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ANALYSIS OF OWNERSHIP BEHAVIOR OF LOW-EMISSION PASSENGER CARS IN LOCAL JAPANESE CITIES

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Abstract: Various measures have been taken to reduce environmental loads. One of the examples is the development of low emission vehicles (LEV), which has become more and more competitive at the market since the Japanese government implemented the LEV authorization system in 2000. On the other hand, people's mobility in local cities highly depends on car traffic, compared with large cities. As a result, it seems difficult to reduce car ownership in these local cities. Considering that passenger cars have been producing a large percentage of CO_2, this paper attempts to examine the effects of car-related tax policies on the ownership of low emission passenger cars (LEPC) based on a stated preference survey. Survey results show that under mixed tax policies, about 60% of respondents would like to own the LEPC. Empirical analysis based on choice model suggests that control of auto tax is most effective to increase the LEPC ownership.

Key Words: low emission passenger car, stated preference survey, tax policies, local city

1. INTRODUCTION

In most countries, energy consumption and pollutants from transport sector have been increasing considerably in the past decade. In Japan, for instance, fuel consumption and CO_2 emissions in transport sector significantly increased by 16% from 1990 to 1995. Assuming such increase rate in the future, emission level in transportation sector is expected to rapidly increase by 40% by 2010, comparing with the 1990 level. Currently, transport sector produces 22% of total CO_2 emissions (2001) in Japan. Considering the growing concerns on global warming, this alarming rate of increase calls for measures of enhancing energy efficiency and reducing emissions in the entire transportation systems. Since passenger cars have been producing large percentage of total exhausted amount of CO_2, this paper focuses on the analysis of ownership behavior of passenger cars.

On the other hand, comparing with large cities, people's mobility in local cities highly depends on car traffic in Japan. As a result, it seems difficult to reduce the ownership of passenger cars in these local cities. This is also true in other developed cities. Many studies about car ownership behavior have been conducted, such as choice of vehicle type, ownership duration, and car use behavior (e.g., Choo and Mokhatarian, 2004; Tam and Lam 2000). However, most of the studies focus on the issues in large cities (e.g., Koh, 2003; Bhat and Puluguranto, 1998) and little research has been done in the context of local cities. It is known that environmental load from automobiles is a function of the number of vehicles, travel distance, travel speed and environmental emission factors. Accordingly, policies of reducing travel distance, control of travel speed and the improvement of environmental emission factors become important in the case of local Japanese cities. Policies of reducing car travel distance include control of land and car use, and promotion of using transit systems and bicycles etc. Control policies of travel speed are mainly related to the mitigation of traffic congestion level. Environmental emission factor reflects the fuel efficiency of vehicles.

Recent years, due to the rapid progress of technologies, low emission vehicles (LEV) can be manufactured much easier than before at the affordable price. Especially, since the Japanese government implemented the LEV authorization system in 2000, the development of low emission vehicles (LEV) has become more and more competitive at the market. Considering the difficulty of reducing car ownership in local cities, it seems much more realistic to promote the ownership of LEVs. However, the number of LEVs in Japan only occupied 11.4% (5,750,000 vehicles) of total automobiles in 2003. It is known that can ownership is influenced by both the body price and the relevant taxes. Under the above-mentioned LEV authorization system, people who want to buy LEVs can receive referential treatment about taxes. Therefore, this paper aims at exploring the possibility of increasing the number of low emission passenger cars (LEPC) in local Japanese cities, especially incorporating the influences of car-related tax policies. The target taxes include vehicle acquisition tax, auto tax, and weight tax. The meanings of these taxes will be explained later. It is also expected that different people might evaluate these taxes in different ways. Such heterogeneous responses are investigated based on a stated preference (SP) survey in this study.

The rest of the paper is organized as follows. Section 2 introduces the car-related tax systems and preferential treatment of LEVs in Japan. The SP survey is summarized in section 3. Section 4 first estimates a binary LEPC choice model of low emission passenger cars (LEPC), explicitly incorporating people's heterogeneous responses to the relevant taxes as well as the influences of land use and daily travel behavior. A simulation analysis is also conducted with respect to the ownership of LEPC. Finally, section 5 concludes the study and mentions about some important future research issues.

2. JAPANESE CAR-RELATED TAX SYSTEMS AND PREFERENTIAL TREATMENT FOR LOW EMISSON VEHICLES

2.1 Car Tax System in Japan

The taxes of passenger cars include acquisition tax, auto tax and light car tax (collected by local governments), and weight tax (collected by central government). These taxes are briefly summarized below. Needless to say, in addition to these taxes, fuel tax is also charged.

Acquisition tax

When a car is purchased, acquisition tax is charged. The tax rate is 5% for passenger cars except for light cars and 3 % for other types of cars.

Auto tax
Auto tax is a kind of property tax, which is charged to the possession of a car. Auto tax for a passenger car with less than 1,000cc is 29,500 yen/year. For the passenger cars with less than 3,000cc, an extra tax of 5,000 yen per 500cc has to be paid. In case that the displacement is larger than 3,000cc, the tax rises sharply, and the amount reaches 111,000 yen/year for a car with more than 6,000cc.

Light car tax
This tax is a kind of priority tax that is charged to the possession of a light car. The tax rate is 7,200 yen/year for a light passenger car, and 4,000 yen/year for a light truck. One can see that there is a large gap between the auto tax and light car tax.

Weight tax
Weight tax is collected in order to promote the construction of road infrastructure. This tax is included in the source of general revenue at the central government. The tax rate is 6,300 yen/year for each 0.5 ton. It is paid at the time of vehicle inspection (usually every two years).

2.2 Preferential Treatment for Low Emission Vehicles

According to the definition by the Ministry of Land, Infrastructure and Transport, Japan, a low emission vehicle (LEV) is a vehicle, which is environmentally friendly, has extremely low level of toxic substance contained in the exhausted gases, and is manufactured using the materials that is easy to be recycled. Currently, natural gas cars, electric cars, hybrid cars, methanol-fueled cars, and other authorized cars with high fuel efficiency and low emissions are classified as low emission vehicles. In order to promote the ownership of LEVs, the Ministry of Land, Infrastructure and Transport already set up various supporting measures including the referential tax treatment when buying the LEVs. For example, when a LEV is purchased, one of the following stickers (see Figure 1) will be awarded to the owner who will receive referential treatment of auto tax.

25% emission reduction from 2000 emission standards
Auto tax 13% off

50% emission reduction from 2000 emission standards
Auto tax 25% off

75% emission reduction from 2000 emission standards
Auto tax 50% off

Figure 1. Preferential Treatment of Auto Tax for Low Emission Vehicles in Japan

3. SUMMARY OF A STATED PREFERENCE SURVEY

3.1 Methodological Issues

To effectively clarify the appropriate measures of reducing the emission production from passenger cars, it is necessary to systematically deal with car ownership behavior. In this study, car ownership behavior is defined as shown in Figure 2 based on the stages of “car purchase”, “car usage”, “duration of car ownership”, and “renewal and destruction”. It is expected that all of these elements interact each other over time. In order to reduce total emissions, it becomes more and more important to promote the ownership of LEVs, to reduce car use frequency or trip distance, and make traffic flow smooth. Car ownership behavior is affected by not only household and individual attributes, but also the policy variables like body price, tax, service levels of transit systems, and land use etc. Car-related taxes have the potential to control the car ownership behavior. One of the important characteristics of such taxes is that the taxes can be collected at different stages. When one wants to buy a car, he/she needs to pay acquisition tax and consumption tax. During the stage of owing the car, one needs to pay not only auto tax each year but also weight tax when the car is inspected every two years. Needless to say, to use the car, one needs to pay fuel taxes.

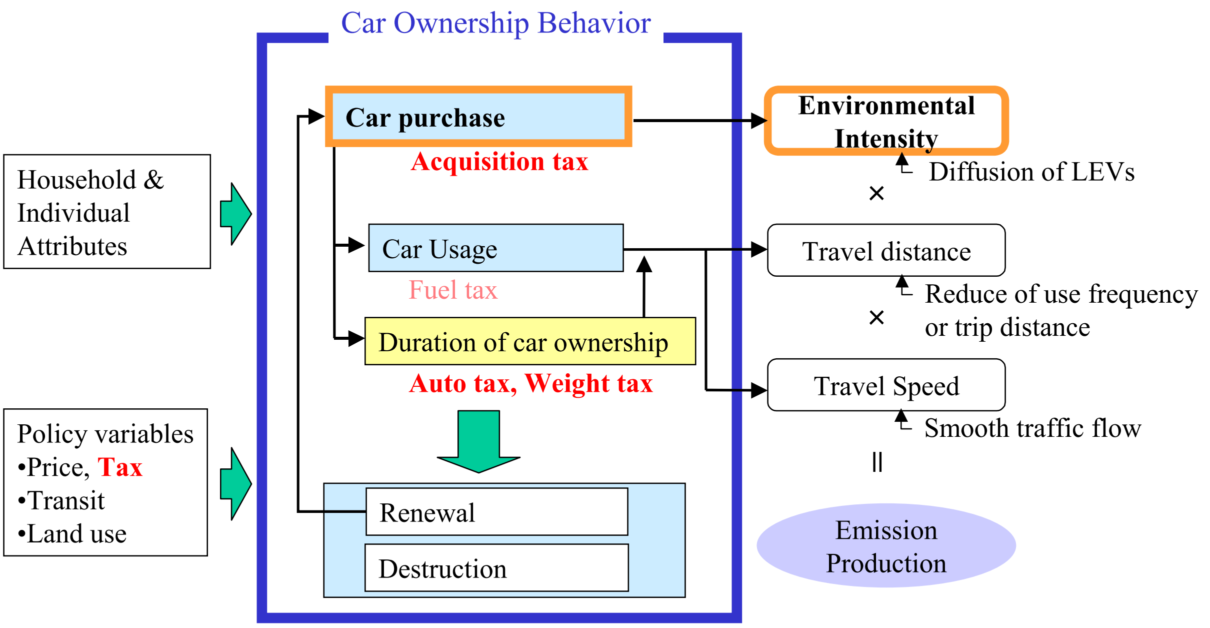

Figure 2. Research Framework of This Study

In this study, we focus on car purchase behavior from the perspective of reducing car environmental intensity and analyze the influence of tax policies on the diffusion of LEVs. And car-related taxes, which we target in this study, are acquisition tax, auto tax, and weight tax. These taxes are important factors affecting consumers’ decisions about the purchase or maintenance of car. Furthermore, it is much easies to apply the preferential treatment measure, comparing with fuel tax that is mainly under control of market mechanisms.

To evaluate the effects of the policies related to car taxes, there have been proposed two major methodologies. One is to use the macro-level modeling approach. For example, Hayashi *et al* (2001) developed such a model system to examine the changes in the car market configuration, the life cycle CO_2 emission from automobiles and the tax revenues due to different taxation policies. Another method is to apply disaggregate-type discrete choice models focusing on the individual choice behavior. For example, focusing the ownership of LEPCs, Adler *et al*. (2003) conducted a large-scale SP survey to explore the appropriate conditions and incentives that might encourage Californian residents to buy or lease alternate fuel vehicles. Their results show that car characteristics and reductions in vehicle purchase taxes provide significant purchase incentives for hybrid electric vehicles. However, they focused only some existing taxes. Since disaggregate choice model are suitable to understand individual responses to various tax policies, this paper adopts the choice models. In contrast to the existing research, this study attempts to explore the influence of new tax policies on the ownership of LEPCs. To this end, a stated preference (SP) survey was conducted in 2003.

The SP approach, originating in mathematical psychology, has been widely used in transportation (Hensher, 1994), since it can measure how people choose not-yet-existing travel modes, or how people take actions in case of introducing new policies (e.g., road pricing, introduction of intelligent transport systems). This approach examines individual response to a series of experimentally designed choice alternatives, which are typically described in terms of combinations of attributes with several pre-defined levels. Besides the ability to directly measure the demand/response under not-yet-existing conditions, the SP approach has some other advantages over the RP (revealed preference) approach, which is based on observed choice in real situations. These advantages include the ability to control statistical problems such as multi-collinearity and lack of variance in explanatory variables, the increased possibility of including subjective or qualitative factors as explanatory variables and cost-efficiency to develop models from a relatively small size of samples (Kroes and Sheldon, 1988; Polak and Jones, 1997; Louviere *et al*, 2001).

3.2 Design of SP Survey

Choice set in the SP survey consists of a LEPC and a non-LEPC. The target variables included in the survey are acquisition tax, auto tax, weight tax, fuel type, and engine displacement. Levels of attributes are assumed in Table 1. Price of main body, vehicle weight, and fuel consumption are assigned automatically as shown in Table 2, if vehicle type, fuel type, and engine displacement are given. As a result, 24 profiles were obtained by excluding some unrealistic profiles. Each respondent was given 6 profiles and asked to choose his/her preferred alternative from each profile (see Figure 3).

Questionnaires were handed out and collected by directly visiting pre-recruited households during October and December 2003. As a result, questionnaires were successfully collected from 219 households (402 individuals), among which 34% come from Hiroshima City, 16% from Higashi-Hiroshima City, 20% from Kure City and 29% from Hatsukaichi City (the unknown is 11%). Observing Figures 5 and 6, one can find that 61% of respondents use the car almost everyday, and 46% use the car for work and school. These results show that people's mobility highly depends on car traffic in the survey area.

Figure 7 shows the LEPC diffusion rate in this study area is very high compared with the national average (11.4%). Moreover, SP surveys show that 60% of respondents prefer to own LEPCs when they replace their car (Figure 8). Therefore, one can surely expect a high LEPC diffusion rate in the future, even taking account of the over-estimated SP answers.

However, the worrying observation result is that the annual travel distance by LEPCs is about 26% longer than that of ordinary passenger cars (Figure 9). We can conclude that this is partly caused by the high fuel efficiency of LEPCs. Fortunately, People in the target local cities tend to choose smaller car when they renew their car. And People who own LEV in the target local cities tend to choose smaller car, as shown in Figures 10 and 11.

3.3. Implementation of SP Survey

The respondents were randomly selected from residents living in Hiroshima City and its satellite cities of Higashi-Hiroshima, Kure, and Hatsukaichi (see Figure 4). The target survey areas were selected based on the consideration that respondents can readily use both passenger cars and transit systems. To the same respondent, a RP (revealed preference) survey was also conducted, where respondents were asked to report their households and individual attributes, car ownership behavior, and current travel behavior.

Table 1. Attributes and Levels for Alternatives

Attributes	Levels		
Fuel type	Gasoline	Hybrid	
Engine displacement (cc)	1500	2000	2500
Discount rate of acquisition tax of LEPCs	0% tax cut	20% tax cut	40% tax cut
Discount rate of auto tax of LEPCs	50% tax cut in the coming year	60% tax cut in the coming year	70% tax cut in the coming year
Discount rate of weight tax of LEPCs	0% tax cut	25% tax cut in the first year	50% tax cut in the first year

Table 2. Other Factors for Alternatives

	Fuel Type	Engine Displacement (cc)	Price of Main Body (yen)	Vehicle Weight (ton)	Fuel Consumption (km/liter)
Non-LEPC	Gasoline	1,500	1,200,000	1.2	10
		2,000	2,000,000	1.6	9
		2,500	2,600,000	2	8
LEPC	Gasoline	1,500	1,500,000	1.2	15
		2,000	2,300,000	1.6	12
		2,500	3,000,000	2	10
	Hybrid	1,500	2,000,000	1.2	33
		2,000	2,800,000	1.6	25
		2,500	3,500,000	2	17

4. MODEL DEVELOPMENT AND FINDINGS FROM MODEL ESTIMATION

It is expected that different people will have different evaluations about the taxes related to car ownership. In other words, there exists the heterogeneity. Heterogeneity can be divided into observed heterogeneity and unobserved heterogeneity. The observed heterogeneity is caused by the factors, which can be objectively observed in real world. Examples of such factors include individual and household attributes. The unobserved heterogeneity takes place

an example of SP question

Question

…. If you purchase or replace your car,
which type of car do you choose? ....

Car type	1. Non-LEV	2. LEV
Engine displacement	1500cc	2000cc
Fuel type	gasoline	hybrid
Fuel consumption	10km/l	17km/l
Price of main body	1,200,000 yen	2,300,000 yen
Acquisition tax	17,400 yen	33,000 yen
Auto tax	34,500 yen/year	11,850 yen/year
Weight tax	36,700 yen/2 year	37,800 yen/2 year
Total price	1,300,000 yen	2,400,000 yen

Figure 3. An Example of SP Question

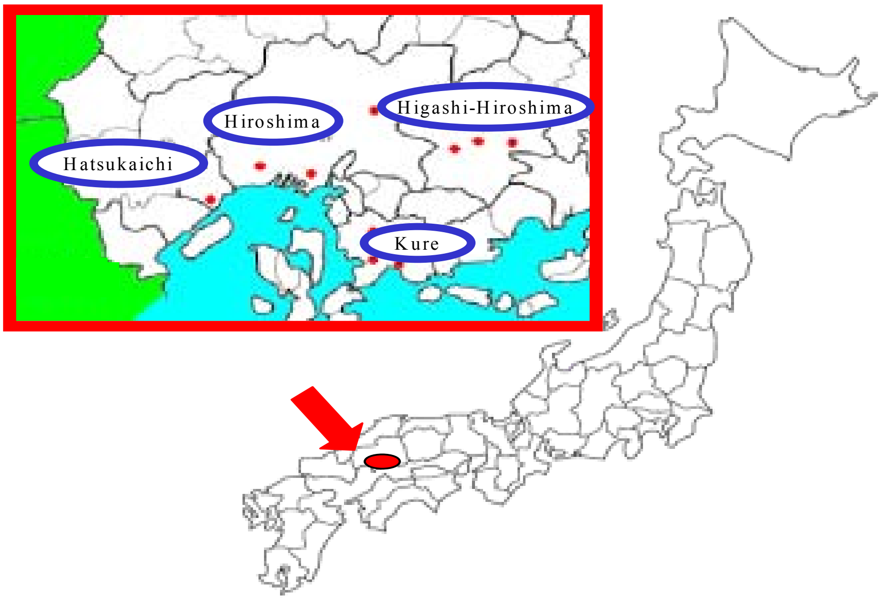

Figure 4. Survey Area

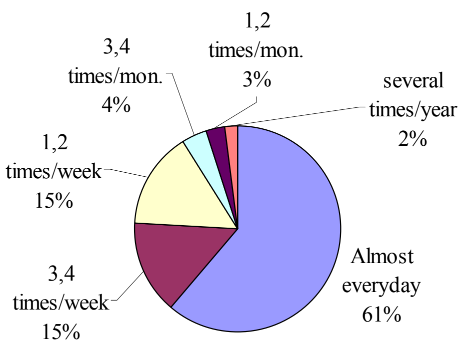

Figure 5. Current Car Usage Frequency

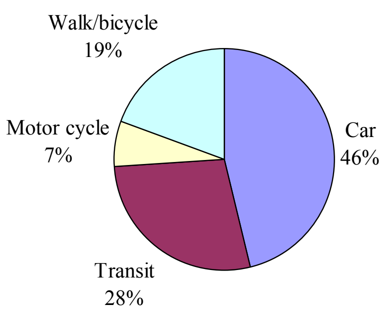

Figure 6. Car Share for Work and School

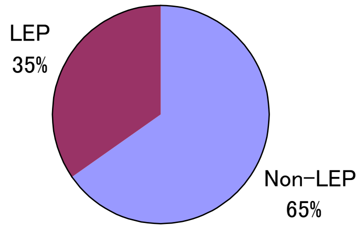

Figure 7. Current Diffusion Rate of LEPCs

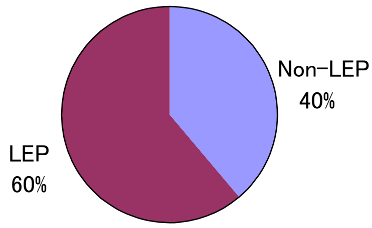

Figure 8. Preference of Purchasing Next Time

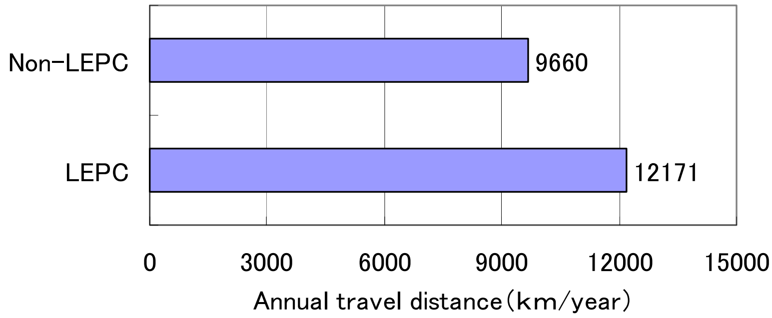

Figure 9. Annual Travel Distances of Non-LEPCs and LEPCs

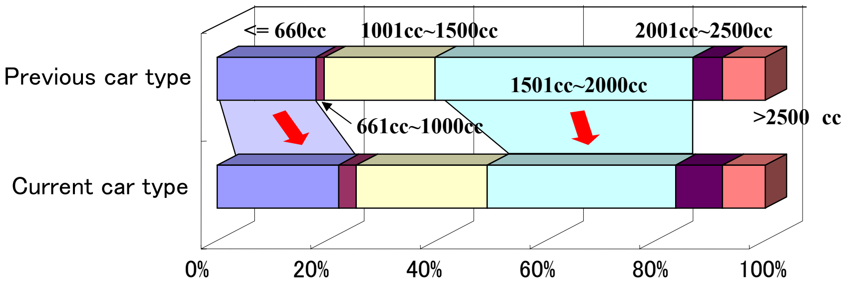

Figure 10. Temporal Change of Car Ownership Behavior

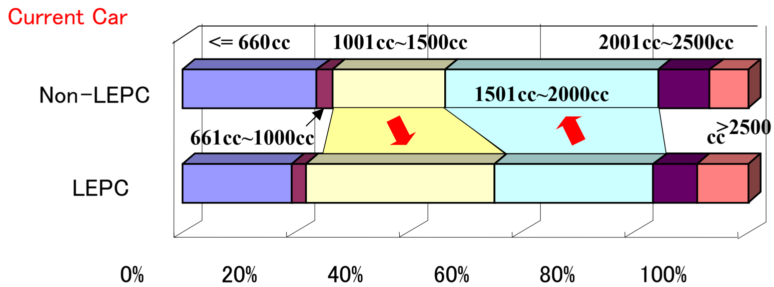

Figure 11. Engine Displacement Comparisons between Non-LEPC and LEPC

if some omitted factors actually affect the choice behavior. Such omitted factors are mainly related to people's taste, attitude, and some other psychological aspects. These days, many studies have been done to deal with the unobserved heterogeneity based on mass point approach (Reader, 1993; Zhang *et al*, 2001), mixed logit model (Rossi and Allenby, 1993; Papatla, 1996; Rossi *et al*, 1996; Revelt and Train, 1998; Brownstone and Train, 1999; Brownstone *et al*, 2000; Bhat, 2001; Bhat and Castelar, 2002; Hensher and Greene, 2003; Bhat and Guo, 2004) and latent class model (Kamakura and Russel, 1989; Wadel and Kamakura, 1998; Boxall and Adamowicz, 1999; Natter and Feurstein, 2002; Walker & Ben-Akiva, 2002; Lee et al, 2003).

To promote the ownership of LEPCs, it is much more important to understand people's observed heterogeneity. For example, policy makers might be interested in understanding the influence of individual and household attributes, their living environments and land use, and daily travel behavior on the car ownership. Market segmentation approach has been widely used (e.g., Roy, 1998; Bock and Uncles, 2002), however, it not only needs large sample size, but also highly relies on some arbitrary selection of segmentation criteria. Instead of the segmentation approach, this study attempts to represent heterogeneous responses on the tax policies by assuming that the parameters of the related taxes are functions of individual attributes, current travel behavior, and residential location.

4.1 Choice Model for LEPC

Here, we establish a choice model for LEPC by using SP data. Since SP response might be influenced by the respondents' current travel behavior, we incorporate the information of current travel behavior into the choice model of LEPC. In the SP survey, we assumed two alternatives: one is the LEPC and another is the non-LEPC. Therefore, we can establish the following binary choice model:

$$p_{ni} = \frac{exp(v_{ni})}{\sum_i exp(v_{ni})} \tag{1}$$

where, n and i indicate the individual and alternative, p_{ni} is the choice probability that individual n chooses alternative i, and v_{ni} is the deterministic term of the choice utility. Since consumers often determine their purchase behavior mainly based on price, we define the deterministic term v_{ni} as follows:

$$v_{ni} = \gamma \sum_{s=1}^{4} w_{ns} y_{nis} + \sum_{q=1}^{Q} \mu_q x_{niq} \tag{2}$$

where, y_{nis} is the price variable including price of the main body y_{ni1}, tax of car acquisition y_{ni2}, auto tax y_{ni3} and weight tax y_{ni4}, and γ refers to the parameter of total price. x_{niq} indicates other explanatory variables (in this study, we adopt the fuel type), and μ_q is the relevant parameter. w_{ns} is the weight parameter (or relative importance parameter) that individual n evaluates each price variable, and is defined in the following equation:

$$w_{ns} = \frac{exp\left(\sum_k \beta_k z_{nisk}\right)}{\sum_i exp\left(\sum_k \beta_k z_{nisk}\right)}, \quad \sum_s w_{ns} = 1 \tag{3}$$

Here, we use z_{nisk} to represent the information that is considered to affect the relative importance parameter for each price variable defined in Equation (3). We adopt the following variables to explain the relative importance parameter:

1) Individual attributes: income, gender, age, employment status, and driver's license.
2) Current travel behavior: car use frequency, shopping and recreational frequencies at different locations (in neighborhood, in city centers, at the road-side large-scale shopping centers, and in Hiroshima City's center).

3) Residential location: travel time to the nearest station or stop of transit systems.

4.2 Model Estimation Results

We show the model estimation results in Table 3. One can see that we got relatively high model accuracy in the sense that the McFadden's Rho-squared is 0.208. For the explanatory variables, the car price parameter has a logically negative and statistically significant value. It seems that the fuel type (gasoline or hybrid) does not influence the choice of LEPC so much. It is obvious that most of the variables for explaining the weight parameters are statistically significant. Income level positively influences the weight of car acquisition tax, and negatively does that of the weight tax; however, income does not affect the auto tax. Males highly evaluate the car acquisition tax and weight tax, while females care about the auto tax very much. The elderly seem to emphasize the weight tax. License holders make light of each price variable; this might imply that license holders regard cars as necessities. Frequent car users attach much importance to the car acquisition tax and the auto tax, but less to the weight tax. The shopping and recreational frequencies, and the residential location to the nearest transit system station or stop show very complex influence structures.

Table 4 shows the average relative importance parameter for each tax variable. Since the obtained model has a good explanatory power of car ownership behavior at the targeted local cities, we conducted a simulation analysis by changing the tax level. Among the weight parameters, one can see that the influence of auto tax is strongest. This implies that auto tax is the most important tax variable for explaining LEPC ownership behavior. Figure 12 shows the simulation results of LEPC choice probability under different levels of the auto tax. It is clear that, at most, the choice probability of LEPC be increased by about 10%.

Moreover, using the estimation results above, we performed a simulation analysis of a diffusion of LEPCs. Here, we show simulation results in urban structure that is likely to have smaller loads to the environment such as TDM and compact city in Figure 12 and 13 and in the current transportation behavior 14. From these results, the longer the distance to the public transit station is, the higher the choice probability of a low emission car become. As well, the choice probability gets higher as travel time and frequency of car usage get greater.

5. CONCLUSIONS AND FUTURE RESEARCH ISSUES

From the perspective of reducing environmental load from automobiles, this paper focuses on ownership behavior of passenger cars, considering that passenger cars are the major contributors of total exhausted amount of CO_2. To promote the ownership of low emission vehicle (LEV) in local cities in Japan, we conducted a revealed preference survey to investigate current household car ownership behavior and daily travel behavior, as well as a stated preference (SP) survey to analyze the LEPC ownership intention in the future under hypothetical mixed tax polices, at four local cities around Hiroshima Metropolitan Area, in 2003. SP survey results show that on average, about 60% of respondents prefer to own LEPC in the future under mixed tax policies. Therefore, one can expect a high LEPC share in the future if proper tax policies will be implemented.

Table 3. Model Estimation Results of LEPC Choice Model

Explanatory variable	Estimated parameter		
Constant term	1.062 **		
Total price (Yen)	-0.118 **		
Fuel type (gasoline=0, hybrid=1)	0.203		
Explanatory variables for weight parameters			
	Acquisition Tax	Auto Tax	Weight Tax
Constant term	-9.999 **	-7.792 **	-11.300 **
Income (10,000 Yen)	0.017 **	0.000	-0.017 **
Gender (Female=0, Male=1)	5.379 **	-6.390 **	7.192 **
Age	-0.006	-0.027	0.335 **
Employment (Yes=1, No=0)	-6.692 **	-1.292	-0.758
License (Yes=1, No=0)	-7.110 **	-3.119 *	-2.954 **
Car use frequency (times/week)	0.365 *	0.867 **	-1.458 **
Shopping frequency (times/week)			
At the neighbors	-0.332	3.725 **	-4.169 **
At the located city center	-2.013 **	-1.287	7.101
At the road-side large-scale shopping center	5.473 **	-1.654	0.534 *
At the Hiroshima city center	-2.373 **	5.039	1.604 **
Recreational frequency (times/week)			
At the neighbors	-6.158 **	-0.645 **	-2.198 **
At the located city center	-0.292 *	2.864 **	2.946
At the road-side large-scale shopping center	3.855	1.482 **	8.703 **
At the Hiroshima city center	2.503 **	5.458 **	-2.344
Travel time to the nearest transit station (stop) (minutes)			
By walk	-1.570 **	0.256 **	0.727 *
By bicycle	0.549 **	-2.530 **	0.161
By motor-cycle	-2.877 **	3.977 **	3.984 **
No. of sample	340		
McFadden's Rho-squared	0.208		

Note: * significant at the level of 95%, ** at the 99%

Table 4. Relative Importance Parameters

	Price of main body	Acquisition Tax	Auto Tax	Weight Tax
Weight parameter	0.197	0.0000	0.803	0.0000

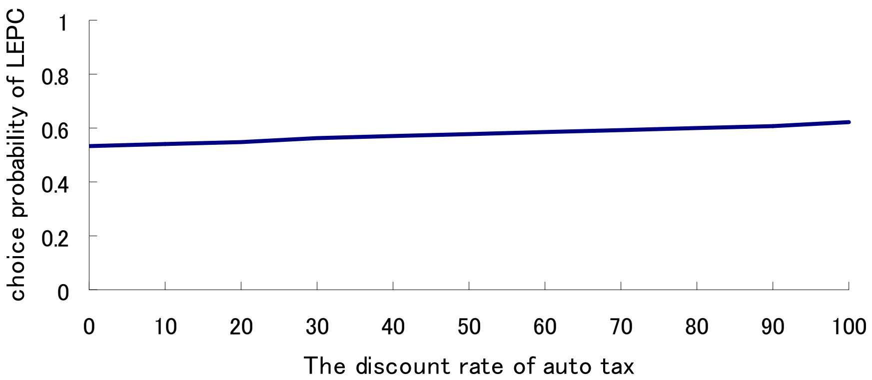

Figure 12. Auto Tax and LEPC Choice Probability

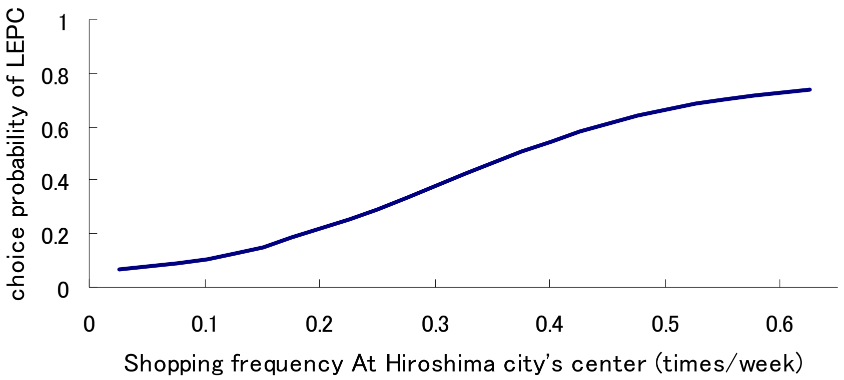

Figure 13. Shopping Frequency at the Center of Hiroshima City and LEPC Choice Probability

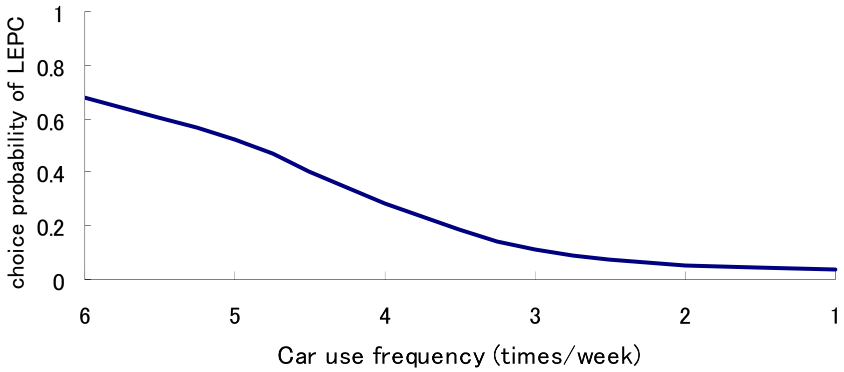

Figure 14. Car Use Frequency and LEPC Choice Probability

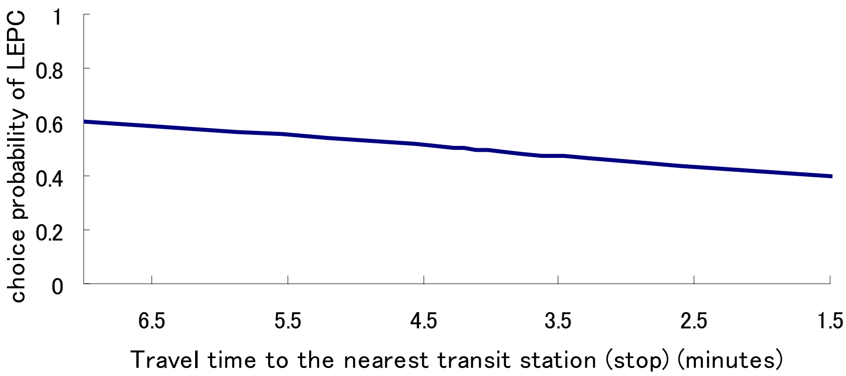

Figure 15. Travel Time to the Nearest Transit Station and LEPC Choice Probability

Based on the above-collected SP data, we developed a LEPC choice model by using a binary logit model. It is known that monetary expenditure usually plays a very important role in the decisions about purchasing a car. In the SP survey, we assume that monetary expenditure related to car ownership is mainly composed of price of main body, tax of car acquisition (paid at the purchasing stage), auto tax (annually paid at the owning stage) and weight tax (paid every car inspection year at the using stage). To properly represent the influences of different expenditure elements on LEPC ownership behavior, we introduced a relative importance parameter related to each expenditure element. Furthermore, it is expected that different consumers might show different relative importance about body price and other taxes. To explain such heterogeneity, we defined each relative importance parameter as a function of individual attributes, their current travel behavior and living environments. Model estimation results showed that LEPC choice behavior is significantly affected by current travel behavior. Moreover, estimation results of relative importance parameters show that auto tax is the most important tax variable of explaining the LEPC ownership behavior. However, RP survey results show that LEPC owners tend to travel longer distances than other owners do. Therefore, policy makers should worry about the effects of LEPC diffusion without the support of other policies. Simulation analysis shows that there might exist an optimal combination between LEPCs and other cars from an environmental perspective, without the support of other policies.

Concerning methodological research issues, we need to first establish the modeling frameworks of car ownership behavior reflecting the dynamic characteristics, and theoretically clarify car ownership behavior as a household decision-making process. As policy research issues, we will examine the relationship between LEPC diffusion and emissions production, and find out how to move the modern car-dependent society toward a less car-dependent one.

REFERENCES

a) Books and books chapters

Louviere, J., Hensher, D.A., and Swait J.D. (2001) **Stated Choice Methods: Analysis and Applications**. Cambridge University Press.

Polak, J.W. and Jones, P. (1997) Using stated preference methods to examine traveller preferences and responses. In P. Stopher and M. Lee-Gosselin (eds.), **Understanding Travel Behavior in An Era of Change**. Pergamon, Oxford, 177-207.

Wadel, M. and Kamakura, W.A. (1998) **Market Segmentation: Conceptual and Methodological Foundation**. Kluwer Academic Publishers, Boston, MA.

b) Journal papers

Bhat, C.R.(2001) Quasi-random maximum simulated likelihood estimation of the mixed multinomial logit model, **Transportation Research Part B, Vol.35**, 677-693.

Bhat, C.R. and Castelar, S. (2002) A unified mixed logit framework for modeling revealed and stated preferences: formulation and application to congestion pricing analysis in the San Francisco Bay Area, **Transportation Research Part B, Vol.36**, 593-616.

Bhat, C.R. and Guo, J. (2004) A mixed spatially correlated logit model: formulation and application to residential choice modeling, **Transportation Research Part B, Vol.38(2)**, 147-168.

Bhat, C.R. and Puluguranto, V. (1998) A comparison of two alternative behavioral choice mechanisms for household auto ownership decisions, **Transportation Research Part B, Vol. 2, No.1,** 64-75.

Bock, T. and Uncles, M. (2002) A taxonomy of differences between consumers for market segmentation, **International Journal of Research in Marketing, Vol.19**, 215-224.

Brownstone, D. and Train, K. (1999) Forecasting new product penetration with flexible substitution patterns, **Journal of Econometrics, Vol.89**, 109-129.

Brownstone, D., Bunch, D.S. and Train, K. (2000) Joint mixed logit models of stated and revealed preferences for alternative-fuel vehicles, **Transportation Research Part B, Vol.34**, 315-338.

Choo, S. and Mokhtarian, P.L. (2004) What type of vehicle do people drive? The role of attitude and lifestyle in influencing vehicle type choice, **Transportation Research Part A, Vol. 38,** 201-222.

Hayashi, Y., Kato, H. and Teodoro, R.V. R. (2001) A model system for the assessment of the effects of car and fuel green taxes on CO_2 emission, **Transportation Research Part D, Vol. 6**, 123-139.

Hensher, D.A. (1994) Stated preference analysis of travel choices: the state of practice, **Transportation, Vol. 21, No. 2**, 107-133.

Hensher, D.A. and Greene, W.H. (2003) The mixed logit model: The state of practice, **Transportation, Vol.30, No.2**, 133-176.

Kamakura, W.A. and Russell, G.J (1989) A probabilistic choice model for market segmentation and elasticity structure, **Journal of Marketing Research, Vol.26**, 379-390.

Koh, W.T.H. (2003) Control of vehicle ownership and market competition: Theory and Singapore's experience with the vehicle quota system, **Transportation Research Part A, Vol. 37,** 749-770.

Kroes, E.P. and Sheldon, R.J. (1988) Stated preference methods: an introduction, **Journal of Transport Economics and Policy, Vol. 22, No. 1**, 11-26.

Lee, B., Fujiwara, A., Sugie, Y. and Namgung, M. (2003) A sequential method for combining random utility model and fuzzy inference model, **Journal of Advanced Computational Intelligence and Informatics, Vol.7. No.2**, 200-206.

Natter, M. and Feurstein, M. (2002) Real world performance of choice-based conjoint models, **European Journal of Operation Research, Vol.137**, 448-458.

Papatla, P. (1996) A multiplicative random-effects choice model of consumer choice, **Marketing Science, Vol.15**, 243-261.

Reader, S. (1993) Unobserved heterogeneity in dynamic discrete choice models, **Environment and Planning A, Vol.25**, 495-519.

Revelt, D. and Train, K. (1998) Mixed logit model with repeated choices: households' choices of appliance efficiency level, **Review of Economics and Statistics, Vol.80, No.4**, 647-657.

Rossi, P.A. and Allenby, G.M. (1993) A Bayesian approach to estimating household parameter, **Journal of Marketing Research, Vol.30**, 171-182.

Rossi, P.A., McCulloch, R.E. and Allenby, G.M. (1996) The value of purchase history data in target marketing, **Marketing Science, Vol.15**, 321-340.

Roy, A. (1998) An error components approach to segmentation and modelling brand choice dynamics, **Journal of Economic Psychology, Vol.19**, 463-484.

Tam, M. L. and Lam, W.H.K.: Maximum car ownership under constraints of road capacity and parking space, **Transportation Research Par**t A, Vol.34, 145-170, 2000.

Walker, J. and Ben-Akiva, M. (200) Generalized random utility model, **Mathematical Social Sciences, Vol.43**, 303-343.

Zhang, J., Sugie, Y. and Fujiwara, A. (2001) A mode choice model separating taste variation and stated preference reporting bias, **Journal of the Eastern Asia Society for Transportation Studies, Vol.4, No.3,** 23-38.

c) Papers presented to conferences

Adler, T., Wargelin, L., Kostyniuk, L., Kalavec, C. and Occiuzzo, G. (2003) Incentives for alternate fuel vehicles: A large-scale stated preference experiment, **Paper presented at the 10th International Conference on Travel Behavior Research.**

d) Other documents

Boxall, P.C. and Adamowicz, W.L. (1999) Understanding heterogeneous preferences in random utility models: The use of latent class analysis, **Staff paper 99-02**, University of Alberta.