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潜在欲求を考慮した自宅外余暇活動の生成モデルに関する研究

MODELLING OUT-OF-HOME LEISURE GENERATION INCORPORATING UNDERLYING NEED DYNAMICS

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The thesis presents an analytical model to interpret the individuals' choices of activity generation on a particular day with a special focus on leisure activities. The model is conceptualized in terms of the theory of needs, hypothesizing that individuals conduct activities to satisfy their need. Different from the existing need-based model with arbitrary definition of needs, this model defines underlying needs according to validated psychological need theory. The interrelationship between leisure activities and underlying needs is investigated to quantify need satisfaction ratio of an activity. An original survey was conducted to conduct an empirical estimation in the context of Japan. The estimation result provides implications connecting people's leisure participation and their well-beings.

INTRODUCTION

Activity generation modelling lies in the field of travel demand analysis from an activity-based perspective which incorporates the behavioral theory underlying people's daily activity-travel patterns. However, current literature still lacks behavioral interpretation about how activities are generated. While the travel demand analyses in the past several decades have provided many insights into fixed activities like work or school, this thesis focuses on leisure activity due to its important post in people's daily life. Evidenced by 2016 Survey on Time Use and Leisure Activities in Japan, the average time use of leisure was 5.6 hours per day, versus 4.43 hours spent on work and work-related activities. Another concern lies in the great spatio-temporal variability of leisure brought by its discretionary nature.

To bring behavioral enhancement into activity generation modelling, several need-based applications have been developed to model activity generation (Nijland et al., 2013; Pattabhiraman, 2012) following an assumption of need theory that individuals perform activities in order to satisfy basic human needs. Need-based models represent the fluctuation of needs over time and model the choices of leisure activity generation by connecting need satisfaction to activity generation from a dynamic perspective. Yet, current analytical models are limited to their arbitrary definitions of needs for specific activities (i.e. need to eat-out, need to play sports, etc.) that are not grounded on theory.

This study proposes an out-of-home leisure activity generation model explicitly incorporating underlying psychological needs as motivators of leisure activities. The model explains how different types of leisure activities are determined according to the activity's effect in need satisfaction and the restriction effects by various constraints. Different from the existing models, validated psychological need theory is applied to the definition of needs in this model. The need satisfaction ratio, which is the potential of various leisure types to satisfy each underlying need, is approximated by measuring the correlations between leisure activities and underlying need satisfaction. With the model formulation, an empirical estimation is carried out to test the model and to bring up some implications regarding leisure participation and well-being in different population segments.

MODEL FORMULATION

1. Utility function

This model is formulated based on the need-based activity generation model proposed by Nijland et al. (2013). While Nijland's model is with arbitrary definitions of needs, this model defines underlying psychological needs according to validated psychological need theory (Beard and Ragheb, 1983).

This model is indeed a binary choice model towards whether to conduct a leisure activity i on day d conditioned by the day of previous leisure activity, denoted as s and the constraints varying across days between day s and day d. The decision rule that triggers an activity is described as Eq.(1).

$$U_{nid}(s) > u_{nd}^{o} \quad (1)$$

where an activity will be conducted if U_{nid}, the utility of need satisfaction that individual n can derive from a leisure activity i on day d exceeds u_{nd}^{o}, the threshold of constraints' disutility. According to the multi-dimensionality of underlying needs, the total amount of need satisfaction of activity i on day d is the summation of different underlying needs which can be simply defined as:

$$U_{nid}(s) = \sum_{k} U_{nikd}(s), \quad \forall k \epsilon K \quad (2)$$

where k is one dimension of underlying need and K is the exhaustive set of all types of underlying needs.

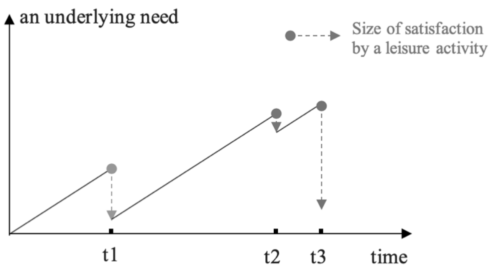

Figure 1 Dynamics of an underlying need

In line with existing models, needs are formulated as dynamic variables growing with time and decaying with activity participation. The figure above sketches out the dynamics of a certain type of underlying needs along with the occurrence of leisure activities. To concern individual's behavior in a longitudinal perspective, $A_{nkd}(s)$, which denotes the current size of need k, is time dependent because the underlying needs require time to rebuild after they get satisfied by a leisure activity on day s.

For individual n, the current need size $A_{nkd}(s)$ is defined in a recursive form, consisting of the need size after the previous activity on day s and the need growth from day s. Need growth is formulated as an increasing function of the need specific growth rate B_{nk} and the time elapsing from day s when last leisure activity i' is performed to the current day d.

$$A_{nkd}(s) = A'_{nksi'} + f(B_{nk}, d, s), \quad \forall k \epsilon K \quad (3)$$

where $A_{nkd}(s)$ is the current size of need k and $A'_{nksi'}$ is the need size after last activity i' has satisfied the underlying need k. In current setting, a simple model is chosen to describe the growth of need as described in Eq.(11).

$$f(B_{nk}, d, s) = B_{nk} \cdot [ln(d - s + 1)], \quad \forall k \epsilon K \quad (3)$$

where f is defined as a logarithm function with no extra parameter to reduce the burden in estimation procedure. Another assumption of need growth is presented by this logarithm function, that the speed of underlying need will flatten gradually when the time interval gets larger. B_{nk} is calibrated by a set of socio-demographic attributes to indicate individual heterogeneity.

$$B_{nk} = \beta_k^0 + \boldsymbol{\beta_k X_{sociodemo1}^n} \quad (4)$$

where β_k^0 is the intercept of the function while $\boldsymbol{X_{sociodemo1}^n}$ and $\boldsymbol{\beta_k}$ are respectively a vector of socio-demographic attributes of individual n and a vector of parameters indicating the impacts of those socio-demographics attributes on the growth rate of need k.

The decay, equalling the need satisfaction $U_{nikd}(s)$ of a certain underlying need k by a leisure activity i is formulated as Eq.(5).

$$U_{nikd}(s) = A_{nkd}(s) \cdot \lambda_{nikd} \quad (5)$$

where λ_{nikd} denotes the satisfaction ratio of the activity i on the underlying need k. λ_{nikd} are individual specific because individual perceptions towards activities can differ greatly with different orientations and propensity towards various leisure. λ_{nikd} ranges between $[0,1]$ to regulate the amount of need satisfaction to not overtake the current need in stock. When λ_{nikd} is valued 1, the totality of need k will be satisfied. In the current model, λ_{nikd} is approximated by the correlation between leisure activities and underlying need satisfaction to be illustrated later, together with the introduction to 4 underlying-need dimensions.

To apply random utility theory to the model, Eq.(1) is rewritten as follow.

$$Z_{nid}(s) = U_{nid}(s) - u_{nd}^{o} + \varepsilon > 0 \quad (6)$$

Following Nijland's model, the error term ε in $Z_{nid}(s)$ is assumed to be Gumbel distributed. While the formulation of $U_{nid}(s)$ has been given above, the disutility of constraints u_{nd}^{o} is defined as

$$u_{nd}^{o} = \alpha_k^0 + \boldsymbol{\alpha_k}(T_{nd} + \boldsymbol{X_{sociodemo2}^n}) \quad (7)$$

where T_{nd} is the day specific time constraints and $\boldsymbol{X_{sociodemo2}^n}$ is a vector of socio-demographic attributes which is different from the $\boldsymbol{X_{sociodemo1}^n}$ defined in Eq.(4).

Both the formulation of choice probability and the likelihood follow the ones given in Nijland et al. (2013). The likelihood is formulated as a conditional probability of conducting a particular leisure activity on a particular day knowing the time when the previous leisure activity has been conducted.

2. Underlying needs and need satisfaction ratios

In this model, underlying needs are defined as the 4 dimensions of psychological needs in the Leisure Motivation Scale (Beard and Ragheb, 1983). These 4 underlying needs are extracted via principal component analysis on the 48 items constituting the Leisure Motivation Scale, which are intellectual, social, competence/mastery and stimulus-avoidance.

The PCA results also provides a matrix of component loadings that are the coefficients indicating how strongly an indicator (item) is associated with the principal component, in this case, the underlying need. Since items in Leisure Motivation Scale are expressed as "whether this activity can satisfy your desire for…", the component scores are utilized as the approximates of need satisfaction ratio by an activity λ. The calculation of component score is formulated as:

$$PC_{nij} = \sum_{t \in T_j} S_{nit} \cdot Loading_{tj} \quad (8)$$

where PC_{nij} is the component score of need component j regarding leisure activity i stated by individual n. T_j denotes the set of items which belong to component j while item t is a component of T_j. S_{nit_j} is the individual's raw score of the item t. $Loading_{tj}$ is the loading of item t on component j. However, the component scores are not naturally within the range [0, 1] as λ's definition in Eq.(5). Thus, a normalization is done to the original component score with the summation of the loadings in the same component and it is be formulated as:

$$\widetilde{PC}_{nij} = \frac{\sum_{t \in T_j} S_{nitj} \cdot Loading_{tj}}{\sum_{t \in T_j} Loading_{tj}} \quad (9)$$

In this sense, $\widetilde{PC}_{nij}$ is individual specific in terms of individuals' various answers to the items. A normalized score of 1 indicates that individual n chose the option "satisfied" for all items in that component while a score of 0 indicates that individual n chose the option "not satisfied" for all items.

DATA CHARACTERISTICS

To collect the data satisfying the input of an empirical analysis of this underlying need model, an original survey was conducted administrated in form of online questionnaire during December 21 and December 27 in 2018 on the Tokyo Metropolis, and the prefectures of Chiba, Saitama and Kanagawa. Respondents were recruited via an internet panel and a quota sampling was used to control the distribution of age and sex in the respondents. The distribution of age and sex of the cohorts is identical to the distribution in Tokyo Metropolis, and the prefectures of Chiba, Saitama and Kanagawa, according to the annual report of Japanese population estimates in 2018 published by Japanese Statistics Bureau.

The survey gathered information on socio-demographic attributes, continuous multi-day leisure participation and perceived need satisfaction of several observed leisure activities. To address the problem of respondent burden which relates to both the response rate and the data quality, a rather short duration of 3 days is considered appropriate. Respondents were asked to recall their out-of-home activities on last Friday, Saturday and Sunday before the day they answered the questionnaire. Although a continuous 3-day activity diary can already provide 3 cross sections of respondents' need size, with such diary, only short intervals can be observed. This will absolutely restrict the calibration with long time intervals. To mitigate the problem, a question was added to collect the date of the latest leisure before last Friday.

Regarding the questions of perceived need satisfaction, which is Leisure Motivation Scale, a pilot study was conducted before the main survey to validate the original scale with its rephrased Japanese version. Through the pilot study, the original scale has been shortened to a 19-item one to mitigate the respondent burden in the main survey.

381 subjects completed the questionnaire and 745 leisure activity observations were collected for estimating the underlying need model.

ESTIMATION RESULT

Unlike the conventional optimization methods like maximum likelihood estimation, a statistical inference method called Bayesian inference is chosen to estimate the model. This is because of the nature of the defined likelihood. The likelihood in this model is not a convex function with which a global optimum referring to the best estimates of parameters can always be found. On the other hand, instead of seeking the optimum of the objective function, Bayesian inference derives and updates the probability distribution of parameters using observed information (Train, 2009). Same as Nijland et al. (2013), an incremental Bayesian procedure has been used by updating the probability distributions of parameters with one observation a time, rather than introducing all 745 observations into the inference simultaneously.

Table 1 shows the estimation results of the underlying need model where some variables are not included in the table as they indicate the base case. As stressed in previous chapters, the key distinction between this model and the existing Nijland's model is the definition of needs when modelling the need dynamics and leisure activity generation. This model incorporates theoretically verified psychological needs rather than arbitrarily defined needs. The 4 dimensions of underlying needs are with the definitions given by Beard and Ragheb (1983).

The estimates of β parameters indicate the desires to satisfy each underlying need in different socio-demographic groups. The variant levels of desire for underlying needs in different groups may provide some implications about their well-being statuses.

Younger generations show less desire for social needs from out-of-home leisure, probably because of ICT use, while elders have lowest need level for exploring and creating according to the result of the intellectual component. Men show stronger propensity for competency/mastery and stimulus-avoidance. The latter can be explained by the considerable gap of work participation between male and female in Japan. Young children in the household lead to low need growth rate in intellectual and competency/mastery which implies parent's limited spare physical and mental energy after childcare. Low income seems to restrain needs for social and competency/mastery in terms of out-of-home leisure participation, likely due to economic constraints related to activity participation.

Meanwhile, estimates of α parameters indicate the impacts of explanatory variables on the disutility of constraints. As shown in Table 1, only the α parameter of time budget is statistically significant. This result is consistent with the assumption of constraint utility, the larger the fixed time is, the greater the constraint an individual is facing with in leisure activity generation. Despite the intuitive assumption that monetary resources and access to car-use also restrict individuals' free choice on conducting leisure activities, α parameters of young children in household, income and car-use are insignificant as suggested by the result.

The rho square and adjusted rho square indicate the model's goodness-of-fit by reflecting how much the likelihood has been enhanced from the null model to the estimated model, while the latter is more objective by involving the impact of parameter number. The adjusted rho square of the underlying need model is 0.128, suggesting a moderately acceptable goodness-of-fit.

CONCLUSION

This model is expected to bring theoretical enhancements to current activity generation choice models by incorporating theoretically validated psychological needs. By inspecting the interrelationship between different leisure activities and underlying need satisfaction, this research also contributes to resolving the complexity in understanding the determinant of leisure activities. Moreover, by conducting an empirical analysis, implications drawn from the estimation result help to understand the unobserved psychological needs of different population segments and indicate the well-being in Japanese society from the perspective of leisure activity participation.

The model deals with individual out-of-home leisure activity choice on a certain day, but in cases where multiple leisure activities are to conduct on one single day, the current formulation still fail to incorporate the interactive impacts of planned activities or candidate activities on the decision-making process of other activities. Another limitation of the current model is in its estimation procedure. Although B_{nk} parameters, the need growth rates, which are defined as positive variables, β parameters, that constitute the linear function of B_{nk}, are unrestricted on their values. Since the estimation procedure only handles the estimates for unrestricted β parameters, there is no guarantee for positive need growth rates B_{nk} for the present.

For future research, an interesting direction is to incorporate the companion choice into the leisure activity generation. When analyzing underlying need satisfactions, in addition to the current concerns for leisure activity type, the framework can be extended to accommodate activity companions. Since leisure activities own a strong social context, sometimes the performance of a leisure activity is more about being with a particular person or group of people than the activity content.

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Table 1 Estimates of underlying need model

		Intellectual		Social		Competency-mastery		Stimulus-avoidance	
		estimate	t statistic	estimate	t statistic	estimate	t statistic	estimate	t statistic
β (need)	intercept	11.410**	4.217	3.792**	2.773	5.437**	4.233	27.471**	16.286
	age from 20 to 39	3.148	0.876	-6.920**	-3.535	4.647	1.084	1.638	0.528
	age from 40 to 59	7.355**	3.558	2.468	0.927	-5.731*	-2.569	0.614	0.235
	male	-1.952	-1.049	6.554*	2.326	8.072**	3.985	6.759*	2.465
	low education level	-0.058	-0.017	-9.974**	-3.322	1.143	0.319	9.535**	2.989
	high education level	3.170	1.582	0.996	0.463	-4.090*	-2.425	-2.763	-1.273
	non-single or non-couple household	10.092**	4.755	0.226	0.110	-7.963**	-4.365	-0.135	-0.055
	number of children under 6	-6.850**	-3.354	-6.445	-1.322	-8.351**	-2.676	2.585	0.994
	yearly income lower than 300	-1.755	-1.035	-4.602**	-2.921	-7.255**	-4.534	1.662	0.883
α (constraint)	intercept	24.201**	4.793						
	daily fixed time in hours	7.686**	3.178						
	number of children under 6	1.088	0.128						
	yearly income lower than 300	5.745	0.827						
	access to car	7.281	1.244						
	Num of obs.	745							
	LL0	-980.704		rho^2	0.17				
	LL	-813.7716		adj. rho^2	0.128				

Note: significant at **p<0.01, *p<0.05.