

Doctoral Dissertation

**Behavioral Analysis of Individual Mobilities  
Based on Life-oriented Approach**  
(Summary)

ZONG WEIYAN

Graduate School for International Development and Cooperation  
Hiroshima University

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Mobility has become an extremely important keyword for the twenty-first century, and it has various implications for sustainable development at global, national, regional, urban and community levels. Associated with this context, people make numerous life choices and participate in various activities, which vary across individuals and from context to context, and change over time and across space. These variations and changes may be associated with an improved or a worsened quality of life at an individual level and an improved or a worsened quality of our society (e.g., change in environmental emission due to energy saving or excessive use of energy) at an aggregate level (e.g., regional, urban or community level). Individual quality of life and quality of our society are crucial to the decision-making of various public policies.

Focusing on individual *mobilities*, this study aims to present a set of new methodologies that can properly reflect interdependent decision-making mechanisms associated with different types of mobilities in the context of regional, urban and transport developments, to empirically confirm the usefulness of these methodologies based on a set of individual-level data originally collected in Japan, and to derive insightful cross-sectoral policy implications.

Here, *mobility* refers to a change (temporal, spatial, or context-dependent) in a certain life domain (i.e., residential behavior, migration, travel behavior, energy consumption, time use, expenditure, or other life choices). Mobility can be just a few-minute walk, a migration to a place 1,000 km away from home, or a set of mobilities at a certain life domain over the life course. Individual mobilities are related to economically, environmentally and socially sustainable development in direct and indirect ways. In many cases, decisions on different mobilities are not independent of each other, as suggested by the *life-oriented approach*. Such potential interdependencies have important implications for both interdisciplinary research and cross-sectoral policymaking. However, multi-faceted individual mobilities have not been well represented in a theoretically sound way and empirically examined in a methodologically convincing manner, due to lack of sophisticated theories/methodologies and data. Theoretically, existing studies have mainly focused on different mobilities in different disciplines and interdependencies across decisions on different mobilities have been ignored. To overcome this shortcoming of existing studies, this study follows the life-oriented approach, which argues the interdependencies across life choices/activities, being attributable to quality of life. With this newly developed approach in recent years, different mobilities can be theoretically connected. Methodologically, suitable survey/data and modeling approaches are important to empirical studies. In this regard, this study focuses on the following four types of mobilities, which are

analyzed by developing/building proper statistically sound or behavior-oriented models based on either large-scale national data or originally collected life-oriented behavioral surveys. Studies on these four types of mobilities are socially important. The extensive review suggests that all these case studies are all initial attempts in the corresponding literature.

[1] *Car ownership and usage: Temporal changes (over a 25-year period)* of household expenditures associated with young people's car ownership and usage

[2] *Population migration: Life-course domestic migration*

[3] *Smart life: Changes in life* caused by use of smartphone applications

[4] *Energy consumption: Locational changes* in household energy consumption

Relevant existing studies have suffered from serious data and modeling issues. Concerning modeling issues of decision-making mechanisms, *cross-domain interdependencies*, *life-course dynamics*, *behavioral complexity* and *context sensitivity* are explored with respect to the above mobilities. These behavioral issues are represented by building a new type of discrete-continuous choice model for car ownership and usage and a life-course discrete choice model with cross-sectional and longitudinal heterogeneities for population migration, by applying a random forest approach for decisions on changes in various life choices, and by developing a copula-based location-sensitive simultaneous-equation econometric model for household energy consumption. These modeling methods are used to empirically examine these behavioral phenomena for the first time in the literature. Regarding data issues, life-oriented survey data are used/collected for the first time in the fields of the above mobilities. Concretely speaking, a longitudinal nation-wide household expenditure survey data is used to investigate young people's car ownership and usage. A life-course survey is conducted to capture individual migration biography. Changes in life caused by use of smartphone applications and household energy consumption are investigated in a comprehensive way by asking respondents to report an extensive set of life choices/activities.

Analyses of the four mobilities are summarized below.

First, this study used a longitudinal national household expenditure data to examine young people's car ownership and usage in Japan. Young people's declining dependence on car in the context of developed countries have been attracting more and more attention from both researchers and policymakers. However, the phenomenon has not been well understood. This study attempts to better understand young people's car ownership and usage by incorporating interactions between expenditures at different life domains based on the concept of multilinear utility, where car-related expenditure was singled out and emphasized. The model is a kind of resource allocation

model consisting of zero expenditure (i.e., discrete choice), amount of expenditure allocated (i.e., continuous choice), and *cross-domain interdependencies* across multiple expenditures (i.e., multiple choices). The data was a large-scale national survey covering a 25-year period starting from 1984, and about 4,000 – 9,000 young respondents were included in each year. It is empirically shown that car ownership and usage of Japanese young people have decreased since 1999, especially for high-income young people. Moreover, the share of car-related expenditure in the overall expenditure of young people with a car has declined since 1994. Modeling analyses revealed that major factors affecting young people's expenditures on car ownership and usage are household size, the number of household members aged under 18 years old, whether young people's income level is low or not, and the number of owned cars. It is also confirmed that the influences of these factors are not static over time: influences of residential attributes on car-related expenditure has diminished while the number of cars owned by household has become more influential since 1999. Methodologically, the concept of multilinear utility can also be used to represent interdependencies existing in continuous choices, such as inter-activity time use decisions, joint decisions on time use and expenditure, and intra-household interactions related to time use and/or expenditure.

Second, individual mobilities over life course have not been well understood in existing studies, and as a result, it has remained fully unknown how to represent the underlying *intertemporal dynamics* and *heterogeneity*. In this context, this study investigates domestic migration of people residing in the Capital Area of Japan at an individual level. Japan has suffered from over-concentration of population in the Capital Area and it has been trying various ways to curb this trend. However, expected changes have not been obviously observed and the trend of over-concentration in the Capital Area is still continuing. Here, a web-based questionnaire survey was conducted to 1,000 working people aged between 20 and 49 years old in the Capital Area, including the Tokyo 23 Wards and seven surrounding prefectures, in December 2015. Respondents were requested to recall their latest five migration experiences (i.e., migration biography). Adopting this data, a dynamic discrete choice model with cross-sectional and longitudinal heterogeneities captured by the concept of quasi-hyperbolic discounted utility is developed based on time preference theory. The theory argues that utility of current decision is affected by not only utility of current utility but also retrospective utility (accumulated state dependence) and future utility (expectation). Influences of life-oriented motivations and intra-household altruism on migration biography decision are further incorporated. And non-linear changes in effects of past,

present and future utility over life course are revealed. The developed life-course model can be extended to cover decisions on multiple mobilities, in theory.

Third, relationships among decisions on different mobilities are *complicated*. Taking smartphones as an example, use of various smartphone applications may cause changes in a variety of life domains, leading to either a better or worse quality of life. There are two challenges: (1) how to capture these changes in a comprehensive way, and (2) how to understand these changes as well as their relationships in a robust way. For the first challenge, this study adopts the life-oriented approach to comprehensively investigate various life choices/activities. For the second challenge, this study applies a random forest approach. Using data collected from 1,000 residents in different regions of Japan in 2017, who reported their ownership and usage of 19 types of smartphone applications and the resulting changes in about 40 life choices/activities. Analysis results show that different life changes triggered by smartphone application usage are correlated, which are observed mainly related to time use. And in some cases, use of smartphone applications worsens people's quality of life. Rich policy implications for the development of smart society are discussed.

Fourth, it is necessary to figure out how to better represent *behavioral complexity* captured based on the above random forest approach in the mobilities research, especially considering that people's behaviors are usually context dependent. Focusing on household energy consumption, this study first explores influential factors associated with choices in other life domains and then develops a copula-based joint decision-making model to incorporate potential correlations between residential location and different types of energy consumption. In this context, encouraging behavioral changes toward an energy-saving and less car-dependent lifestyle needs to better understand how various life choices affect household energy consumption, which includes both in-home and out-of-home consumption. However, impacts of a large set of life choices on energy consumption have remained unknown. This study makes an initial attempt to apply the life-oriented approach to investigate household energy consumption by using data from about 900 respondents living in different parts of Japan in 2014. Considering that Japan has the highest elderly ratio (about 28%) in the world, relatively more elderly samples are included in the data. The random forest approach is applied to identify the influences of 87 life choices in ten life domains on household consumption of electricity, gas, kerosene, gasoline, and diesel, in a robust way. As a result, it is shown that a variety of life choices affect household kerosene and gasoline consumption, but only a limited number of life choices are influential to electricity and gas. This

may be partially due to the fact that the random forest approach cannot represent joint decisions on multiple life choices. To overcome this shortcoming, this study develops a copula-based simultaneous-equation model consisting of residential location choice (a continuous choice) and its associated electricity and gas consumption, where the association is further assumed to vary with residential regions. Incorporating such an association is for reflecting location-sensitive decision-making mechanisms (or context-dependent decision-making mechanisms). Copula approach is able to represent complicated correlations across various life choices/activities by decomposing a multivariate joint distribution into a set of (univariate) marginal distributions with the assistance of copula function. The results show that household residential energy consumption is closely related to life choices related to residential environments, commuting, time use, and lifestyles. And disparities in energy consumption patterns between different residential regions and within the same region are revealed. In theory, the copula approach can be used to represent various life choices/activities within a unified modeling framework.

In summary, this thesis study has advanced research on individual mobilities in several ways. From a methodological perspective, this study has built/applied a new type of multiple discrete-continuous choices based on multilinear utility, a life-course choice model based on time preference theory, random forest approach, and a copula-based simultaneous-equation econometric model, which is actually a multiple continuous choice model with context-dependency. Even though these models are applied to investigate different types of mobilities, theoretically, they can be jointly used, and even integrated into a unified modeling system. In this sense, there are still many promising developments in the future. On the other hand, from a phenomenal perspective and in the context of Japan, young people's declining trend of car ownership and usage, over-concentration of population in the capital region, smart society, residential location and energy consumption are extensively examined in this study. These phenomena seem irrelevant to each other; however, they are actually well connected. The over-concentration of population in the Capital Area of Japan has been mainly caused by young people's out-migration from local areas. The declining trend of car ownership and usage is obviously influential to household energy consumption. Furthermore, young people have been a major population group, whose lives have been affected by use of various smart technologies such as smartphone applications. Changes caused by smartphone application use are associated with car use, in-home and out-of-home energy consumption, and accumulative changes over a longer period could further motivate people to migrate across regions. Use of the life-oriented approach

allows the aforementioned mobilities to be analyzed in a theoretically consistent way and has consequently enriched our understanding of various mobilities. The potentially integrated use of these methods is expected to further advance the research on both individual mobilities and the life-oriented approach. The findings derived from this thesis study have various important policy implications for sustainable development.