論文の要旨
Summary of the Dissertation

論文題目
Dissertation Title

Road Traffic Safety Determinants and Interventions: Incorporating Multi-source Heterogeneities in Human Factors and Built Environments

(道路安全の決定要因と対策：人的要因と構築環境における多次元の異質性を考慮する)

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This research aims to provide a thorough analysis on the determinants related to road safety by incorporating multi-source heterogeneity and provide tailored policy recommendations to mitigate injury severity, reduce road crashes, decrease crash casualties and implement advanced driver assistant systems. The research objectives are as follows: (1) Identify the temporal and seasonal heterogeneity of the relationship between explanatory variables and injury severity. Provide tailored policy recommendations to mitigate injury severity by considering these temporal and seasonal variations. (2) Quantify the spatial heterogeneity of built environments, climatic characteristics and crash frequency. Analyze the causalities between these factors and crash frequency and provide tailored policy recommendations to reduce zonal road crash frequencies. (3) Examine the dependence between multi crash outcome variables, such as injury severity and crash size. Provide less biased estimation results of the relationship between human factors, road environment and the multiple crash outcomes, and then offer tailored policy recommendations to reduce injury severity and crash size. (4) Evaluate the effectiveness of nudge approach on drivers' willingness to utilize driving tracking. Explore the heterogeneities between demographic groups and provide tailored policy recommendations to improve driver's willingness to utilize driver tracking.

In summary, there are 8 chapters included in this research. Chapter 1 introduces the research background, research objectives, research framework, contributions, and outline of this dissertation. Chapter 2 summarizes the literature reviews of the research contents in this dissertation: seasonal and temporal heterogeneity in modelling injury severity, spatial heterogeneity in modelling crash frequency, road crashes with bivariate dependent modelling approach, and behavioral changing intervention approaches in road safety. Chapter 3 presents the data and survey used in this dissertation.

For the temporal and seasonal heterogeneity, (Chapter 4) fills the research gap by investigating injury severity and its seasonal transferability and temporal instability based on a random parameter logit model with heterogeneity in means and variances (RPLMV), which is useful to capture various heterogeneities in factors affecting injury severity. Three other models are calculated for comparison: a fixed parameters multinomial logit model (MNL), a random parameter logit model (RPL), a random parameter logit model with heterogeneity in means (RPLM). These models are estimated based on rainy and dry seasons motorcycle crash data between 2015 and 2017. Results indicate that the RPLMV model outperforms the other three models in explanation performance. It is revealed that head on collision and the presence of elderly riders increase the probability of fatal injury severity across all time periods. Motorcycle-to-motorcycle crashes significantly increase the likelihood of motorcyclist casualties suffering from severe injuries during the rainy season. Crashes on weekends are more likely to result in fatal injuries during the rainy season. In contrast, during the dry season, riders face a greater risk of severe injury compared to pillion riders, and crashes on national roads have a higher probability of resulting in casualties suffering fatal injuries. Moreover, temporal stability tests indicate that the effects of exogenous variables on the motorcyclist injury severity are different across year-wise models. The non-transferability between rainy season and dry season crashes provides insights into developing differentiated strategies targeted at mitigating and preventing different types of crashes.

For the spatial heterogeneity of road crashes, (Chapter 5) examines the spatial influence of built environment and climate characteristics on motorcycle crash frequency, using the data from 197 districts in Cambodia during 2019 as a case study. Spatial autocorrelation of motorcycle crash frequency and various

built environment and climate characteristics was confirmed using Moran's Index. After checking the motorcycle crash frequency distribution, and the multicollinearity of these explanatory variables, we employed and compared different regression models to understand these relationships: Ordinary Least Squares regression (OLSR), Poisson regression (PR), Negative Binomial regression (NBR), and Geographically Weighted Negative Binomial regression (GWNBR). Our findings indicate that GWNBR is most effective in capturing the spatial dependencies and heterogeneities in how built environment and climate factors influence motorcycle crash frequency. From an overall perspective, road density, major and minor road length, residential area, and precipitation positively correlate with motorcycle crash frequency and should be primary focus areas for motorcycle crash mitigation strategies. Conversely, factors like population density, intersection density, and annual rainy days show a negative correlation.

Regarding the joint modeling analysis, two key outcomes of road crashes are injury severity and crash size, notably the number of injuries. Typically, these indicators are analyzed independently to understand the impact and consequences of motorcycle accidents. Nevertheless, it is critical to recognize that both observed and unobserved factors may concurrently affect these crash indicators, indicating a possible interrelationship between injury severity and crash size. Neglecting the joint occurrence of these variables can result in biased and incorrect parameter estimation. (Chapter 6) contributes to the existing body of knowledge by simultaneously analyzing the factors influencing both injury severity and crash size, using motorcycle as a case study. This approach further distinguishes itself by considering the interdependence between these two results utilizing a copula-based approach. Six models based on copulas were developed using the ordered logit model, which was designed to capture the ordinal nature of injury severity and crash size. By analyzing motorcycle crash data from 2016 in Cambodia, the Frank copula framework was identified as the most effective among the five approaches. The findings revealed that factors such as motorcycle-to-pedestrian collisions, head-on collisions, X junctions, and national roads significantly increase both motorcyclist injury severity and crash size.

(Chapter 7) Due to the fact that human factors account for more than 70% of road accidents, changing road users' behavior through behavior change architecture is effective. Driver tracking has the potential to improve driving skills and reduce traffic accidents. Nudging drivers toward the widespread utilization of driver tracking holds significant potential for enhancing traffic safety. Nudge approach gained popularity by changing environmental factors through careful design and guiding people to make certain choices under non-mandatory conditions. This research is dedicated to examining the impact of nudge approach on driver's willingness to use driver tracking across different age, marital, and income groups. Survey data were collected from a sample of 1054 respondents throughout Japan in 2020. Together with the PLS-SEM model and multigroup analysis, results reveal that (1) natural consequences, comparison of behavior, shaping knowledge, covert learning, identity nudge approaches could all have positive impact on driver's willingness to use driver tracking; (2) it is significantly effective to deploy shaping knowledge nudge approach for the drivers under 50 years old to encourage them to use driver tracking; (3) natural consequence nudge approach is more suitable for drivers older than 50 years old, while the convert learning nudge approach is more appropriate for drivers younger than 50 years old; (4) natural consequences nudge approach is more effective in influencing the willingness of unmarried respondents to use driver tracking, while the covert learning nudge approach is more effective in influencing the willingness of married respondents; (5) comparison of behavior nudge approach is 2 times more effective at persuading drivers to use driver tracking for the higher income group, while driver's identity nudge approach is 2 times more effective for the lower income group.

Based on all the above analysis and policy recommendations, (Chapter 8) finally concluded this dissertation from a systematic perspective. The study recommends improvements in stakeholder coordination, human resource management, public transport, infrastructure, and traffic law enforcement as managerial strategies to achieve sustainable transport goals, encompassing social, economic, and environmental dimensions. Future research recommendations were also provided.

Based on the above conclusions, enhanced road safety intervention strategies and policy recommendations for mitigating traffic accidents are proposed as follows: (1) Targeted educational campaigns: Develop and implement targeted safety campaigns that address the specific risks associated with different seasons and rider demographics. Special attention should be directed towards elderly riders and high-risk periods such as weekends and festivals. (2) Infrastructure improvements: Enhance roadway infrastructure by implementing barrier medians to prevent head-on collisions, improving road signage and markings at critical locations like X junctions and national roads, and delineating traffic flow between motorcyclists and pedestrians. (3) Localized safety measures: Local conditions should consider unique district characteristics that influence crash frequencies to deploy effective localized interventions. (4) Behavioral change strategies: Utilize behavioral change insights to adapt interventions tailored to specific

demographic groups to enhance the road safety intervention efficacy. (5) Continuous monitoring and research: Establish mechanisms for ongoing monitoring and research to continuously update and refine safety measures. This should include assessing the temporal stability of risk factors and the effectiveness of implemented policies. (6) Interdisciplinary collaboration: Encourage collaboration between traffic safety experts, urban planners, and behavioral scientists to ensure a holistic approach to traffic safety that integrates diverse expertise. These recommendations provided aim to foster safer traffic environments, ultimately reducing the incidence and severity of traffic incidents across varied contexts.

備考　論文の要旨はＡ４判用紙を使用し，4, 000字以内とする。ただし，英文の場合は1, 500語以内とする。

Remark: The summary of the dissertation should be written on A4-size pages and should not exceed 4,000 Japanese characters. When written in English, it should not exceed 1,500 words.