

論文の内容の要旨

Thesis Summary

Comparative Analysis of Sequential Time Discount Rate in Differential Disastrous Networks

(異なる災害時ネットワークにおける逐次時間割引率の比較分析)

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Transportation networks are subjected to significant delays and caused operational irregularities due to both natural or man-made extremes. Natural extremes could either be unexpected like earthquake, fire, landslide or expected like heavy rainfall, flood, snowfall. Respectively, man-made events also either could be unexpected such as explosion, terrorist attack, vehicular collision or expected such as end of a famous game (e.g. world cup final), protesting rally, famous festival and so forth. Even though the severity of these events are different to each other, occurrence of such events often disturbed the normal travel plans of the people and are forced to make in-situ decisions on their route choices. Identifying the altering travelers' decision-making dynamics and degree of network cognition together with their travel behavior under these circumstances has a paramount importance in saving lives of disaster victims, saving travel time and fuel of travelers, and reducing environmental pollution which could create due to a congested network.

In the literature, studies have been done based on the disastrous networks, but many of such are steady state analysis. Further, it was highlighted the problems such the data limitations and their accuracy. Specially in the case of using questionnaire survey data of a disaster travel behavior, they could be affected by the memory decay and the emotional trauma of the event. As a solution, probe data can be presented as a good reliable data where it gives the Global Positioning System (GPS) trajectories of the travel paths. Probe data has been an emerging and encouraging data source among the transportation researchers even though they were very less used in the case of understanding travel behavior in disaster conditions. With the vast development in the field of computer technology, solving complex mathematical problems become easier. Correspondingly, number of modeling tools have been developed to appropriately assess and mitigate the prevailing issues in transport planning. But when it comes to address the transportation problems in unexpected or disastrous situations, such tools are limited in the literature.

With that background, this research is set up to make a comparative analysis on differential disastrous networks by using probe taxi data based on sequential time discount rate which was estimated as a parameter in an unsteady travel behavior model called β -Scaled recursive logit (β -SRL) model. The model falls to the category of Markovian route choice models and the route choice behavior is described through the sequential time discount rate (β) which is recognized as a generalization of drivers' decision-making dynamics and a representation of the degree of spatial cognition of networks. In order to succeed the aforementioned purposes, the following objectives were set up for the study.

Illustrate the behavior of sequential time discount rate through a sample sensitivity analysis, accomplish a comparative study on stability of sequential time discount rate subjected to moving time, sampling rate, peak hour periods, unsteady state, different networks and find out the answers to the questions how many trips are needed for stable estimations under recursive logit framework, does it stable under different traffic conditions, what are the characteristics of sequential time discount rate. Further, the estimation results of sequential time discount rate are strongly related with the link usage. Hence, identify the mathematical characteristics of value function of β -SRL model and carryout model performance analyses through normalized network, scaled network, extended network and based on the number of links per trip. Another objective is to Carrying out a comparative study on two differential distinct disasters focusing on exploring link speed characteristics in time-space, scrutinizing trajectory patterns and their behavior and analyzing travel behavior through parameter estimation.

In the thesis chapter 3, the sensitivity of the sequential time discount rate on route choice probabilities was tested. Three different values of sequential time discount rate were used as $\beta = 0, \beta = 0.5$ and $\beta = 1$ for understanding the deviations in link assignments under each condition by using a hypothetical network. Five scenarios as the original network conditions, introducing low cost links at the downstream, introducing high cost links at the downstream, introducing low cost links near the origin and introducing high cost links near the origin were used for the analysis. Route choice probabilities and link assignments under the recursive logit framework indicated that myopic decisions become crucial when the $\beta = 0$ and link choices being made based on the separated link costs. Further it clearly visualized the worst impacts of myopic decisions for route choosing by assigning larger flows to high costs links. This could lead to make heavy congestions in congested links. In addition, its further showed that making changes on link cost at downstream has no impact on the network assignments under the myopic decisions. Meanwhile higher values of sequential time discount rate always made the route choice decisions considering route-based decisions from origin to destination. Hence, it was clearly visualized that under the condition of $\beta = 1$, larger flows being assigned to low cost routes as they were given higher probabilities. As a conclusion, the analysis clearly showed the impact of sequential time discount rate on predicting link assignments under different circumstances.

The stability of sequential time discount rate under different network settings were tested in chapter 4. In usual practice in modeling route choice behavior, parameters are estimated by considering hourly periods of data. Since this could miss tiny variations of the network behavior in between the considered periods, stability of the sequential time discount rate was tested with the moving time. The results showed, that the β -SRL model is capable

of estimating stable and reliable values for sequential time discount rate for the entire considered period of time. Finding the adequate minimum number of trips for stable estimation is always important for saving simulation time. Hence, model stability of estimating sequential time discount rate was evaluated under three categories as 10 trips, 20 trips and 30 trips. Visual observations together with statistical parameters illustrated that the 20 trips and 30 trips samples produced more stable results comparatively to the 10 trips samples. Besides, the asymptotic t test was performed and the resulted t values were insignificant for all the considered samples and hence, it indicated that there are no significant differences between the estimated sequential time discount rates in each category. Precisely, the model estimations are stable. With this base, same sampling technique was tested by estimating in distinct networks such as different time zones, different networks and different size of trips. The overall results showed that β – SRL model estimate better results under all 03 categories while 20 trips and 30 trips samples always provide stable and reliable results compare to the 10 trips samples. Further, the improvements of the results from 10 trips samples to 20 trips samples was larger in comparison with the improvements from the 20 trips samples to the 30 trips samples.

Former part of the chapter 5 is utilized for explaining the mathematical characteristics of solving the value function in the β – SRL model while the latter part of the chapter described the model performances under different network settings. Since the value functions with respect to each link of the considered network can be determined by solving the system of non-linear equations of the sequential time discount rate, here we produced the element base changes of such a system of non-linear equations by using a hypothetical network. In the second half of the chapter 5, the model performances were discussed based on normalized network, scaled network, extended network and number of links per trip. Changes in the route choice probabilities from myopic decisions to route-based decisions were observed by changing the sequential time discount rate in a hypothetical network. These characteristics were changed with the normalized network where it assigned the links with equal probabilities at decision making nodes under the myopic conditions. Meanwhile, route choice probabilities also observed to be normalized under the condition of sequential time discount rate was equal to one. The analyses with the real world data showed a lowering of sequential time discount rate, improvements in log likelihood ratio index, and reduction of simulation time in normalized network conditions in comparison with the real network conditions. The analysis based on scaled network showed that the results are holding the equivalent differences property between the alternatives. Lower sequential time discount rates were observed in the extended networks as it kept the original route choices unchanged. The results based on the influence of the number of links per trip showed that the model performance become more consistent and the estimations become more stable when estimating the samples having trips with their number of links per trip is more than 50 links.

Comparative analysis of network behavior under two distinct and divergent disasters, the great east Japan earthquake and a torrential downpour was done at chapter 6 as a case study. Probe taxi data collected under the aforementioned disaster conditions and normal days as one week after each disaster were used for the analysis. Route choice characteristics were visualized by making a cross sectional analysis and travel behavior under each disastrous conditions were compared with a normal day variations. During both

disasters that altered the normal city life, drivers had to change their original travel plans and choose alternatives. The sequential time discount rate was estimated together with two other parameters, travel time and right turn dummy variable in both circumstances. The estimated values of sequential time discount rate indicated the transition of drivers' decision-making process from global decisions to myopic decisions. In addition, the estimated values of travel time parameter under both events indicated the difficulty for drivers to evaluate travel time properly, under the congestions. The estimations of right turn dummy variable showed an increasing difficulty of making right-turns under both disaster scenarios.