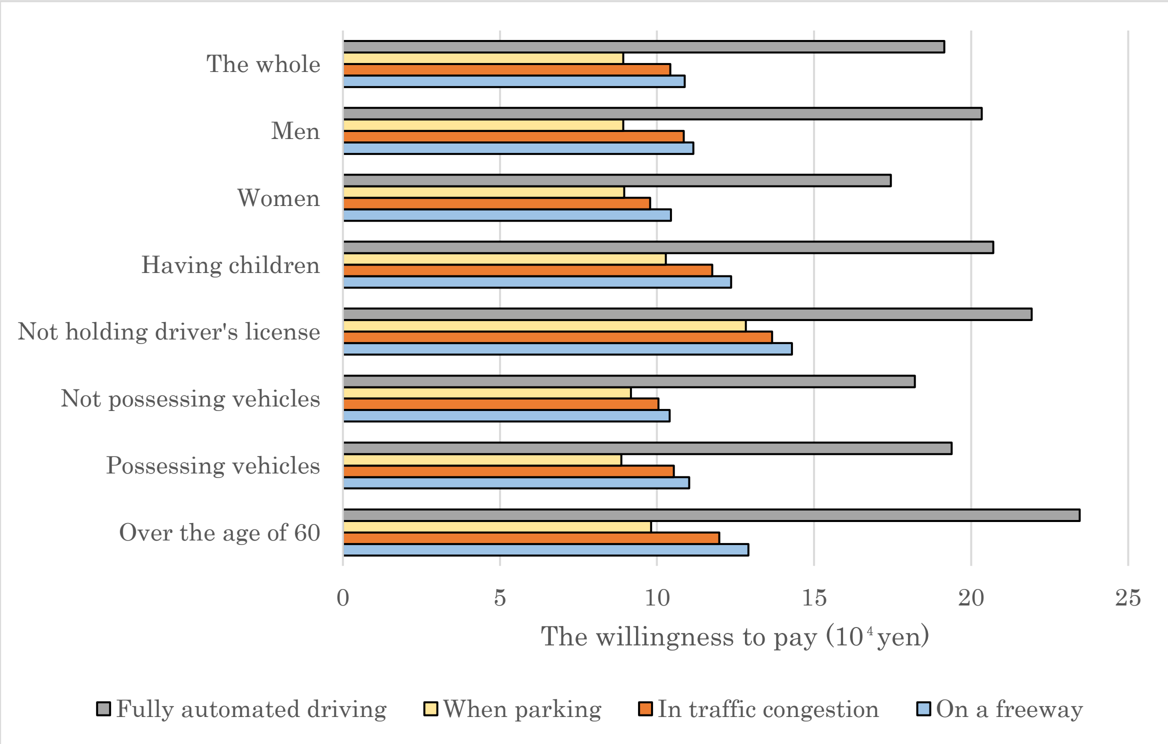

Figure 5. WTP of FADS by consumer characteristics（N: 188,089）

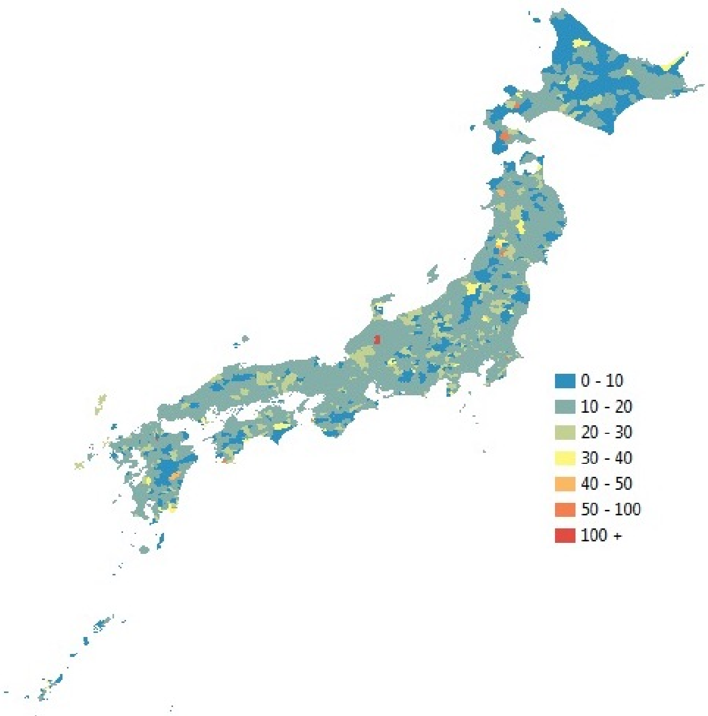

Figure 6. Distributions of WTP at municipality level

*Numerical ranges in 10,000 yen

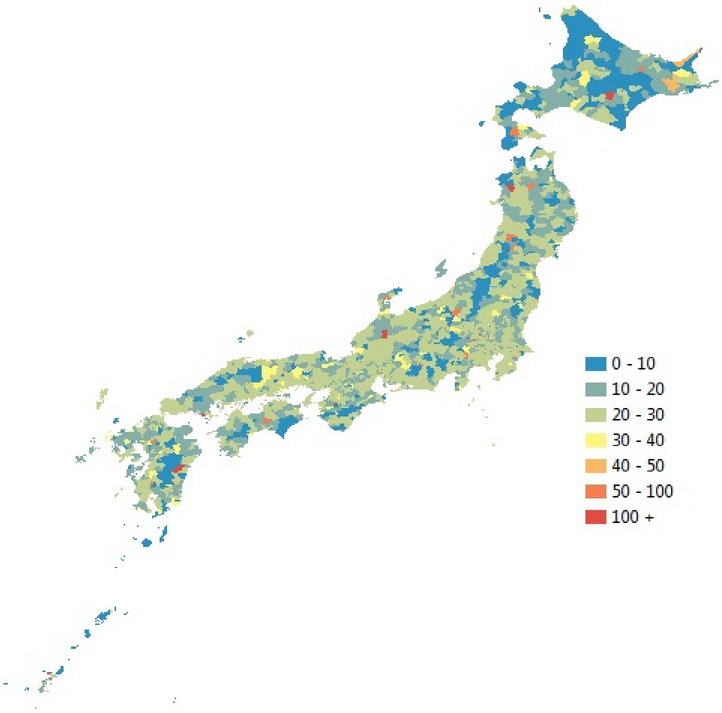

Figure 7. Distributions of WTP at municipality level: Consumers with high PI

*Numerical ranges in 10,000 yen