Time Allocation of Leisure activities of Workers on Holidays Considering Effect of Weekday Activities: Comparison of Urban and Rural Areas

The 17th summer course
Behavior modeling in transportation networks
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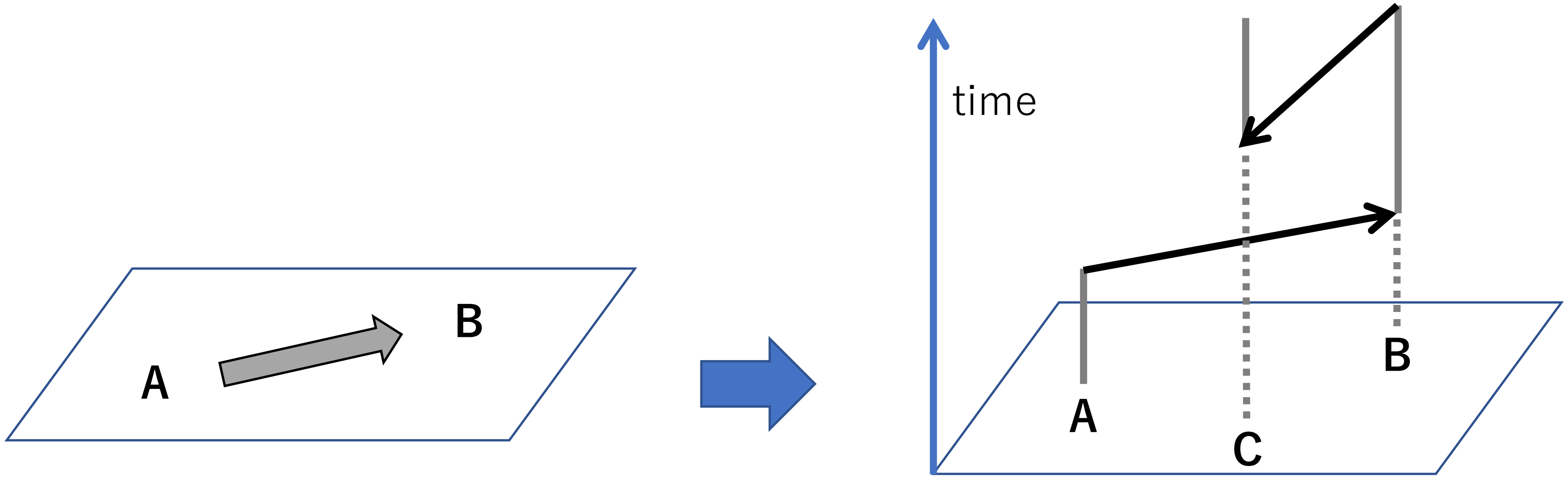
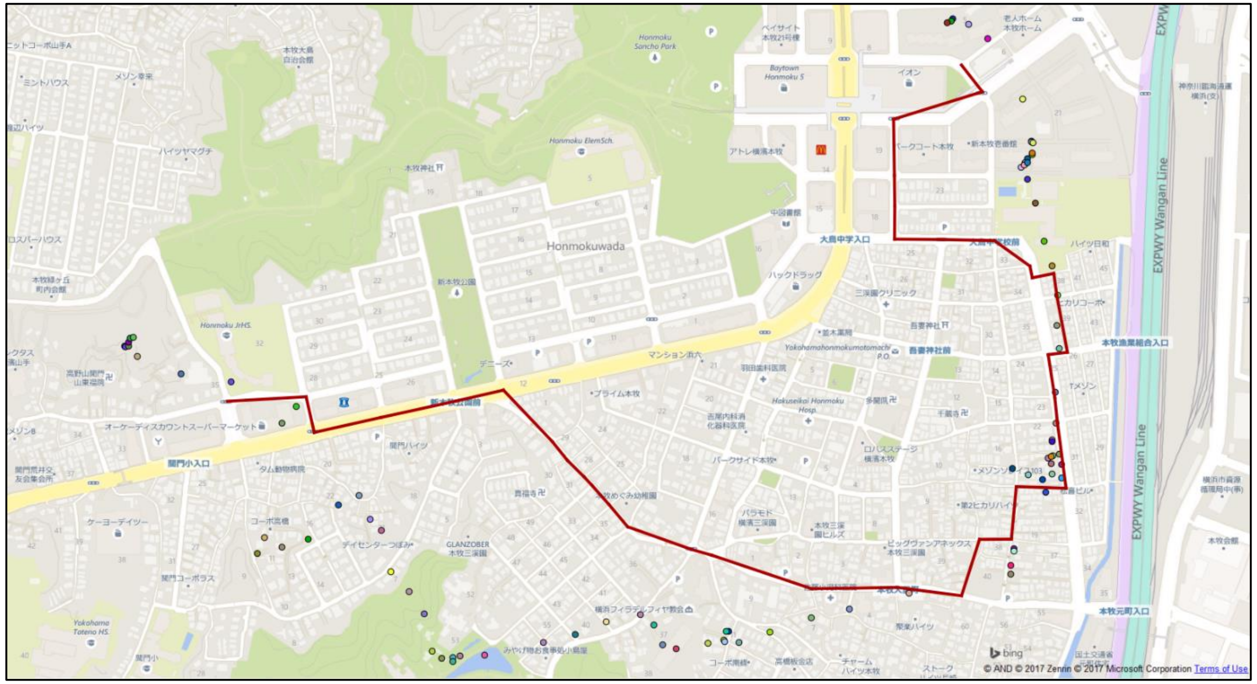
Activity-based Modelling & Activity Survey

- Travel demand is derived from activities
- Better understanding of behavior



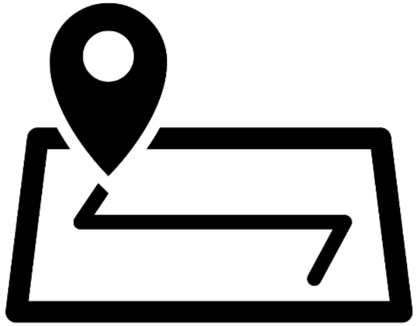
Trip-based four stage model **Activity-based travel demand model**

Probe Person(PP) survey



GPS satellites

GPS mobile phone



Real time location positioning data

＋

Web diary

- ✓ Disaggregate data
- ✓ Travel mode
- ✓ Origin and destination
- ✓ Departure and arrival time
- ✓ Trip purpose

Etc…

Advantages of PP data

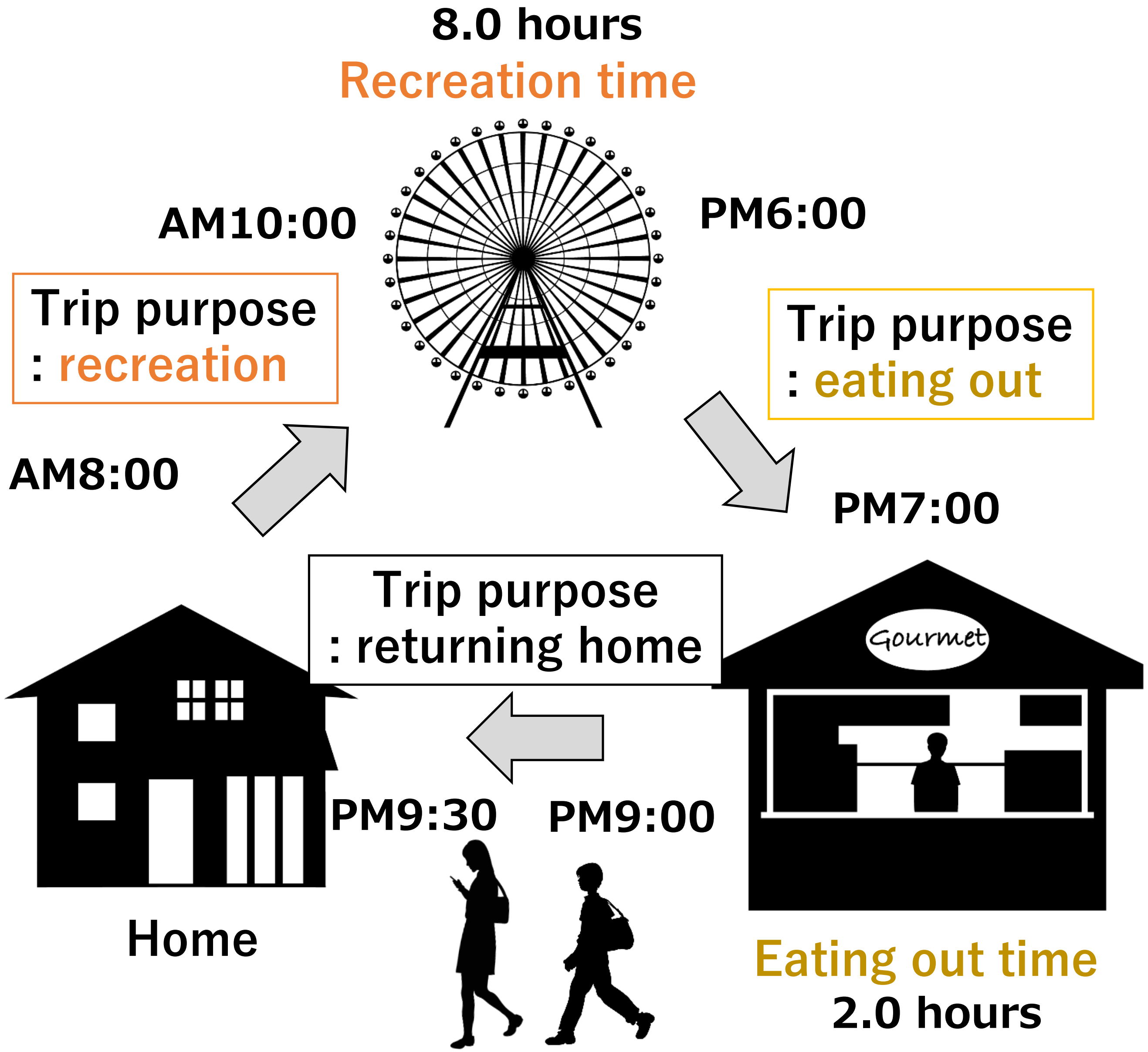
- Collecting time data more accurately
- Day-to-day data (Both weekday & holiday)
- Long term observation data(during about 1month)

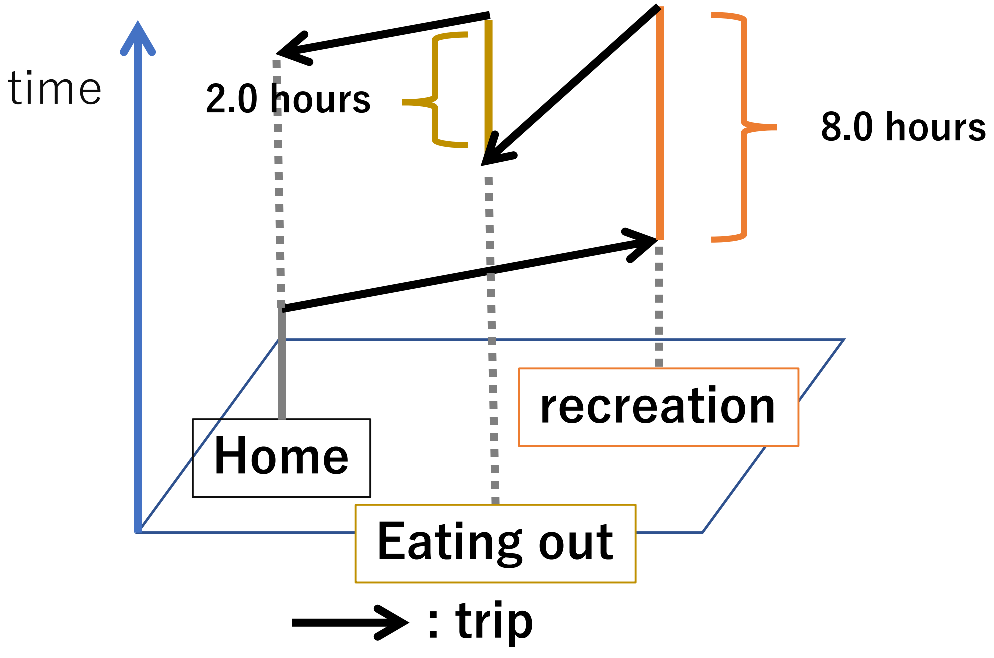
	Time accuracy	Enough sample size	Long term observation	Weekday & holiday data
PP survey (GPS based)	○	△	○	○
PT survey (paper based)	△	○	○	△
Activity diary survey (paper based)	△	△	△	○

○ : OK

△ : Not Enough

Focus on time-use behavior





The day's time-use behavior of the participant

- <u>Recreation 8.0 hours</u>
- <u>Eating out 2.0 hours</u>

Time-use analysis from some perspectives

- **Time-use patterns of inhabitants may vary across cities.**

(It could depend on regional characteristics and urban settings)

- **There can be relationships between weekday time-use and holiday time-use.**

Research Questions:

What's the difference between urban city and rural city in time-use behavior of workers ?

Is the leisure time of workers on holidays related to the time-use behavior on weekdays ?

Do the regional characteristics have an impact on the time-use behavior ?

Objectives

- To develop an activity-based model (MDCEV model) and clarify how much time-use on weekdays have an effect on that on holidays.

- To clarify how much regional characteristics have an impact on the time-use behavior on holidays through comparison of urban city & rural city.

Case study: Comparison of Urban & Rural Areas

Matsuyama

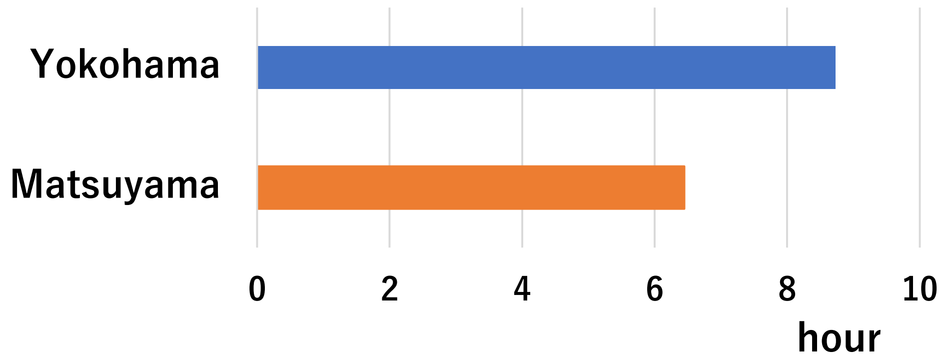
Yokohama

Land area : 429.40km2
Population : 512,780
Population density : 1190/km2

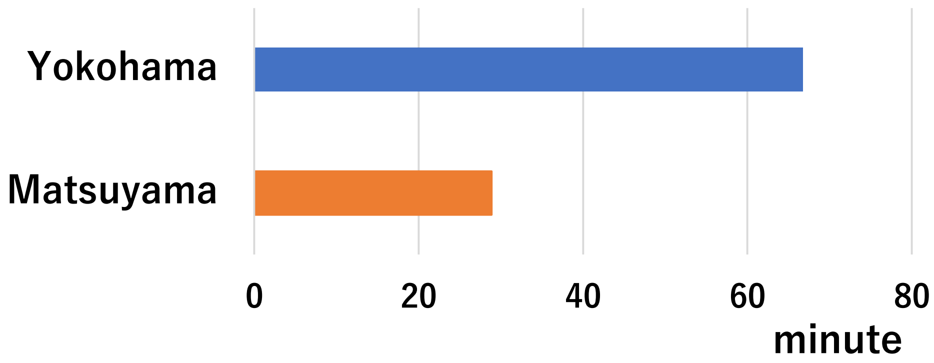
Land area : 437.56km2
Population : 3,733,807
Population density : 8,530/km2

Basic analysis on workers in the two cities from PP data

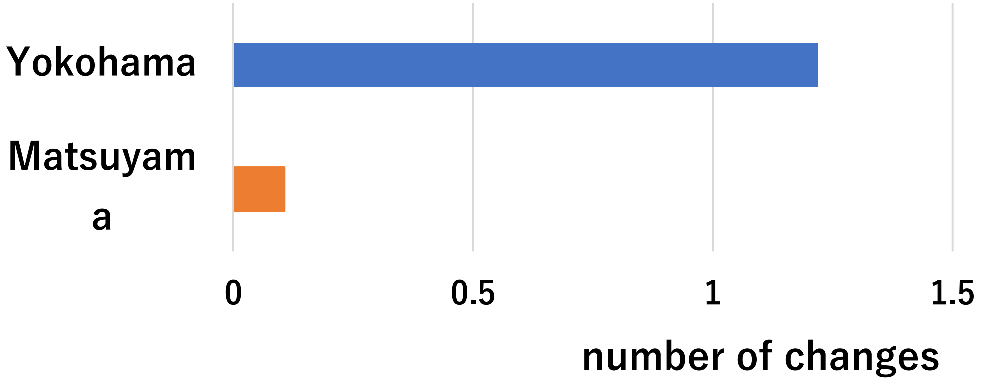
Average of working time



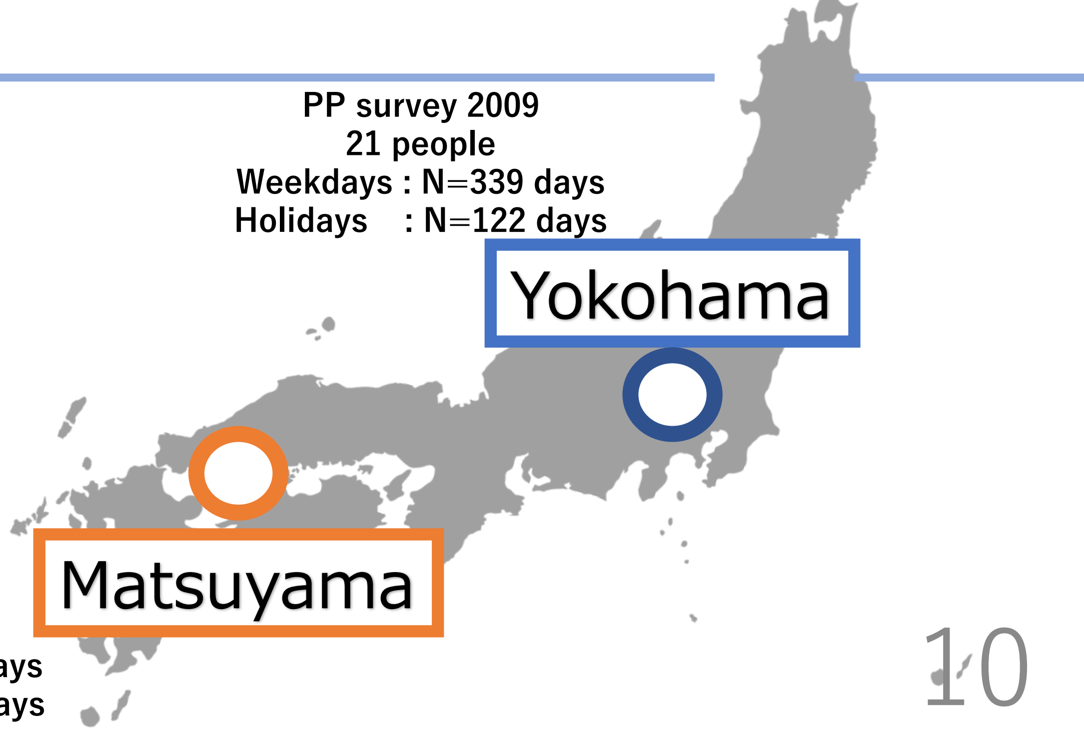
Average of commuting time



Number of transport mode changes to commute



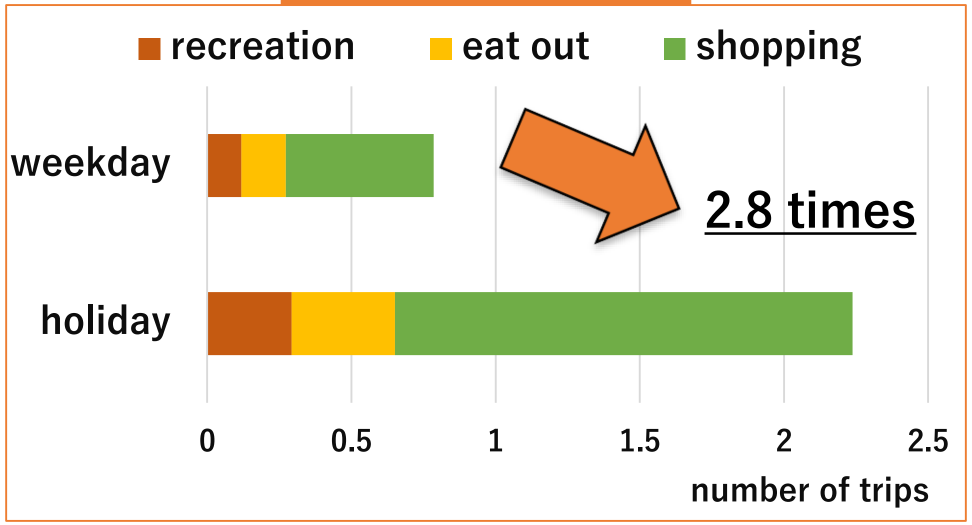
PP survey 2009
21 people
Weekdays : N=339 days
Holidays : N=122 days



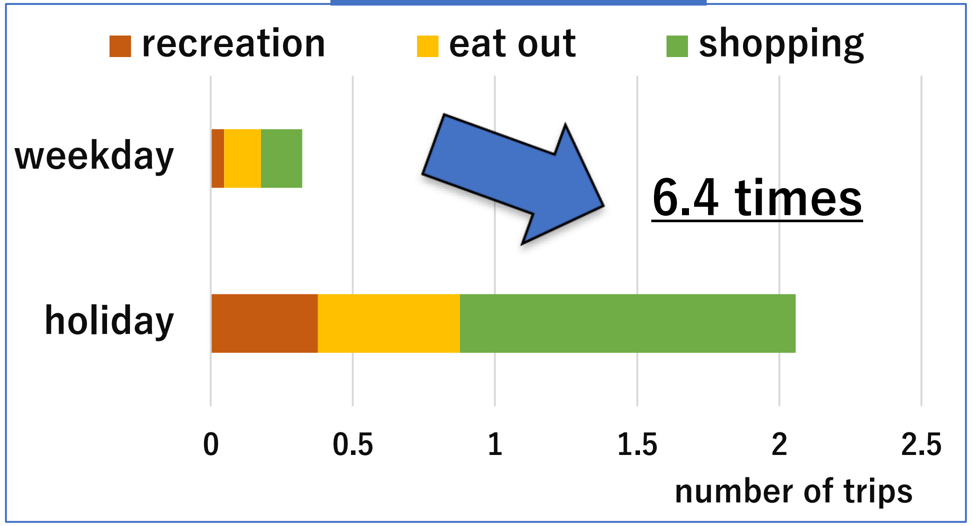
PP survey 2007
50 people
Weekdays : N=793 days
Holidays : N=298 days

Basic analysis based on average number of trips (Leisure activity)

Matsuyama



Yokohama



- The number of trips on holiday is 6.4 times as many as that on weekday in Yokohama.

(2.8 times in Matsuyama)

→ Do inhabitants in Yokohama tend to refrain from the leisure activities on weekdays ?

PP survey 2009
21 people
Weekdays : N=339 days
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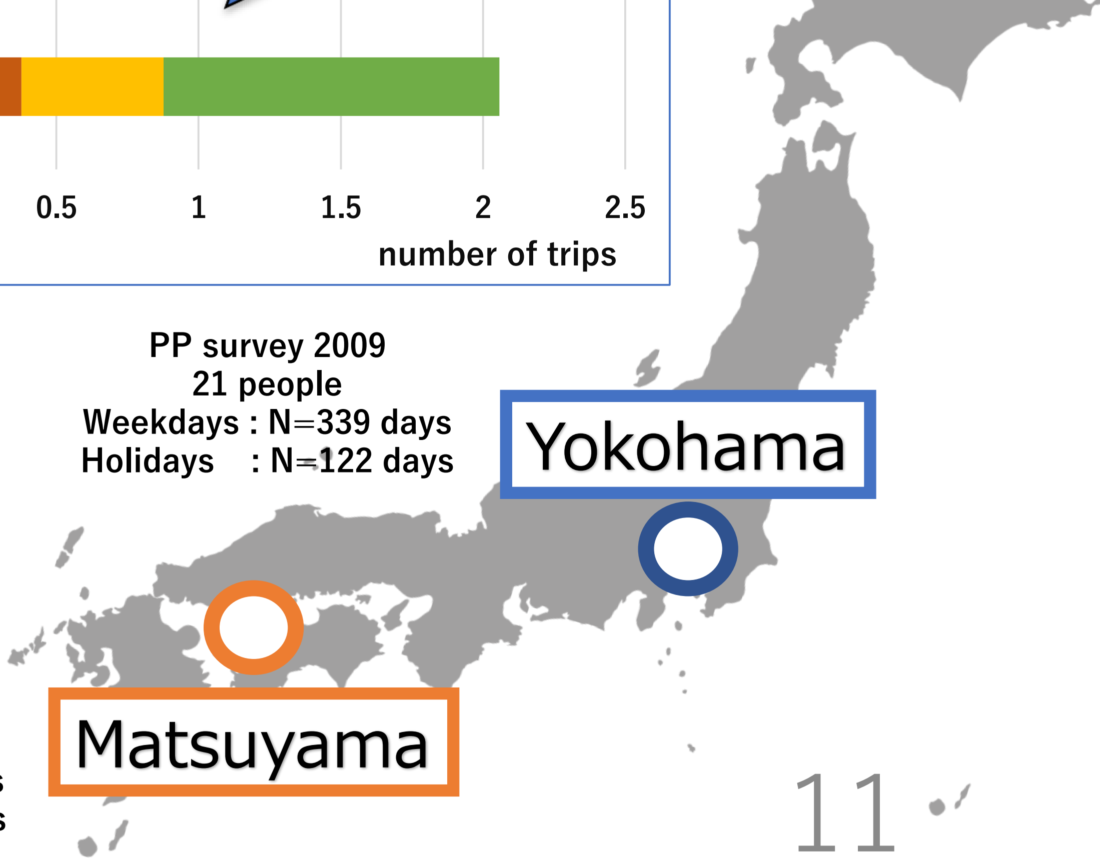

PP survey 2007
50 people
Weekdays : N=793 days
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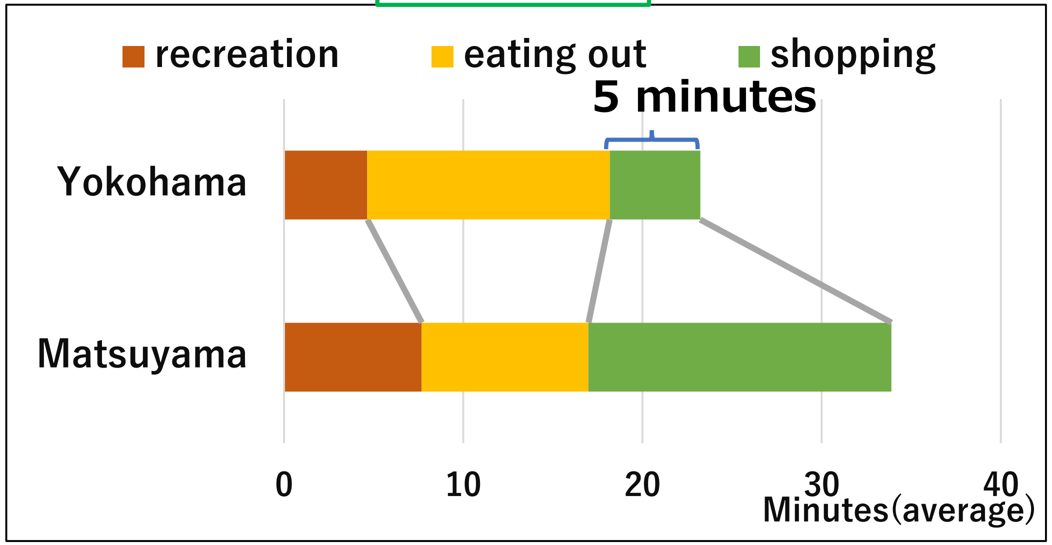
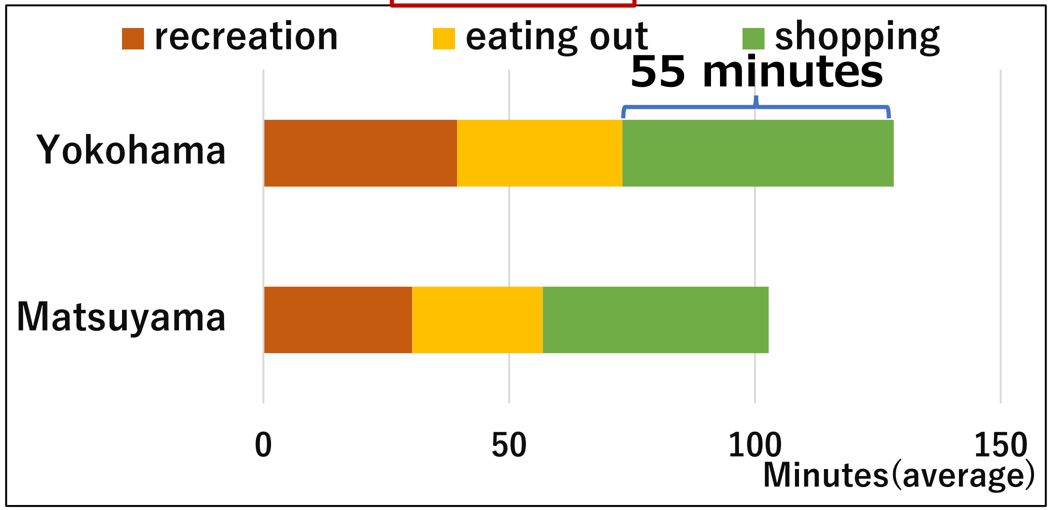
Basic analysis on time-use (Leisure activity)

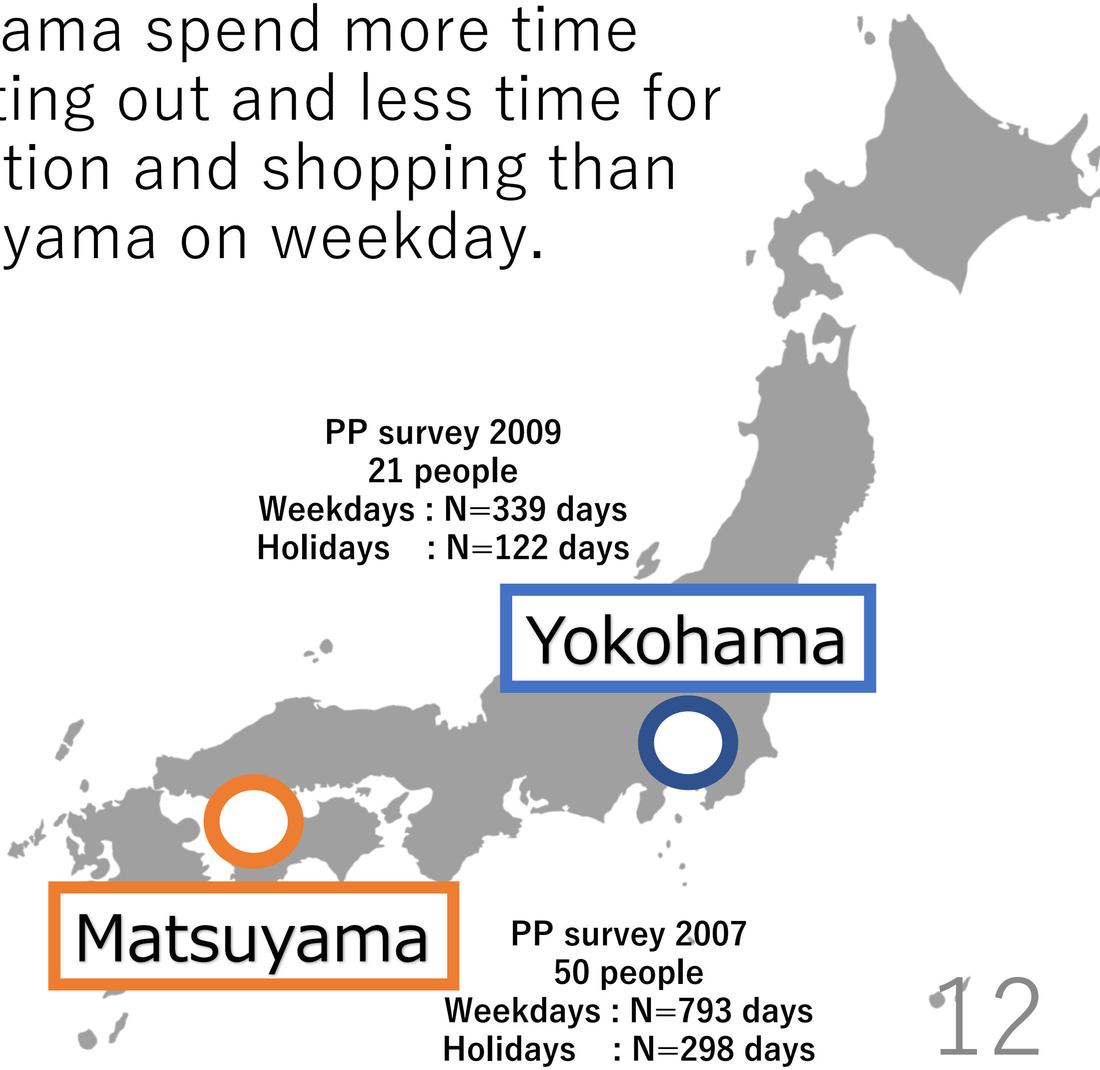
On weekday



On holiday



- Yokohama spend more time for eating out and less time for recreation and shopping than Matsuyama on weekday.



MDCEV (Multiple Discrete-Continuous Extreme Value) model

(Bhat 2005, 2008)

Random utility function

$$U(x) = \frac{1}{\alpha_1}\psi_1 x_1^{\alpha_1} + \sum_{k=2}^{K}\frac{\gamma_k}{\alpha_k}\psi_k\left\{\left(\frac{x_k}{\gamma_k}+1\right)^{\alpha_k} - 1\right\}$$

where $\psi_1 = \exp(\varepsilon_1)$, and $\psi_k = \exp(\beta' z_k + \varepsilon_k)$

$\alpha_k \rightarrow 0$ $\gamma_k \rightarrow 1$

$$U(x) = \psi_1 \ln x_1 + \sum_{k=2}^{K}\psi_k \ln(x_k+1)$$

$$V_k = \beta' z_k - \ln(x_k^* + 1)$$

$$V_1 = -\ln(t_1^*)$$

$(k \geq 2)$

Ψ_k : baseline utility

α_k : satiation parameter

γ_k : translation parameter

ε_k : error term

β' : parameter

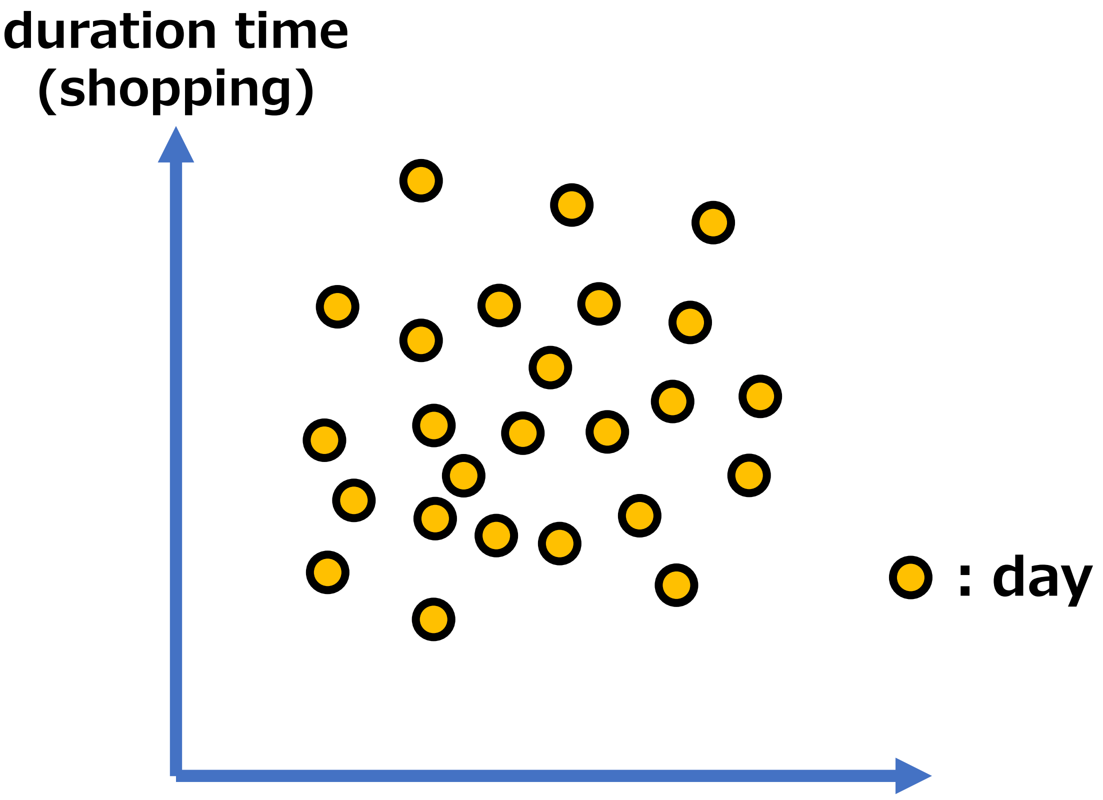
z_k : explanatory variables

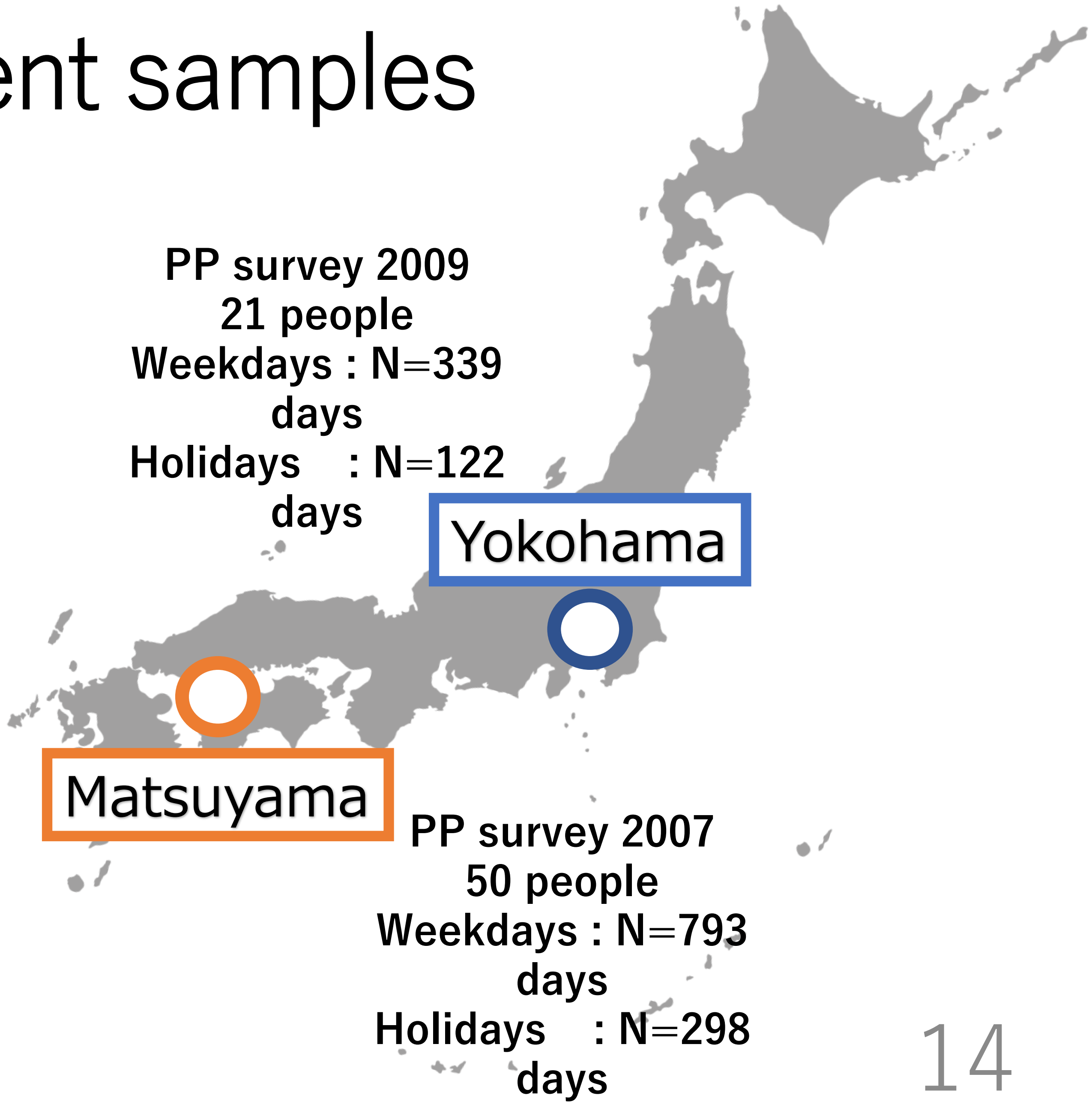
x_k : consumption of good k

$$\mathrm{P}(t_1^*, t_2^*, \dots, t_M^*, 0, \dots, 0) = \left[\prod_{i=1}^{M} f_i\right]\left[\sum_{i=1}^{M}\frac{1}{f_i}\right]\left[\frac{\prod_{i=1}^{M} e^{V_i}}{(\sum_{k=1}^{4} e^{V_k})^M}\right](M-1)! \quad \text{where } f_i = \left(\frac{1}{t_i^*+1}\right)$$

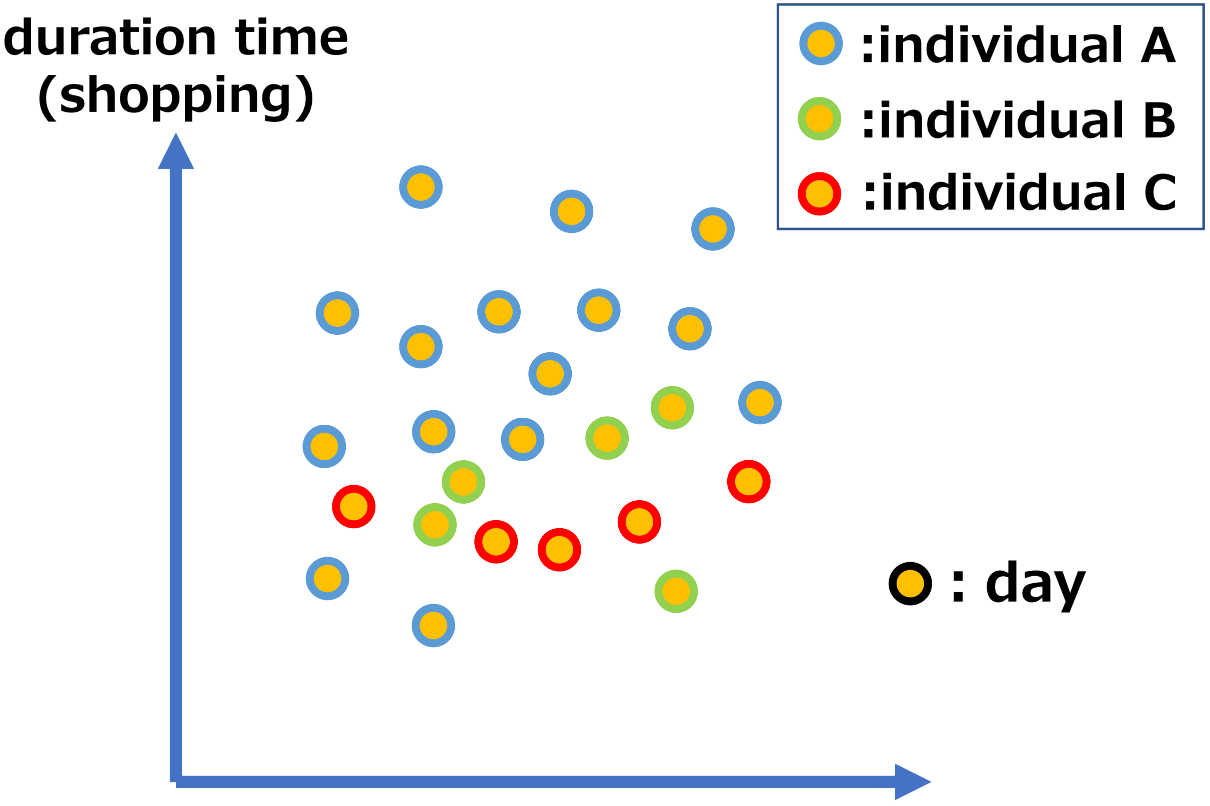
- **MDCEV is one of the discrete-continuous choice models**
- **MDCEV is only model to analyze multiple activity choice & duration choice behavior simultaneously**

Example of independent samples

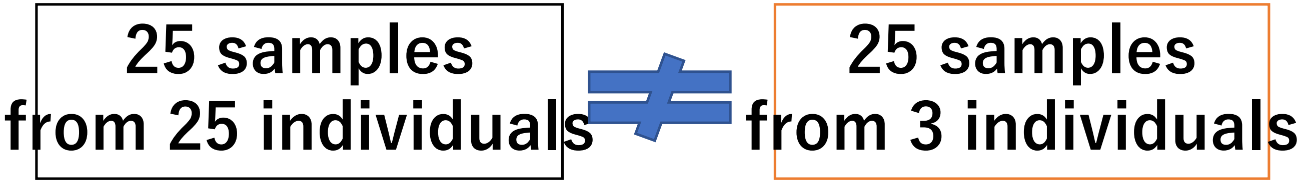




Example of dependent samples



The number of sample from individual A is large



- **<u>Applying panel-model is needed for unbiased estimation</u>**

Panel-MDCEV model (Mixed MDCEV model)

(Bhat 2008)

$$\eta_{ij} \sim N(0, \sigma^2_{\eta_j})$$

$$\psi_{idj} = \exp(\beta' z_{idj} + \eta_{ij} + \varepsilon_{idj})$$

Normal distribution

Gumbel distribution

$$L(\beta, \sigma_\eta | t^*_{id}, z_{id}) = \int_{\eta_i} \left\{ \prod_{N_{id}} P(t^*_{id} | \beta, \eta_i) \times f(\eta_i | \sigma_\eta) \right\} d\eta_i$$

$$\pi(\beta, \sigma_\eta | t^*_{id}, z_{id}) \propto \prod_{N_{id}} P(t^*_{id} | \beta, \eta_i) f(\eta_i | \sigma_\eta) \varphi(\sigma_\eta) \varphi(\beta)$$

$$P(t^*_{id1}, t^*_{id2}, \dots, 0, 0 | \eta) =$$

$$\frac{1}{\sigma^{K_{id}-1}} \left[\prod_{k=1}^{K_{id}} f_{idk} \right] \left[\sum_{k=1}^{K_{id}} \frac{1}{f_{idk}} \right] \left[\frac{\prod_{k=1}^{K_{id}} e^{(V_{idk} + \eta_{ik})/\sigma}}{\left(\sum_{j=1}^{J_{id}} e^{(V_{idj} + \eta_{ij})/\sigma} \right)^{K_{id}}} \right] (K_{id} - 1)!$$

$$V_{idj} = \sum_q^Q \beta_{jq} z_{idjq} - \ln(t^*_{idk} + 1), \quad \text{where } f_{idk} = \frac{1}{t^*_{idk} + 1}$$

- We use a Bayesian procedure based on Markov Chain Monte Carlo (MCMC) method to estimate the parameter β and σ_η.

Using the explanatory variables as follows:

- Age
- Dummy variable (Male=1, female=0)
- Average work time
- Average commuting time
- Average number of trips on weekday
- Average recreation time on weekday
- Average eating out time on weekday
- Average shopping time on weekday

Individual attributes

Work-related characteristics (regional characteristics)

Time-use for the activities on weekday

Estimate the model and clarify these effects which affect time-use behavior for recreation, eating out and shopping on holiday.

MDCEV model (last year)

Yokohama

variable	parameter	t-value
recreation (holidays)		
constant	−9.22	−9.92 ***
average number of trips (weekdays)	0.24	0.79
recreation time (weekdays)	−4.21	−2.75 ***
eating out time (weekdays)	−6.44	−1.91 *
shopping time (weekdays)	4.05	3.41 ***
satiation parameter	80.80	2.22 **
eating out (holidays)		
constant	−9.89	−8.03 ***
average commuting time	−0.72	−1.73 *
age	0.07	2.20 **
eating out time (weekdays)	2.53	1.18
satiation parameter	36.56	2.92 ***
shopping (holidays)		
constant	−8.56	−10.81 ***
average working time	0.21	2.44 **
female dummy	2.25	2.59 ***
eating out time (weekdays)	8.45	3.87 ***
shopping time (weekdays)	−2.53	−3.49 ***
satiation parameter	18.46	3.80 ***
sample size		122
initial likelihood		−1178.50
final likelihood		−1151.75
rho square		0.023

Matsuyama

variable	parameter	t-value
recreation (holidays)		
constant	−5.99	−7.69 ***
average number of trips (weekdays)	−0.31	−3.65 ***
age	−0.03	−1.36
female dummy	−0.87	−2.60 ***
recreation time (weekdays)	1.15	1.89 *
satiation parameter	105.64	3.09 ***
eating out (holidays)		
constant	−7.07	−11.56 ***
average commuting time	0.55	2.49 **
transport mode changes to commute	0.50	1.15
age	−0.04	−2.53 **
recreation time (weekdays)	−1.20	−1.85 *
eating out time (weekdays)	0.40	0.65
satiation parameter	50.43	3.78 ***
shopping (holidays)		
constant	−8.69	−13.58 ***
average working time	0.04	1.14
age	0.04	2.95 ***
female dummy	0.57	2.67 ***
shopping time (weekdays)	0.79	2.27 **
satiation parameter	10.84	6.25 ***
sample size		298
initial likelihood		−2576.08
final likelihood		−2536.20
rho square		0.015

Panel-MDCEV model

Yokohama

variable	parameter	t-value	
recreation (holidays)			
constant	-15.36	-3.36	***
average number of trips (weekdays)	1.02	0.65	
recreation time (weekdays)	-13.38	-1.61	
eating out time (weekdays)	-22.21	-1.64	
shopping time (weekdays)	13.58	2.26	**
eating out (holidays)			
constant	-15.78	-3.24	***
average commuting time	-2.91	-1.88	*
age	0.24	2.11	**
eating out time (weekdays)	8.02	1.78	*
shopping (holidays)			
constant	-4.43	-1.42	
average working time	0.39	2.01	**
male dummy	-4.12	-1.60	
eating out time (weekdays)	15.54	2.91	***
shopping time (weekdays)	-4.53	-2.15	**
sample size		122	
DIC		1490.78	

Matsuyama

variable	parameter	t-value	
recreation (holidays)			
constant	-6.54	-2.08	**
average number of trips (weekdays)	-0.81	-1.99	**
age	-0.14	-1.70	*
male dummy	2.82	1.84	*
recreation time (weekdays)	4.39	1.43	
eating out (holidays)			
constant	-6.65	-2.89	***
average commuting time	1.51	1.31	
transport mode changes to commute	1.78	0.96	
age	-0.13	-2.06	**
recreation time (weekdays)	-3.53	-1.33	
eating out time (weekdays)	1.40	0.49	
shopping (holidays)			
constant	-8.06	-7.02	***
average working time	0.10	1.40	
age	0.07	3.25	***
male dummy	-1.10	-2.51	**
shopping time (weekdays)	1.33	1.61	
sample size		298	
DIC		3322.67	

Panel-MDCEV model

Yokohama

variable	paramete	t-value	
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constant	-15.36	-3.36	***
average number of trips (weekdays)	1.02	0.65	
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tr[illegible]	[illegible]	[illegible]	
a[illegible]	[illegible]	[illegible]	
re[illegible]	[illegible]	[illegible]	
e[illegible]	[illegible]	[illegible]	
s[illegible]			
constant	-8.06	-7.02	***
average working time	0.10	1.40	
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Weekday time-use variables significantly influence holiday time-use behavior in Yokohama

Panel-MDCEV model

Yokohama

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constant	-15.36	-3.36	***
average number of trips (weekdays)	1.02	0.65	
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No weekday time-use variable significantly influence in Matsuyama

Matsuyama

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average number of trips (weekdays)	-0.81	-1.99	**
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Individual attribute variables significantly influence in Matsuyama

Matsuyama

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Panel-MDCEV model

Yokohama

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Only one individual attribute variable significantly influence in Yokohama

Conclusion

- The number of statistically significant variables is decrease after applying panel-MDCEV model

- Weekday time-use variables significantly influence holiday time-use behavior in Yokohama, but not in Matsuyama.

(average working time and shopping time on weekdays for shopping on holiday)

- The dominant factors affecting activity time-use behavior on holiday are different in the two cities.

➢Weekday time-use variables (in Yokohama)

➢Individual attributes such as age and gender (in Matsuyama)

Future Work

- More sample size and applications to other regions
- To estimate both time allocations jointly (weekdays and holidays)

Astroza, S., Bhat, P. C., Bhat, C. R., Pendyala, R. M., & Garikapati, V. M. (2018).

Understanding activity engagement across weekdays and weekend days: A multivariate multiple discrete-continuous modeling approach. Journal of Choice Modelling, 28, 56-70.

Thank you for your listening !

References

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Estimated results (summary)

:Similar tendency :Opposite tendency

Urban city (Yokohama)

Recreation

- Participants with long-time recreation in weekday spend **more** time on recreation in holiday.

Eating out

- Participants with long-time eating out in weekday spend **more** time on eating out in holiday.

Shopping

- The elderly tend to spend **less** time on shopping in holiday.
- Participants with long-time work in weekday spend **more** time on shopping in holiday.

Rural city (Matsuyama)

Recreation

- Participants with long-time recreation in weekday spend **more** time on recreation in holiday.
- Participants with many trips in weekday spend **less** time on recreation in holiday.

Eating out

- The elderly tend to spend **less** time on eating out in holiday.

Shopping

- The elderly tend to spend **more** time on shopping.
- Participants with long-time shopping in weekday spend **more** time on shopping in holiday.

Yokohama

	recreation	eating out	shopping
individual variation(s.d.)	1.91 (1.99)	1.81 (1.07)	1.233 (0.60)

Matsuyama

	recreation	eating out	shopping
individual variation(s.d.)	1.95 (1.32)	2.16 (1.02)	0.94 (0.27)