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Analysis of changes in purchase intention of electric vehicles due to the spread of ICT-based sharing and reservations for in-town recharging facilities.

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1. Introduction

Efforts to promote the widespread adoption of electric vehicles (EVs), which contribute to the realization of a carbon-neutral society, are being discussed. According to the Japan Automobile Dealers Association, the share of EVs in new passenger car sales was approximately 1.16% in the period ending December 2024, with a total share of about 1.85%. Past surveys related to Battery Electric Vehicles (BEVs) indicate that factors such as driving range and vehicle specifications, as well as the availability of charging facilities, are key to their widespread adoption (Pysalska et al., 2022; Phillipson et al., 2020; Khan et al., 2017; Kudoh and Motose, 2010).

There are different types of EV charging facilities, such as regular recharging facilities which take several hours to charge for a 100 km drive and fast charging facilities which take about 30 minutes to charge for a 100 km drive. The installation cost of the former is relatively low, and it can be installed in individual homes using subsidies. In contrast, the installation cost of the latter ranges from 10 to 20 million yen, making it impractical for individual homes and used by the public in a manner similar to current gasoline stations. Additionally, there are Super-fast charging facilities called Superchargers, dedicated to Tesla vehicles, which allow significantly faster charging than fast charging facilities. Currently, fast charging facilities are mainly installed in locations such as automobile dealerships, convenience stores, roadside stations, and expressways (SA/PA), with 40% of installations at automobile dealerships, while only 10% are at convenience stores and roadside stations/highways (Source: March 2023, e-mobility power charging spot list). On the other hand, regular recharging facilities are installed mainly in destinations with long stay times such as hotels and shopping malls, in addition to individual home installations.

The necessity for adequate recharging facilities is evident as BEV usage can only become widespread if users have convenient access to recharging options. In Japan, over 29,000 recharging facilities exist, with approximately 70% being regular recharging facilities and 30% being fast recharging facilities. It is relatively easy to install in detached houses but challenging in apartment buildings. According to the "Housing and Land Statistics Survey" by the Statistics Bureau of Japan in 2018, 53.6% of households live in detached houses, and 43.5%

live in apartment buildings, with the percentage of apartment dwellers reaching 71% in Tokyo. This higher ratio in urban areas presents a challenge to the widespread installation of charging facilities.

While installing regular recharging facilities in individual homes is relatively easy, in apartment-type residences, it is necessary to obtain approval from the residents' association, which is organized by the inhabitants, to install charging facilities in communal parking areas. These households face significant constraints in installing personal recharging stations in their parking spaces. This is one reason why apartment dwellers hesitate to purchase BEVs.

Charging facilities remain idle when not in use and are suitable for shared use. In fact, public fast recharging facilities are used as shared infrastructure. While regular recharging facilities are generally installed in individual homes and are not typically considered for shared use, the advancement of ICT and the widespread ownership of smartphones suggest that shared use of regular recharging facilities in individual homes would be quite feasible.

Previous studies highlight the critical role of ICT in optimizing various services and systems, including transportation. For instance, Benevolo et al. (2016) and Jittrapirom et al. (2017) emphasize how ICT can enhance smart mobility and user-centered mobility services. Breidbach and Brodie (2017) discuss the sharing economy's reliance on ICT for facilitating value co-creation and engagement. Billhardt et al. (2019) demonstrate how ICT improves the matching efficiency of cab dispatch services. These studies would indicate that ICT may contribute the matching efficiency of recharging facilities online. In Japan, currently, it is possible to search for recharging facilities online, but there are not many facilities that can be reserved via apps. If recharging facilities become more widely available, and if it becomes possible to check their real-time availability and make reservations using a smartphone app, this is likely to increase the willingness to purchase EVs. Especially in Japanese urban areas with a high ratio of apartment dwellers, the efficient use of infrastructure, including regular recharging facilities, is essential for high EV adoption rates. Based on this awareness, this study aims to explore the impact of enhanced availability of charging facilities, such as through sharing and online reservations, on the intention to purchase BEVs in urban areas of Japan with high apartment dwelling ratios.

2. Data and Hypothesis

The data used in this study are from a web survey conducted in January 2024. The survey targeted respondents aged 20 and above who could reflect their own decision-making when purchasing a private car and who owned a private car at home. The sample size was 17,076. For hypothesis testing, a conjoint analysis was adopted, a method prominently represented in Green and Rao (1971). The objective of this study is to investigate the potential for efficient

utilization of charging facilities through the integration of ICT in urban areas of Japan with high apartment dwelling ratios. Accordingly, the hypotheses to be tested are as follows: "How does the availability of charging facilities in urban areas, which can be monitored in real-time and reserved through ICT, influence consumers' willingness to purchase BEVs?" We hypothesize that the implementation of ICT-based reservation systems for underutilized recharging facilities can enhance their efficiency, improve social welfare, and stimulate consumer interest in purchasing BEVs.

2.2. Conjoint Questionnaires

The survey using this study designed conjoint questions by assuming that respondents are at the timing of car purchase and by setting "If The total cost of ownership over a period of approximately five years, including fuel, purchase price, taxes, and maintenance, is roughly the same for both the BEV and the gasoline car". In addition, Given the limitations on BEV lineups and the expectation that the lineup will increase in the future, the assumption was also made that "both gasoline and BEVs are listed as purchase candidates for respondents". The assumption of "comparable total cost over five years" was based on the idea that if the government promotes BEVs from a carbon-neutral perspective, it could meet this condition through subsidies. In the FLP Nakamura Seminar (2024), it was empirically verified whether there was a difference in purchase intention between gasoline and hybrid vehicles by controlling vehicle prices, various expenses, government subsidies, fuel costs, and resale prices. It was confirmed that when these related costs were totaled over approximately five years, the costs were almost the same for both vehicle types. In other words, for environmentally friendly vehicles, if the total cost is not comparable to that of gasoline vehicles over a certain period, consumers are unlikely to consider them as purchase candidates.

The following attributes and levels were set for the conjoint questions as shown in Table 1. To test the hypotheses, conjoint questions were designed using three types of charging facilities (regular, fast super-fast recharging facility), each with three levels. Regular recharging facilities were assumed to have three levels: "Available in the home parking lot", "Not available in the home parking lot but within a 10-minute walk and can be reserved online," and "Not available at home or within a 10-minute walk". This attribute allows measuring the impact of shared use of regular charging facilities on the intention to purchase BEVs. Fast recharging facilities were not assumed to be non-existent, considering their existing installations at convenience stores. The installation levels for fast charging facilities were set based on the installation rate at convenience stores: "Available at about 20% of convenience stores," "Available at a half of convenience stores," and "Available at all convenience stores." Super-fast recharging facilities, assumed to be Tesla Superchargers, were

also included with the levels: "Not available," "Available at about 20% of convenience stores," and "Available at a half of convenience stores." The hypothesis of this study includes the effect of efficient use of charging infrastructure through online reservations and real-time availability checks. To verify the hypothesis, the availability of online reservations and real-time availability checks for fast and super-fast recharging facilities was set with two levels by each level: "Possible" and "Not possible." A Sample question and answer form are shown in Appendix A.

Table 1 Conjoint questions (attribute and levels)

attributes	levels
Regular recharging facility	"Available in the home parking lot", "Not available in the home parking lot but within a 10-minute walk and can be reserved online," and "Not available at home or within a 10-minute walk"
Fast recharging facility	"Available at about 20% of convenience stores," "Available at a half of convenience stores," and "Available at all convenience stores."
Super-fast recharging facility	"Not available," "Available at about 20% of convenience stores," and "Available at a half of convenience stores."
the availability of online reservations and real-time availability checks for fast and super-fast recharging facilities	"Possible" and "Not possible."

2.3. Estimation method

As evident from the example questions (see Appendix A), the responses to the conjoint questions in this study are a binary choice model indicating whether BEVs will be considered as purchase candidates. Therefore, the estimation model for this study is specified as a conditional logit model, which is a representative estimation method for binary choice models. The specific estimation formula is as follows:

$$ans_{ij} = \alpha + \beta_1 Fhome_{ij} + \beta_2 F10_{ij} + \beta_3 QC_{ij} + \beta_4 QCN_{ij} + \beta_5 SC_{ij} + \beta_6 SCN_{ij} + \beta_7 SCO_{ij} + \varepsilon_{ij} \quad (1)$$

ans_{ij} is the binary dependent variable that equals 1 if respondent i considers BEVs under

condition j as a purchase candidate and 0 otherwise. $F_{home_{ij}}$ is a dummy variable that equals 1 if regular recharging facilities are available at home and 0 otherwise. $F_{10_{ij}}$ is a dummy variable that equals 1 if regular recharging facilities are not available at home but are available within a 10-minute walk and can be reserved online, and 0 otherwise. QC_{ij} is a variable representing the installation rate of fast recharging facilities in convenience stores, with values 1, 0.5, and 0.2 corresponding to installations in all, half, and 20% of convenience stores. QCN_{ij} is the interaction term of QC_{ij} and NET (a dummy variable for online reservation and real-time availability check). SC_{ij} represents the installation rate of Super-fast recharging facilities in convenience stores, with values 0.5, 0.2, and 0 for installations in half, 20%, and none of the convenience stores, respectively. SCN_{ij} is the interaction term of SC_{ij} and NET. $SC0_{ij}$ is a dummy variable that equals 1 if SC_{ij} is 0 and 0 otherwise. The model is estimated using pooled data from 17,076 respondents, each answering 6 conjoint questions.

3. Result

The estimation results for the conditional logit model are shown in Table 2. The results indicate that, except for the coefficient estimates related to the online reservation and real-time availability check for Super-fast recharging facilities, which were not significantly different from zero, the results are generally favorable.

Table 2 The result of estimation

	Coef.	P-value	Coef.	P-value
F _{home}	1.2414	(0.000)	1.2448	(0.000)
F ₁₀	0.3108	(0.000)	0.3125	(0.000)
QC	0.2710	(0.000)	0.2702	(0.000)
QCN	0.4369	(0.001)	0.6070	(0.000)
QCN(over 60 old)	-	-	-0.3225	(0.051)
SC	0.3928	(0.027)	0.3966	(0.025)
SCN	-0.2822	(0.398)	-0.1827	(0.627)
SCN(over 60 old)	-	-	-0.1906	(0.582)
Constant term	-2.1850	(0.000)	-2.1872	(0.000)
Sample size	17,076		17,076	

Pseudo R-squared	0.0588	0.0604
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While the online reservation and real-time availability check for Sper-fast recharging facilities are not significantly demanded by consumers, the estimate for fast charging facilities is statistically significant at about the 1% significance level. the coefficient estimates for $F10_{ij}$ is significantly different from zero.

Therefore, these results suggest that if regular recharging facilities cannot be installed at home, the intention to purchase BEVs will increase if recharging facilities can be efficiently used through online reservations and real-time availability check and if regular charging facilities that can be shared are available near the home. This supports the hypotheses we have established.

4. Discussion

We also analyzed the impact on user's utility in case of fast recharging facilities at the place where users would take little time (convenience store) and at the place where users would take a couple time (restaurant / shopping mall).

Table 3 The result on the Impact of Fast recharging facilities locations on consumer utility

	Unconnected ICT		Connected ICT	
	Coef.	P-value	Coef.	P-value
Convenience stores	0.9744	(0.000)	1.0299	(0.000)
Restaurant and shopping mall	0.3983	(0.000)	0.3029	(0.000)
Sample size	4,269		4,269	

The result being shown in Table 3 reveal that if fast recharging facilities installed such both places, it can be compensated that there isn't home recharging facility. Furthermore, at convenience store, recharging facilities connecting with ICT would improve user's utility.

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Appendix A: Sample question and answer form of conjoint questions

EXAMPLE: Question (In English)

Please consider whether a Battery Electric Vehicle (BEV) would be a viable purchasing option under the following home charging conditions: 'Scenario A' and 'Scenario B'. Additionally, if you were to purchase a BEV, which scenario between 'Scenario A' and 'Scenario B' would you prefer for your household? Share your thoughts.

NOTE1: All charging facilities are available for use at the cost of electricity only.

NOTE2: A Battery Electric Vehicle (BEV) refers to an automobile powered solely by batteries and an electric motor, without any gasoline engine or other type of internal combustion engine.

	SCENARIO A	SCENARIO B
Regular recharging facility	At home	Can be installed within 10-minute walk and be reserved online.
The number of fast recharging facility	Available at all convenience stores in Japan (and online reservations are available)	Available at a half of convenience stores in Japan (and online reservations are not available)
The number of Super-fast recharging facility	Available at a half of convenience stores in Japan (and online reservations are not available)	None

	All Scenarios in which you can consider a BEV as a purchase option. (multiple responses allowed)	Which scenario is more likely to result in considering a BEV as a purchase option? (single response required)
SCENARIO A	<input type="checkbox"/>	<input type="radio"/>
SCENARIO B	<input type="checkbox"/>	<input type="radio"/>
Neither scenario applies.	<input type="checkbox"/>	