THE IMPACT OF LIFE-COURSE EVENTS ON VEHICLE OWNERSHIP DYNAMICS

– The Cases of France and Japan –

Toshiyuki YAMAMOTO
Associate Professor, Department of Civil Engineering
Nagoya University
Nagoya, Japan

(Received September 5, 2008)

The attention to life-course events for better understanding travel behavior has increased recently. The impacts of life-course events such as birth of a child, residential relocation, change of employment status, etc. on vehicle ownership are investigated in this study. The data from two surveys are used for empirical analysis: first, nationwide household panel data with 15 subsequent waves in France and, second, a small-sized retrospective survey data on three years in Kofu, Japan. Both sets of data contain information on changes in household attributes and vehicle ownership, but the structure of the data is quite different from each other. Vehicle transaction models are developed, and the impacts of life-course events on vehicle ownership dynamics are quantified for each data. Competing-risks hazard-based duration models are applied to the French panel data, containing replacement, disposal and acquisition of a vehicle to fleet as distinct transactions, called as hazards in duration models. On the other hand, multinomial logit models of decrease, increase, and no change in the number of household vehicles are applied to the retrospective data in Kofu. The types of data and models are different for the two empirical analyses, but the results are consistent with each other. The results confirm that changes in household attributes significantly affect both acquisition and disposal of vehicles, resulting the changes in vehicle ownership. Especially, the change in the number of adults among other things strongly affects both the probability of disposing and acquiring a vehicle. Also, residential relocation has a statistically significant impact on the probability of disposing of a vehicle. However, the explanatory power of the life-course events on vehicle ownership dynamics, in terms of contribution to the improvement in the goodness-of-fit statistics of the model to the data, is found to be small.

Key Words: Vehicle transaction, Key events, Life stage, Residential relocation

1. INTRODUCTION

Climate change has become a serious global concern recently. Transport accounts for 14% of global greenhouse gas emissions, and 76% of these emissions are from the road transport sector[1]. In Japan, transport accounts for 19.3% of 1,293 Mt-CO_2 emissions and 90% of these emissions are from the road transport sector in 2005[2]. The share of the road transport sector is much larger in Japan, for which significant technological developments in other sectors might be the reason. According to the Kyoto Protocol, the average emissions of greenhouse gases for the five years from 2008 to 2012 should be reduced by 6% from the base year in Japan. In order to achieve environmentally sustainable transport, many projects have been carried out recently. The sustainable mobility approach requires action to reduce the need for travel, to encourage modal shift, to reduce trip length and to encourage greater efficiency in the transport system[3]. Thus, the key is public involvement in the action. However, travel behavior tends to be habitual, and difficult to make changes[4].

Recently, the attention to life-course events for better understanding travel behavior has increased. The life-course events such as marriage, residential relocation, birth of a child, etc. are thought to have strong impacts on travel behavior, or at least become a trigger to reconsider current travel behavior. Van der Waerden and Timmermans examined the effects of life-course events on mode choice switching behavior, and found that a change in the work situation including change in work location, profession, employer, and income is the most important event by an exploratory pilot survey[5]. Van der Waerden et al. selected residential relocation, starting to work, change in work situation, getting a driver's license and purchasing a car as most frequently occurring key events, and showed that these events result in changes in choice set composition, attitude against aspects of mode alternatives and mode choice[6]. These studies are descriptive analyses with small-sized data pool obtained in the Netherlands. Other more recent studies developed behavioral models focus-

ing on the impact of life-course events. The type of models vary among studies, but suits to the behavioral aspect examined in the studies. Verhoeven et al. developed a Bayesian belief network of transport mode choice decisions with small-sized pool data in the Netherlands[7]. Prillwitz et al. developed a binary probit model of increasing the number of vehicles[8], and Prillwitz and Lanzendorf developed a linear regression model of change in commute distance[9]. Both studies use large-sized data pools obtained in Germany, the German Socio-Economic Panel (GSOEP). Of these, Prillwitz et al.[8] found that the changing number of adults in a household, birth of the first child, changing weighted monthly income and change of residence from a regional core to a regional core area have a strong impact on the increase in the number of vehicles. Here, weighted monthly income is calculated as the household income divided by the sum of the following factors: 1 for the first adult in a household, 0.5 for every other adult, 0.3 for every child younger than 15-years-old. The authors stated that the weighted income better represents the available budget per person and the economic situation than the total income. Also, regional core is defined as municipalities that are the destination of a significant share of the commuters from other municipalities within the same region with at least 50,000 inhabitants. The change of residence from a regional core to a regional core area does not distinguish the move within the same core and the move to another core.

Here, the ambiguity in the causal relationship between residential relocation and vehicle ownership dynamics should be mentioned. It is probable that a household changes their residence location, which changes the needs for their vehicle, and then they increase or decrease the number of vehicles to suit their new needs. In this case, residential relocation is the cause of the vehicle dynamics. On the other hand, it is also possible that the need for a vehicle increases at first because one of the household members changes his/her job etc., and then they move to the suburbs to obtain a parking space, and finally they add a vehicle to their fleet. In this case, the residential relocation is not the cause of the vehicle dynamics. The ambiguity also applies to the statistical analysis of this study, so the interpretation of the results should be treated with caution. Possible future research directions to overcome this ambiguity are discussed in the conclusion.

However, the findings of the relationship between the life-course events and the vehicle dynamics are useful for developing policy measures to influence household vehicle transaction behavior. If the life-course events that result in higher probability of vehicle transactions are specified, the policy measures such as incentives specific to those households who recently experienced or will experience the life-course events can be developed to effectively induce environmentally desirable vehicle transactions and discourage environmentally undesirable ones. For example, incentive programs[10] and travel feedback programs[11] for new residents are found effective to induce public transit use and travel behavior modification. It means that residential relocation is one of the potential timings of travel behavior changes, when the policy measures can be effective to induce the change. Other life-course events, too, may be used to identify the policy target to reduce vehicle ownership if the relationship between the life-course events and vehicle dynamics is found in this study.

In this study, the impacts of life-course events on vehicle ownership are investigated by using the data obtained in France and Japan. The impact on the decrease as well as increase in the number of vehicles is examined in this study for both sets of data. The consistency and the difference in the impacts of life-course events on the increase and the decrease in the number of vehicles are empirically investigated.

France is a member of the European community like the Netherlands and Germany, which were used in the preceding studies mentioned above. Thus the impact of life-course events in France might be consistent with the literature. Japan, on the other hand, is located far from Europe, thus the comparison with the French case seems interesting. However, the two data pools are quite different. The French data are obtained from a large-scale panel survey, thus a detailed investigation can be applied. On the other hand, the Japanese data are obtained from a retrospective survey of a relatively small size, so the accuracy and richness of the information obtained may be lower than the French data. Thus, the difference in the types of data in addition to that in the behavioral difference between the two areas, the latter is our main concern, may cause a difference in the results of the analysis. Nonetheless, the international comparison is valuable to examine the generality and the variability of the relationship between the life-course events and the vehicle ownership dynamics over the world, which allows us to better understand the nature of the household vehicle ownership dynamics. Thus, the comparative analysis is carried out in this study, and the results should be carefully interpreted taking into account the difference in the types of data.

The two types of data are different from each other, so the behavioral models are developed for each data set. A competing-risks hazard-based duration model is used

for the French case, and a multinomial logit model is used for the Japanese case. The difference in the methodological approaches is mainly based on the types of data set, but the comparison of the results becomes difficult. The hazard-based duration model well represents the temporal aspects of the behavior, which cannot be basically represented by the multinomial logit model. This limitation prevents the comparison of the lagged effects of the life-course events on vehicle transactions between the two areas.

2. FRENCH CASE

2.1 Data

The data set used in the empirical analysis for France is the panel survey data conducted nationwide by a French marketing firm, SOFRES. The panel survey, called Parc-Auto, adopted mail-out and mail-back self-administered questionnaires on vehicle ownership[12]. The sample size has been maintained at about 7,000 households each year. A rotation panel system was employed by the survey, where the participants were originally assigned to stay on the panel for four years, but could renew the stay. The questionnaire included questions concerning the characteristics of up to three vehicles in a household, vehicle use in terms of odometer reading, annual mileage, main purposes of vehicle use, etc. Also included were the attributes of the main driver and household. The life-course events were extracted from this information. The sample used for the empirical analysis of this study was 3,638 households who answered the questionnaire between 1984 and 1998. A household stayed in the panel for an average of 5.1 years. The data are a little dated, but the dataset used in the study is well prepared, and by no means insufficient for the investigation of the impacts of life-course events on vehicle ownership.

The sample means of attributes of household and its change per year are given by Table 1. The means are across all households over all years. Included life-course events are the increase and decrease in the number of adults, the increase in the number of children, the increase and decrease in the household annual income, and the residential relocation. Because the respondents stayed in the panel for at least four years, lagged effects of these life-course events as well as instantaneous ones can be considered in the analysis. This is one of the advantages in the panel survey. Among the life-course events, the changes in household income have the highest rate of occurrence; more than 40% of households experienced a change in the household income per year. Here, the household annual income is represented by the 12 categories from less than 50,000FF to more than 500,000FF, and the dummy variables take one when the household annual income changes across the category. Annual inflation as well as the changes in the number of workers in the household and the employment status might be the reason for the income variability in the data. Other than the income changes, about 10% of households experienced changes in the number of adult members per year. Residential relocation had a lower probability of occurrence.

The number of vehicles and the rate of vehicle transactions per household per year is also calculated across all households over all years. The average number of vehicles per household was 1.29, and the rates of re-

Table 1 Household attributes and changes per year

Variable	Definition	Mean
Number of adults	Number of household members of 18 years old or older	2.170
Increased adults	1, if the number of adults increased in this year; 0, otherwise	0.042
Decreased adults	1, if the number of adults decreased in this year; 0, otherwise	0.051
Number of children	Number of household members less than 15 years old	0.449
Increased children	1, if the number of children increased in this year; 0, otherwise	0.022
Low income household	1, if household annual income is less than 75,000 FF; 0, otherwise	0.037
High income household	1, if household annual income is over 200,000 FF; 0, otherwise	0.321
Increased income	1, if household annual income increased in this year; 0, otherwise	0.226
Decreased income	1, if household annual income decreased in this year; 0, otherwise	0.249
Paris	1, if residential zone is in the metropolitan area of Paris; 0, otherwise	0.167
Second largest cities	1, if residential zone is in the metropolitan areas of Lyon, Marseille, Lille, Nice, Bordeaux or Toulouse; 0, otherwise	0.118
Large cities	1, if residential zone is in the metropolitan areas with more than 100,000 inhabitants; 0, otherwise	0.282
Rural areas	1, if residential zone is in the rural areas; 0, otherwise	0.074
Moving	1, if household moved its residential location in this year; 0, otherwise	0.032

Source: Calculations from panel survey, Parc-Auto by SOFRES (1984-1998)

placement, disposal and acquisition were 20.4%, 6.5% and 6.0%, respectively. As expected, the rates of disposal and acquisition were much smaller than that of replacement. Also, the rates of disposal and acquisition were almost the same. This suggests that the number of household vehicles remained almost constant during the survey period.

2.2 Model

The vehicle transaction behavior and the life-course events are both extracted reliably from the panel data set, and the sample size is large enough. Thus, data intensive modeling approaches are applicable. Hazard-based duration models have been applied for vehicle transaction behavior (e.g., Mannering and Winston[13]; Gilbert[14]; De Jong[15], Hensher[16], Yamamoto et al.[17, 18], Yamamoto and Kitamura[19], Chen and Niemeier[20]; Chen and Lin[21]; Lin, et al.[22]). Hazard-based duration models represent the duration between successive vehicle transactions, thus the timing of the next vehicle transaction can be predicted by the model. Competing-risks duration models are used to account for the presence of several possible types of events at the end of the duration. In our application, the vehicle transaction can be categorized as replacement, disposal without replacement or acquisition without disposal. Competing-risks duration models represent the type of transaction as well as the duration until the next transaction.

Two important features characterize hazard-based duration models[23]. One is the treatment of censored observations. Censored observation is defined as the case where the beginning and/or end of the duration are not observed during the survey period. In the panel data used in this study, the vehicles owned by the household when they left the panel result in the censored observations because neither the replacement nor the disposal of those vehicles are observed during the survey period. Hazard-based duration models treat these censored observations as the duration is longer than the elapsed time from the beginning of the ownership to the end of the survey period.

The other is the treatment of the change in the value of the explanatory variables during the event spell. The focus of this study is on the life-course events, thus the proper treatment of the change in the value of the explanatory variables is prerequisite. In hazard-based duration models, the effects of the time varying explanatory variables can be properly treated.

The Weibull distribution with unobserved heterogeneity of a gamma distribution is adopted as the baseline hazard function as used in a previous study[24]. Assuming independence of the unobserved heterogeneity among the hazard functions across transaction types, the function for each type of transaction can be estimated separately. In reality, the unobserved heterogeneity may have any correlation. Such correlations can be represented parametrically or non-parametrically (e.g., Yamamoto and Kitamura[19]), but are not considered in this study for the simplicity of the computation. Please refer to the preceding study[24] for the detailed description on the formulation of the model.

2.3 Results

Coefficient estimates of household attributes in the competing risks duration model of household vehicle transaction behavior are shown in Table 2. For compari-

Table 2 Coefficient estimates of household attributes with and without changes in competing risks duration model of household vehicle transactions behavior

Type of transaction	Replacement		Disposal		Acquisition	
Life-course events	With	Without	With	Without	With	Without
Number of adults	−0.0494^{+}	−0.0447			−0.948**	−0.945**
Increased adults			0.611*		−0.688*	
Decreased adults			−1.184**			
Number of children			0.140*	0.200**	−0.263**	−0.339**
Increased children					−0.605*	
Increased children (t-1)					−0.971**	
Low income household	0.354*	0.354*	−0.453^{+}	−0.679**	0.854*	0.889**
High income household	−0.228**	−0.229**	0.676**	0.823**	−0.440**	−0.435**
Decreased income			−0.416**			
Paris			−0.687**	−0.775**	0.297*	0.305*
Second largest cities			−0.422**	−0.477**	0.249	0.250^{+}
Large cities					0.194^{+}	0.198^{+}
Moving			−0.612**		−0.587*	
Moving (t-1)	−0.233*					
Moving (t-2)	−0.264*					

$^{+}$ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$
Source: Calculations from panel survey, Parc-Auto by SOFRES (1984-1998)

son purposes, the models incorporating the life-course events and without these variables are estimated. The full set of parameter estimates with the life-course events is reported in Yamamoto et al[24]. In Table 2, positive (negative) coefficient estimates mean that the expected duration becomes longer (shorter), and that the probability of occurrence of the transaction of the type in question decreases (increases). In addition to the immediate effects where the life-course events cause the vehicle transaction in the same year, the lagged effects are investigated where the life-course events cause the vehicle transaction in the following years. The lagged effects are presented as (t-1) and (t-2) in Table 2, suggesting that the life-course event in question occurred in the last year and the two years prior, respectively.

Looking at the model with the life-course events, the results confirm that many life-course events have significant effects on household vehicle transaction behavior. *Increased adults* has a positive coefficient estimate for disposal function and a negative coefficient estimate for acquisition function. The results suggest that the probability of disposing of a vehicle without replacement decreases and that the probability of acquiring a vehicle increases when the number of adults increases. On the other hand, *Decreased adults* has a negative coefficient estimate for disposal function, suggesting that the probability of disposing of a vehicle increases when the number of adults decreases. The magnitude of this coefficient estimate is large and statistically highly significant, meaning that the decrease in the number of adult members is the largest opportunity for decreasing the number of vehicles. Both *Increased children* and *Increased children (t-1)* have negative coefficient estimates for acquisition function, suggesting that the birth of children becomes a positive effect on the probability of acquiring a vehicle even in the next year. Moreover, the larger coefficient estimate in absolute value for the lagged effect than that for the immediate effect indicates that more households acquire a vehicle one year after the birth of children rather than during the same year, though the reason is not obvious.

Both *Low income household* and *High income household* have significant coefficient estimates for all three functions, suggesting that the household income is an important determinant for household vehicle transactions. *Decreased income* has a significant coefficient estimate for disposal function in addition to the above two variables, which suggests that the decrease in household income is the important trigger to decrease the number of household vehicles. Looking at the coefficient estimates of *Moving*, both disposal function and acquisition function have negative coefficient estimates, suggesting that the residential relocation increases the probability of the change in the number of vehicles regardless of the direction of the change. Conversely, *Moving* does not have a significant impact for the replacement, but *Moving (t-1)* and *Moving (t-2)* have significant negative coefficient estimates. The results suggest that the effect of the residential relocation on the replacement of vehicles has a time lag.

Comparing the models with and without the life-course events, the log-likelihood at convergence shown in Table 3 improves statistically significantly by incorporating the life-course events as the explanatory variables for all three functions of replacement, disposal and acquisition. Especially, the improvement is larger for disposal and acquisition than for replacement. These results suggest that the life-course events are significant factors on the vehicle transaction behaviors especially for changing the number of household vehicles. Also, the coefficient estimates of the household attributes in the models with and without the life-course events are similar, and the difference is found to be statistically insignificant for all the pairs. The results suggest that the life-course events have independent impacts from those by the household attributes. However, the size of the improve in the log-likelihood at the convergence by incorporating the life-course events is relatively small compared to the difference in the log-likelihood between the constant-only model and model without life-course events. From the results above, it is not confirmed that the life-course events

Table 3 Log-likelihood at convergence of models with and without the life-course events

Type of transaction	Replacement	Disposal	Acquisition
Constant model[a]	−8,277	−3,540	−3,486
Model without life-course events	−8,022	−3,107	−2,988
Model with life-course events	−8,017	−3,034	−2,971
Sample size[b]	9,988	9,988	3,184

[a] Constant model is estimated by setting all coefficients to 0, except γ and constant.
[b] Sample size is based on the vehicles for the hazard of replacement and disposal, and the households for that of acquisition.
Source: Calculations from panel survey, Parc-Auto by SOFRES (1984-1998)

are the dominant factors on the household vehicle transaction behavior, though it is confirmed that those are one of the contributing factors in addition to other explanatory variables.

3. JAPANESE CASE

3.1 Data

The data set used in the empirical analysis for Japan is a person trip survey data conducted by Yamanashi prefecture in 2005-2006. Yamanashi prefecture is located in the central part of Japan, and 100 km west of Tokyo. Kofu City is the capital city of the prefecture, and has a population of about 200,000. The research area was the Kofu urban area with a population of about 550,000 including surrounding cities. The Kofu urban area is one of the typical mid-scale urban areas in Japan: elderly people aged 65 or over account for 20% of the population, and the car trip share is 68%. This survey included an add-on questionnaire about vehicle ownership and public transportation usage for a part of the respondents as well as basic one-day trip questionnaire. Retrospective information on vehicle transaction behavior and household attributes and its change in recent three years were included in the vehicle ownership questionnaire. The sample used for this empirical analysis was 2,183 households who answered the vehicle ownership questionnaire.

The sample means of attributes of household and its change in three years are given in Table 4. Included life-course events were similar to those in the French data: the increase and decrease in the number of adults, the increase in the number of children, and so on. Although the change in the household annual income was not included because the income was not asked in conventional person trip surveys in Japan, the increase and decrease in the number of workers were included, hopefully as a proxy for the income change to some extent. Obviously, obtaining and quitting a job by any household members affects household income, thus the change in the number of workers was correlated with that in the household annual income. Of course, the change in the number of workers also affects the need for car commuting, so does not working as a pure proxy. Among the life-course events investigated in the survey, the highest was the rate of decreased adults, where about 10% of the households experienced a decrease in the number of adults in three years. Residential relocation had 6.3% of the occurrence in three years, which is a lower probability than that of the French data of 3.2% per year.

The sample distribution of household vehicle ownership dynamics in the three years was also calculated. The average number of household vehicles was 1.90, and the rates of decrease, increase, and no change in the number of vehicles were 4.5%, 22.0% and 73.6%, respectively. No change included both cases where the household had and had not replaced their vehicles during the three years. The average number of vehicles was much higher than that in the French data, which was 1.29. The Kofu urban area is a highly car dependent areas like other mid-scale urban areas in Japan, and the car dependency is

Table 4 Household attributes and changes in three years

Variable	Definition	Mean
Young couple	1, if household is a couple aged under 40 without child; 0, otherwise	0.032
Family with infants	1, if the youngest child is up to 6 years old; 0, otherwise	0.099
Family with kids	1, if the youngest child is 7 to 12 years old; 0, otherwise	0.116
Elderly household	1, if household is only elders aged 65 and over; 0, otherwise	0.176
Household size	Number of household members	2.58
Increased adults	1, if the number of adults increased in three years; 0, otherwise	0.026
Decreased adults	1, if the number of adults decreased in three years; 0, otherwise	0.105
Increased children	1, if the number of children increased in three years; 0, otherwise	0.065
Number of drivers	Number of driving license holders	1.64
Increased drivers	1, if the number of driving license holders increased in three years; 0, otherwise	0.067
Decreased drivers	1, if the number of driving license holders decreased in three years; 0, otherwise	0.032
Number of workers	Number of workers	1.31
Increased workers	1, if the number of workers increased in three years; 0, otherwise	0.054
Decreased workers	1, if the number of workers decreased in three years; 0, otherwise	0.028
Farmers	1, if farmer is included in household members; 0, otherwise	0.078
Distance to station	Distance to the nearest train station in km	2.10
Bus frequency	Bus frequency at bus stop less than 1 km from home (/1000/day)	0.112
Moving	1, if household moved its residential location in three years; 0, otherwise	0.063

Source: Calculations from Kofu person travel survey (2005-2006)

much closer to one vehicle per one driver than one vehicle per one household. This might cause the differences in the effects of the life-course events of the household members on the vehicle transaction between the two areas, which should be confirmed by comparing the results of the analysis. The rate of the increase is consistent with the French case, where the rate of the acquisition per year is 6.0% resulting in 18.0% for three years. On the other hand, the rate of the decrease is much smaller than that of the increase in the Japanese case. Also, the rate of decrease of Japanese data is much smaller than that of the disposal in the French data. The reason is not obvious, but the underreporting of the disposal in Japanese data is one of the possible reasons. This is one of the limitations in a retrospective survey, where some of the households might have forgotten to report the disposal of their vehicles because the disposed vehicles were not owned any more at the time of the survey. Such households, if any, are treated as if they did not change the number of vehicles. Possible underreporting should be considered for the modeling and the interpretation of the results with this type of the data.

3.2 Model

Retrospective data, in general, have a disadvantage in the preciseness of the information compared to the panel survey data, especially the timing of the life-course events might be incorrectly reported in the retrospective survey (e.g., Groves[25]; Armoogun and Madre[26]). Thus, a simple model structure is applied to the data, where the three years are treated as one period and the information on the detailed timing of the vehicle transaction and life-course events is not used in the analysis. Prillwitz et al.[8] applied a binary probit model for the increase in the number of household vehicles. In this study, taking into account the relationship between the decrease and increase in the number of household vehicles, multinomial logit models of household vehicle ownership dynamics are developed. The alternatives of the choice set include the decrease, the increase, and no change in the number of vehicles. The last one includes both cases where the household has and has not replaced their vehicles during the three years. The possible error correlations among the alternatives are not considered, but remains as a future research task.

One of the advantages of multinomial logit models is the consistency of the coefficient estimates except constant terms even when the conventional maximum likelihood estimator is applied to the choice-based samples[27,28]. The underreporting of the disposal mentioned in the previous sub-section is not pure underreporting represented as the choice-based sample because those with the underreporting of the disposal are not only excluded from the sub-sample of the decrease in the number of household vehicles, but also included into the sub-sample of the no change in the number of household vehicles. However, the consistency of the multinomial logit models for the choice-based sample can be effective to some extent even

Table 5 Multinomial logit model of household vehicle ownership dynamics with and without life-course events

Life-course events	With		Without	
Type of dynamics	Decreased	Increased	Decreased	Increased
Constant	−4.589	−1.022	−4.454**	−1.093
Number of vehicles	1.099**	−1.260**	1.015**	−1.208**
Elderly household		−1.294**		−1.362**
Increased adults		0.621		
Number of drivers	−0.419**	0.975**	−0.286*	1.065**
Increased drivers		1.356**		
Decreased drivers	1.528**			
Increased workers		0.847**		
Farmer		1.388**		1.215**
Distance to station	−1.852*		−1.814*	
Distance to station for elderly household		2.098		2.184
Bus frequency for family with kids		−3.998*		−4.600*
Bus frequency for family with infants	0.508**		0.564**	
Bus frequency for increased drivers		−3.379**		
Moving of young couple or family with infants	1.862**			
Sample size	1,849		1,849	
Log-likelihood of constant model	−1,291		−1,291	
Log-likelihood at convergence	−1,058		−1,092	

* $p < 0.05$, ** $p < 0.01$
Source: Calculations from Kofu person travel survey (2005-2006)

for this case.

3.3 Results

The results of multinomial logit model of household vehicle ownership dynamics are shown in Table 5. Models with and without the life-course events are estimated and shown in the table. The utility of no change in the number of vehicles is fixed at 0 without any loss of generality. In Table 5, positive (negative) coefficient estimates mean that the expected probability of the occurrence of the dynamics of the type in question increases (decreases) along the value of the explanatory variable.

Looking at the coefficient estimates of the life-course events, *Increased adults*, *Increased drivers* and *Increased workers* have positive coefficient estimates for the utility function of increase in the number of vehicles, suggesting an increase in the number of adults, especially drivers and workers, has a significant impact on the increase in the number of household vehicles. The results are consistent with those of the French data. In the utility function of the decrease in the number of vehicles, *Decreased drivers* has a significant positive coefficient estimate, suggesting the decrease in the number of drivers has a significant impact on the decrease in the number of household vehicles, the same as the increase in the number of drivers on the increase in the number of household vehicles. The result is also consistent with that of the French data. The sizes of the coefficient estimates for the increase and decrease in the number of drivers for the increase and decrease in the number of vehicles respectively are about the same, suggesting that the change in the number of drivers has a symmetric effect on the change in the number of household vehicles.

Moving by itself turned out to be insignificant in the utility functions of decrease and increase, thus discarded from the model. However, combined with the household attributes, it is found that *Moving of young couple or family with infants* has a significant positive coefficient estimate for the utility function of decrease. The result suggests that the residential relocations of young couple and family with small children have a higher probability of reducing the number of household vehicles. The effect of residential relocation on the probability of decrease is consistent with the result using the French data, although the effect on the probability of increase observed in the French data is not found with the Japanese data.

Comparing the models with and without the life-course events, the coefficient estimates of the household attributes are similar for the utility functions of both decrease and increase, and the difference is not significant. Also, the improvements of the log-likelihood at convergence are statistically significant, but the size of the improvement is small compared to the difference in the log-likelihood between the constant-only model and model without life-course events. These results are consistent with those using the French data, and confirming that the life-course events are one of the contributing factors in addition to other explanatory variables.

4. SUMMARY AND CONCLUSIONS

The impacts of the life-course events on vehicle ownership dynamics were empirically investigated in this study. Two data sets, French nationwide panel survey data and Japanese small-sized retrospective survey data, were used in the empirical analysis, and two methodological approaches, a competing-risks hazard-based duration model and a multinomial logit model, were applied for the two data sets, respectively, according to the preciseness of the observation. The types of data and models were different for two empirical analyses, but the results were consistent with each other.

This empirical analysis indicated that the life-course events have significant impacts on household vehicle transaction behavior, and including the life-course events into the explanatory variables significantly improves the goodness-of-fit statistics. However, the size of the improvement was not large, thus it was not confirmed that the life-course events were the dominant factors on the household vehicle transaction behavior, though it was confirmed that those were one of the contributing factors in addition to other explanatory variables.

The change in the number of adults had a strong impact on both disposing of and acquiring a vehicle for both data sets. The result was also consistent with the preceding study by Prillwitz et al.[8]. The residential relocation was found to have strong effects on the probability of disposing of and acquiring a vehicle for the French data set, and found to have a strong effect on the probability of disposing of a vehicle for young couples and households with small children for the Japanese data set. At least, the effect of the residential relocation on the disposing of a vehicle is consistent between the two data sets. Insignificance in the coefficient estimates of the effect on the disposal for other household types and that on the acquisition with the Japanese data set might be caused by a small percentage in the occurrence of the residential relocation in the Japanese data set, or by the lag between the residential relocation and the vehicle transactions. In order to correctly distinguish the effects of dummy variables which

apply to only a small percentage of respondents, a large scale survey or enriched sample data should be obtained. In this study, only a small-sized data set was available for the Japanese case. On the lag between the residential relocation and the vehicle transactions, the lagged effects were considered for the French data set, and found significant for the replacement. However, the lagged effects of the residential relocation were not considered for the Japanese data set. It is because retrospective survey data for only three years was used for the Japanese case study, and the information on the relocation preceding the vehicle transactions was incompletely obtained. This is one of the limitations of retrospective surveys, and a more reliable survey format should be used in future studies on household vehicle transactions. More in-depth analysis with an enriched sample is required for the investigation of the impacts of residential relocation on the vehicle transaction behavior, especially in Japan.

More in-depth analysis is also required to distinguish the causal relationship from the correlation. As mentioned in the introduction section, the statistical analysis used in this study can not distinguish the causal relationship and the correlation, similar to previous studies. Thus, the results shown in this study might represent the correlation rather than the impact of residential relocation on vehicle ownership dynamics. One way to overcome this limitation of the study and clear away the ambiguity is to obtain information on the reasons for each vehicle transaction and residential relocation. A qualitative interview survey might be useful for this purpose, which should be examined for the next step.

Although more in-depth analyses are required for the clarification of the results, the findings of this study are useful in developing policy measures to influence household vehicle transactions. The change in the number of adults and the residential relocation especially for young couples and households with small children are found to have a higher probability of change in the number of household vehicles, thus the policy measures including incentive programs and travel feedback programs for these segments are considered as effective in encouraging environmentally desired household vehicle transactions. An experimental study for these measures should be the next step to investigate the effectiveness of these measures.

REFERENCES

1. Stern, N. The Economics of Climate Change: The Stern Review. Cambridge University Press. (2007).
2. Ministry of the Environment, Japan. National Greenhouse Gas Inventory Report of Japan. (2007).
3. Banister, D. The sustainable mobility paradigm. “Transport Policy” 15: pp.73-80. (2008).
4. Verplanken, B., Aarts, H. and Van Knippenberg. A. Habit, information acquisition, and the process of making travel mode choices. “European Journal of Social Psychology” 27: pp.539-560. (1997).
5. Van der Waerden and Timmermans, H. Key events and critical incidents influencing transport mode choice switching behavior: an exploratory study. Transportation Research Board 82nd Annual Meeting Compendium of Papers. (CD-ROM). Washington, D.C. (2003).
6. Van der Waerden, P, Timmermans, H. and Borgers, A. The influence of key events and critical incidents on transport mode choice switching behaviour: a descriptive analysis. Proceedings of 10th International Conference on Travel Behaviour Research. (CD-ROM). (2003).
7. Verhoeven, M., Arentze, T., Timmermans, H. and van der Waerden, P. Modeling the impact of key events on long-term transport mode choice decisions: a decision network approach using event history data. Transportation Research Board 84th Annual Meeting Compendium of Papers. (CD-ROM). Washington, D.C. (2005).
8. Prillwitz, J., Harms, S. and Lanzendorf, M. Impact of life-course events on car ownership. “Transportation Research Record” 1985: pp.71-77. (2006).
9. Prillwitz, J. and Lanzendorf, M. Interactions between residential relocations, life course events, and daily commuting distances. “Transportation Research Record” 2021: pp.64-69. (2007).
10. Ambruso, C. Direct-mail marketing to new residents, “Transportation Research Record” 1297: pp.40-49. (1991).
11. Matsumura, N. Evaluation of the effect of attitude and travel behavior modification by one-shot TFP for incomer and residents. “JSCE Journal of Infrastructure and Planning and Management” 64: pp.77-85. (2008). (in Japanese)
12. Hivert, L. Le Parc Automobile des Ménages: Étude en find’année 1998, à partir de la source “Parc Auto” SOFRES. Report for the French Agency for Environment and Energy Savings (ADEME). (2000). (in French)
13. Mannering, F. and Winston, C. Brand loyalty and the decline of American automobile firms. Brookings Papers on Economic Activity, Microeconomics. pp.67-114. (1991).
14. Gilbert, C.C.S. A duration model of automobile ownership. “Transportation Research Part B” 26: pp. 97-114. (1992).
15. De Jong, G. A disaggregate model system of vehicle holding duration, type choice and use. “Transportation Research Part B” 30: pp. 263-276. (1996).
16. Hensher, D. The timing of change for automobile transactions: competing risk multispell specification. in J.D. Ortuzar, D. Hensher and S. Jara-Diaz (Eds.) Travel Behaviour Research: Updating the State of Play. Elsevier, Amsterdam. pp.487-506. (1998).
17. Yamamoto, T., Kitamura, R. and Kimura, S. Competing-risks duration model of household vehicle transactions with indicators of changes in explanatory variables. “Transportation Research Record” 1676: pp.116-123. (1999).
18. Yamamoto, T., Kitamura, R. and Fujii, H. An analysis of the effects of a periodical vehicle inspection program on household vehicle ownership. in D.A. Hensher (Ed.) Travel Behaviour Research: The Leading Edge. Pergamon, Oxford. pp.435-450.

(2001).
19. Yamamoto, T. and Kitamura, R. An analysis of household vehicle holding durations considering intended holding durations. “Transportation Research Part A” 34(5): pp.339-351. (2000).
20. Chen, C. and Niemeier, D. A mass model. “Transportation Research Part B” 39: pp.401-415. (2005).
21. Chen, C. and Lin, J. Making an informed decision. “Transport Reviews” 26: pp.731-748. (2006).
22. Lin, J., Chen, C. and Niemeier, D.A. An analysis on long term emission benefits of a government plan in northern Illinois. “Transportation” 35: pp.219-235. (2008).
23. Bhat, C.R. Duration modeling. in D.A. Hensher and K.J. Button (Eds.) Handbook of Transport Modelling. Pergamon, Oxford. pp.91-111. (2001).
24. Yamamoto, T., Madre, J.-L. and Kitamura. An analysis of the effects of French vehicle inspection program and grant for scrappage on household vehicle transaction. “Transportation Research Part B” 38: pp.905-926. (2004).
25. Groves, R.M. Survey Errors and Survey Costs. John Wiley & Sons. (1989).
26. Armoogum, J. and Madre, J.-L. Accuracy of data and memory effects in home based surveys on travel behavior. Preprint CD-ROM of the 76th Annual Meeting of the Transportation Research Board. (1997).
27. Cosslett, S.R. Efficient estimation of discrete-choice methods. in C. Manski and D. McFadden (Eds.) Structural Analysis of Discrete Choice Data with Econometric Applications. MIT Press, Cambridge, MA. pp. 51–111. (1981).
28. Cosslett, S.R. MLE for choice-based samples. “Econometrica” 49: pp.1289–1316. (1981).

ACKNOWLEDGEMENTS

The author acknowledges the constructive comments given by anonymous reviewers who significantly aided in improving the quality of the paper. The French panel data set was provided by SOFRES, and the survey was funded by ADEME (Agency for Environment and Energy Savings) and CCFA (Committee of French Car Manufacturers). The French data set was organized by INRETS (The French National Institute for Transport and Safety Research), to which the author expresses his gratitude for providing the data used in this research. The Japanese retrospective data set was provided by Yamanashi Prefectural Government as a part of travel demand forecasting work at Urban Transportation Planning Council for Kofu metropolitan area. The author appreciates the efforts of Kozue Katagiri on assembling the Japanese data set.