

September 1, 2025  
The 16th EASTS Keynote  
@Surakarta, Indonesia

# **Beyond Trips and Flows**

## **Toward Human-Centric Transport Systems**

Hiroshima University  
Makoto Chiakraishi

# Co-evolution of transport systems and society

新たな社会  
"Society 5.0"

5.0



1.0  
Society 1.0 狩猟



2.0  
Society 2.0 農耕



3.0  
Society 3.0 工業



4.0  
Society 4.0 情報



Source: Cabinet Office, Japan

Animal-powered movement

Invention of the wheel  
(c. 3500 BCE, Sumerians)

Use of livestock  
(wheel + draft animals)

Birth of long-distance trade

Progress in navigation (1400s)

Global trade

Steam automobile (1801)

Steam locomotive (1804)

Industrial revolution

Spread of gasoline automobiles  
(early 1900s)

Drastically change lifestyle

A human-centric society  
harmonizing growth and  
well-being

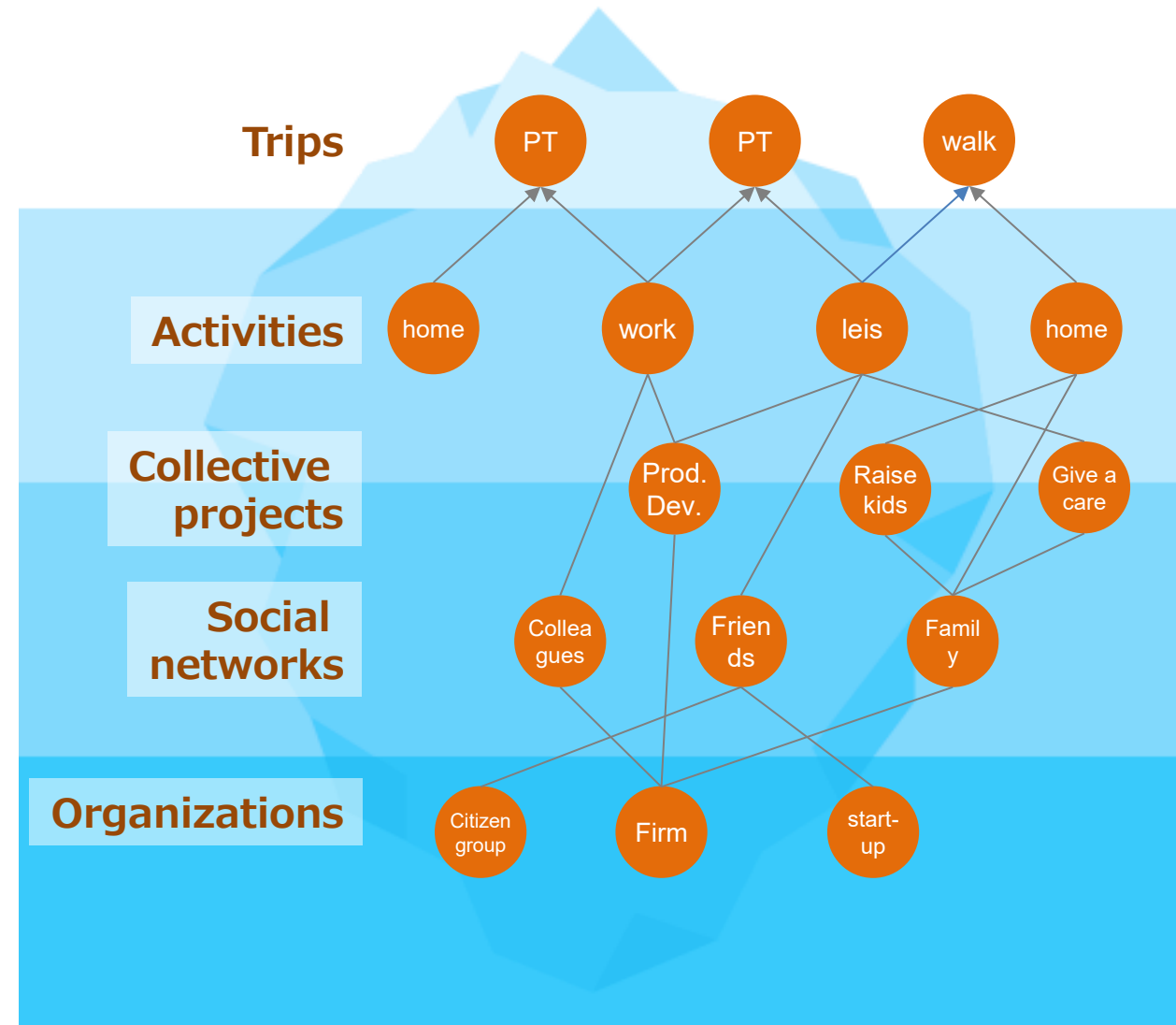
Transport systems  
contributing to resolving  
social issues

Automobile CASE

Connected  
Autonomous  
Servicized  
Electric

# Social consequences of mobility

Mobility is like an iceberg:  
beyond trips, it generates the  
**hidden layers of social life.**



# Jacobs externalities

Diversity in cities, enabled by streets and mobility, fosters encounters, social ties, and innovation.

Jacobs externalities in our research:

1. **Social networks & activities** co-evolve
2. **Co-location** reveals social interactions
3. Streets foster **encounters & staying**



Source: Wikipedia

# A co-evolutionary simulation of social network and activity engagement

Collaborators:



Noboru Harata



Swarnali Dihingia



Kiyoshi Takami

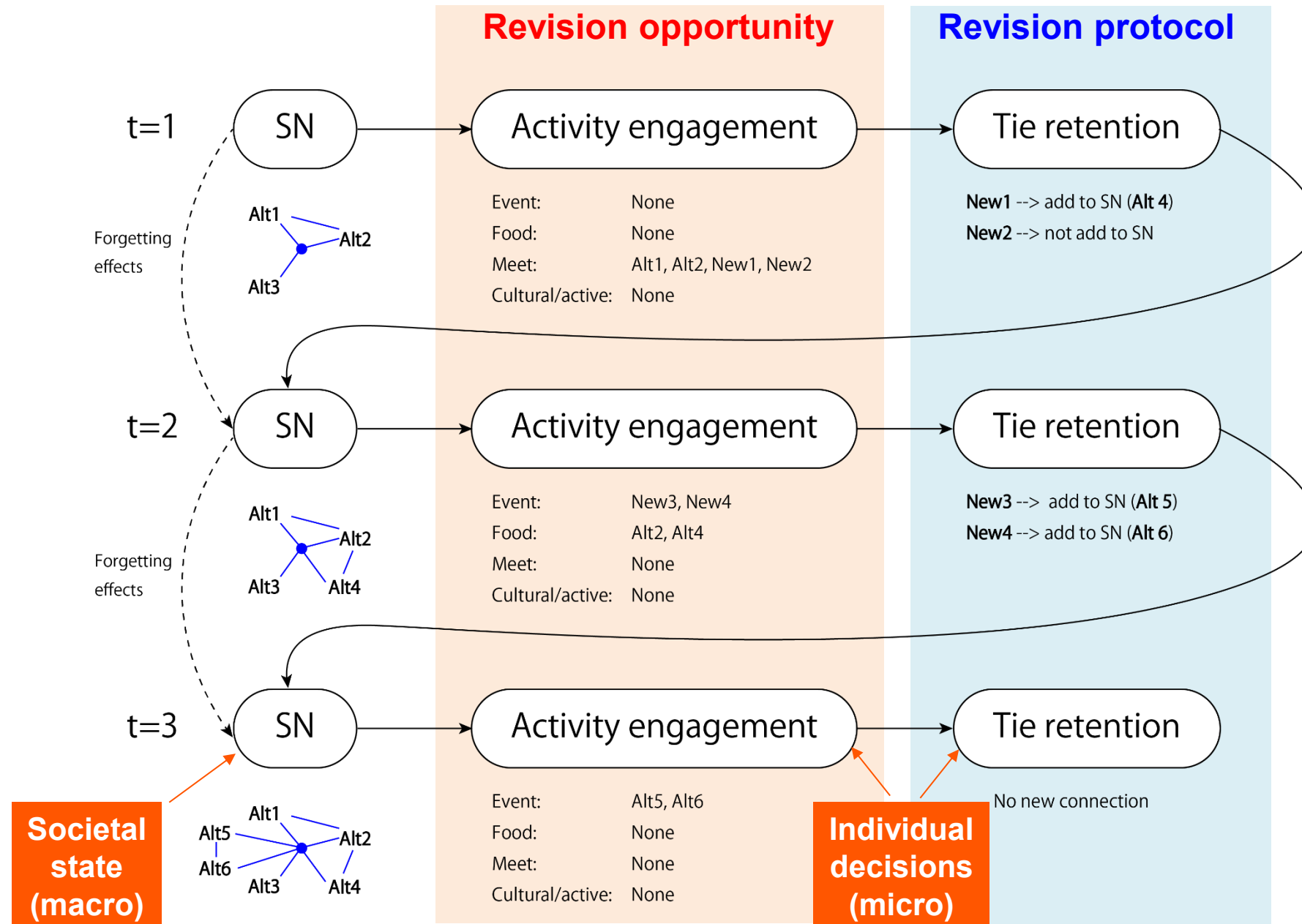


Giancarlos Parady

**Reference:**

Chikaraishi, M., Harata, N., Dihingia, S., Takami, K., Parady G. (2025)  
A co-evolutionary simulation of social network and activity engagement. Transportation (Accepted).

# Proposed framework



# Empirical analysis: Data collection

**Respondents:** international students who just enrolled at the University of Tokyo on April, 2019 (the number of valid respondents: 16).

## 1. Individual attributes:

- age, gender, nationality, campus, Japanese language ability, etc.

## 2. List of friends (before survey):

- Use name generator.

## 3. Three-week joint activity diary:

- reporting joint activity participations during three weeks, with whom (if he/she is not in the social network, asking age, gender, nationality, and religion), activity type, and location.

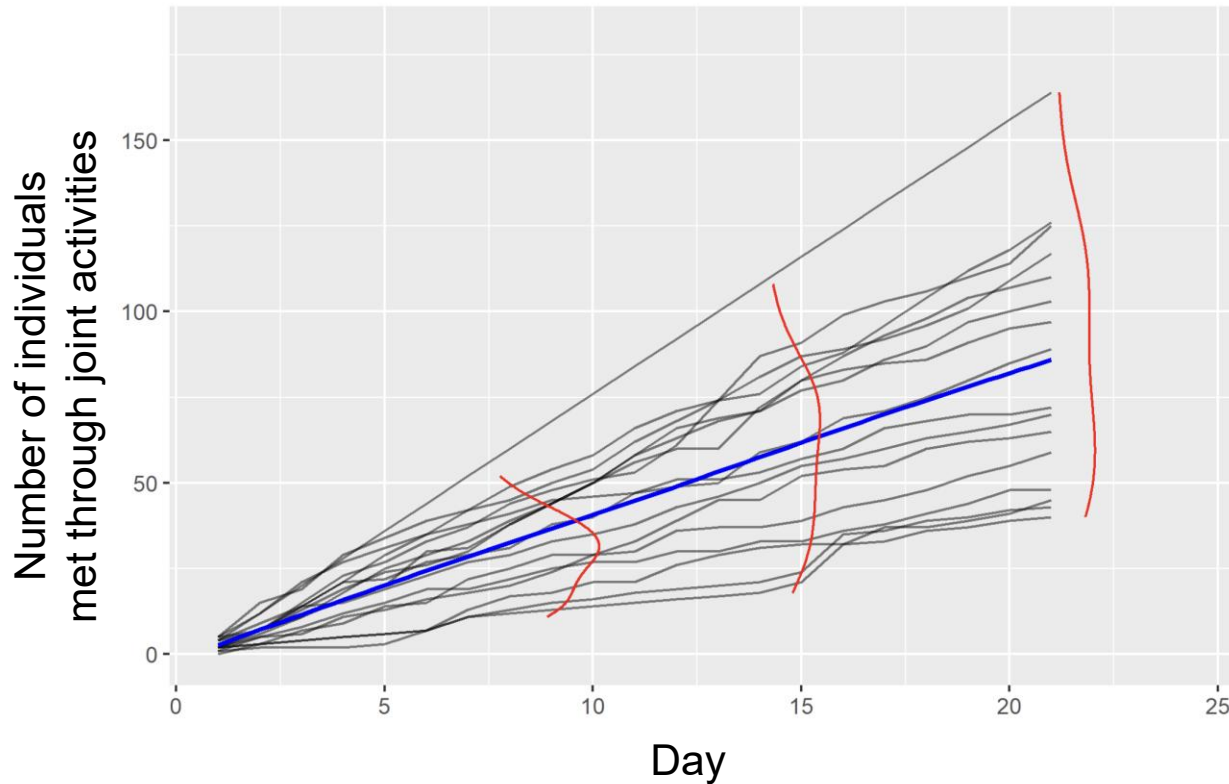
## 4. Club activities

## 5. List of friends (after survey) :

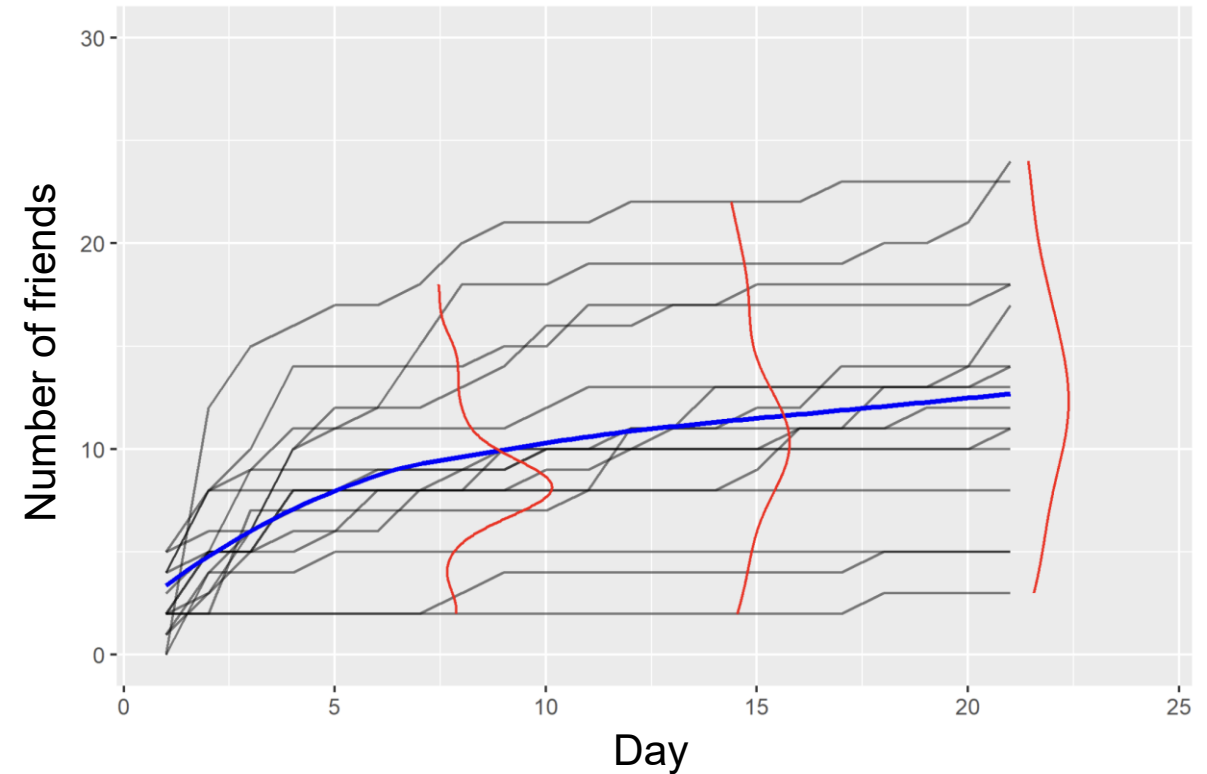
- Use name generator.

# From encounters to connections

## Changes in number of persons met through joint activities

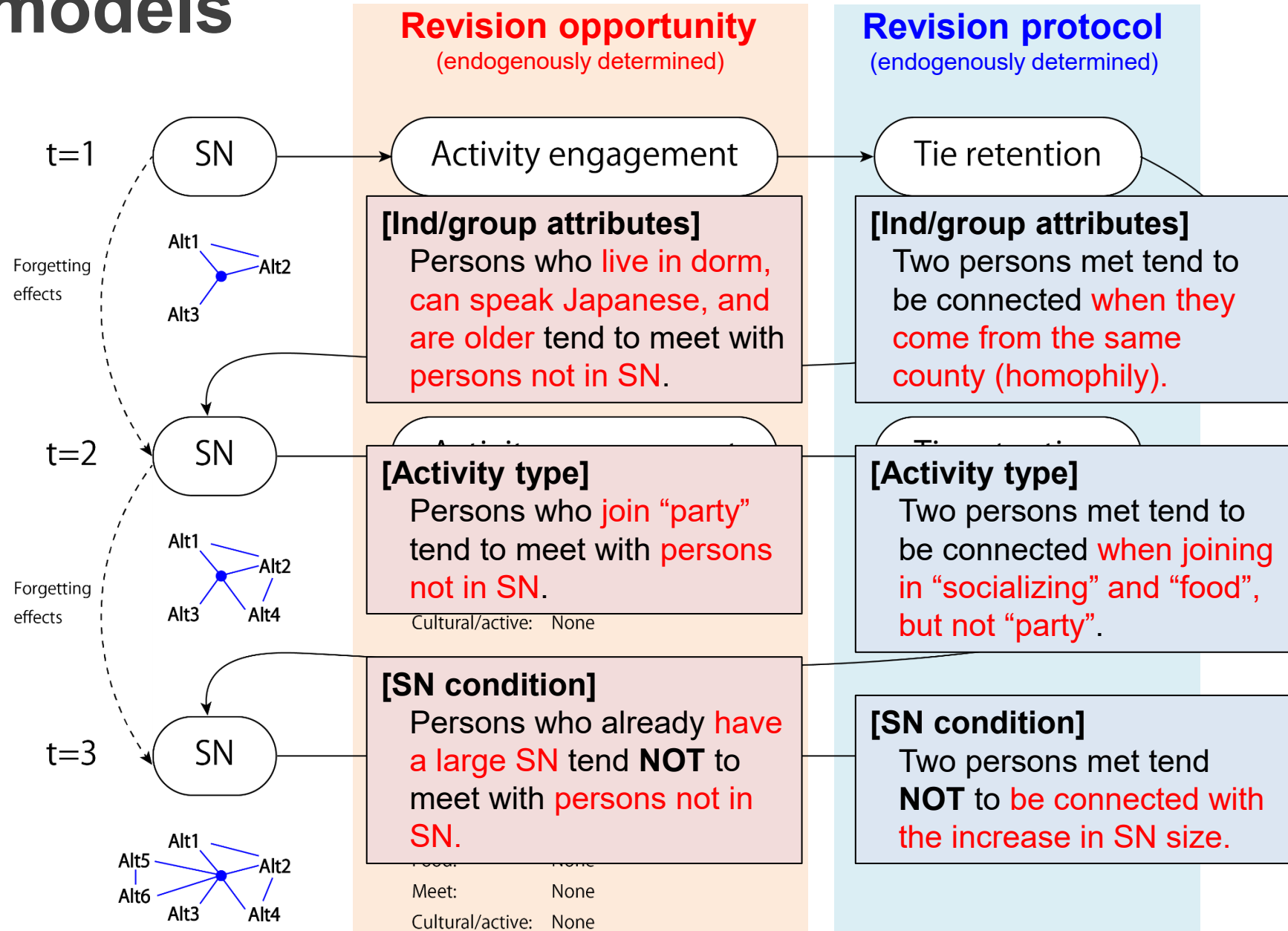


## Changes in number of friends

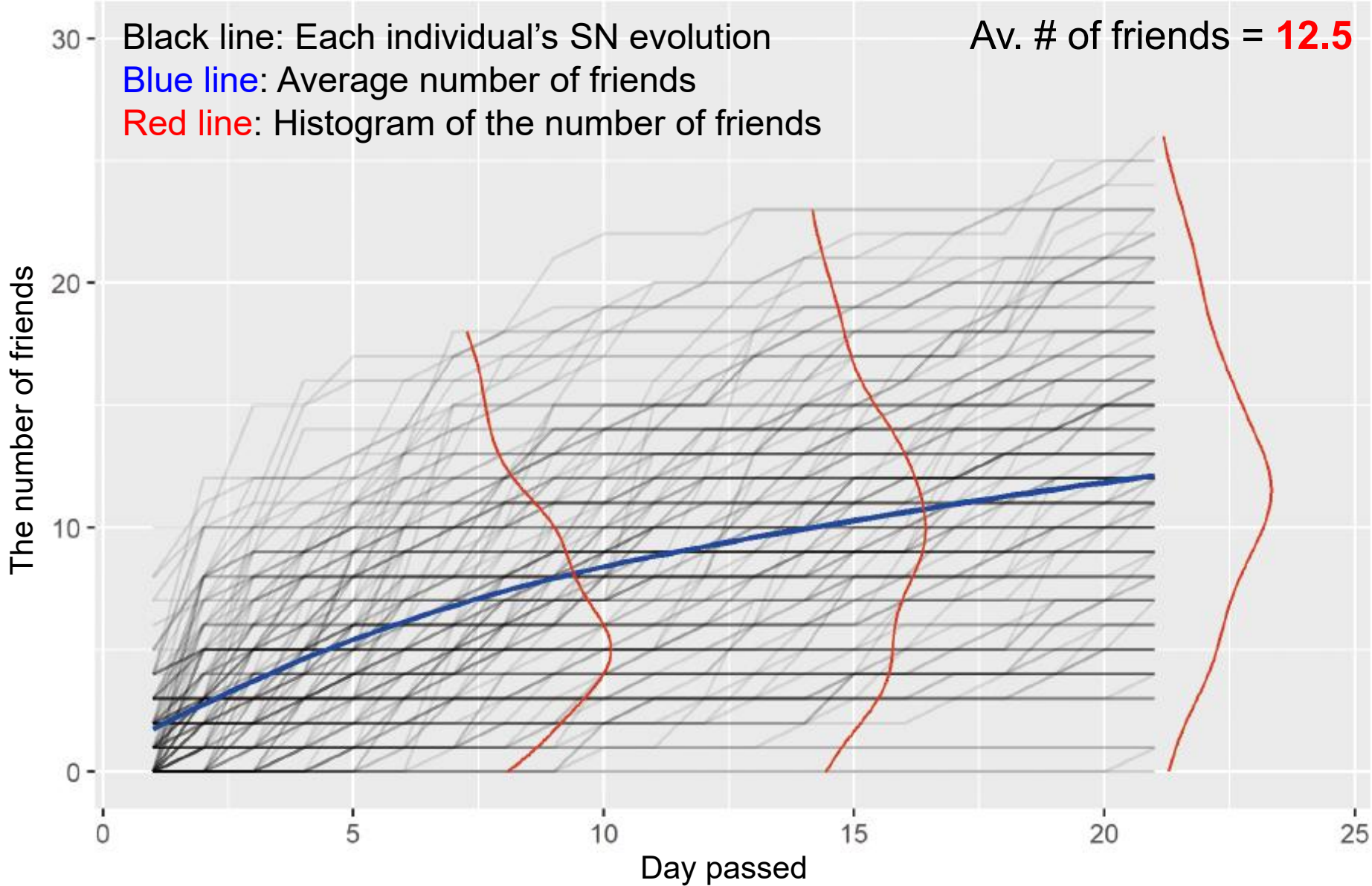


Number of persons met are linearly increasing, while number of persons get connected decreases as time passes.

# Findings from activity engagement and tie retention models



# Simulation results (baseline)



# Scenario analysis

## 0. Baseline (no intervention)

- Average # of friends at  $t = 21$  : **12.5** persons

## 1. Provide dorm to all students

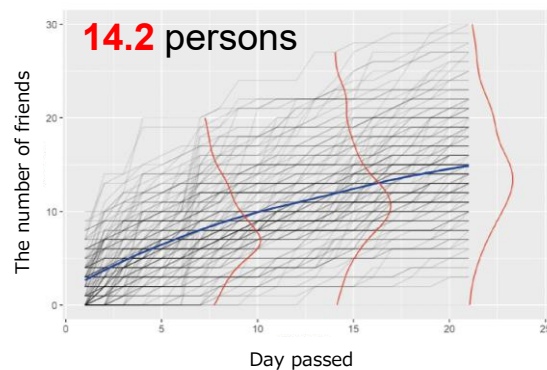
- Average # of friends at  $t = 21$  : **14.2** persons

## 2. Provide Japanese language education to all students

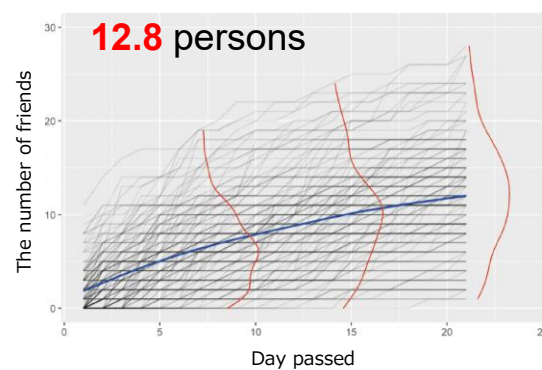
- Average # of friends at  $t = 21$  : **12.8** persons

## 3. Restrictions on party, food, and other activities

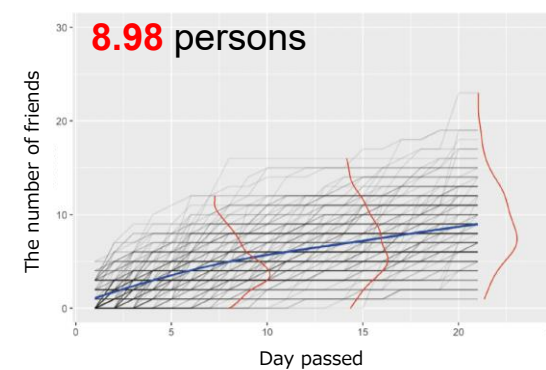
- Average # of friends at  $t = 21$  : **8.98** persons



**Scenario 1**



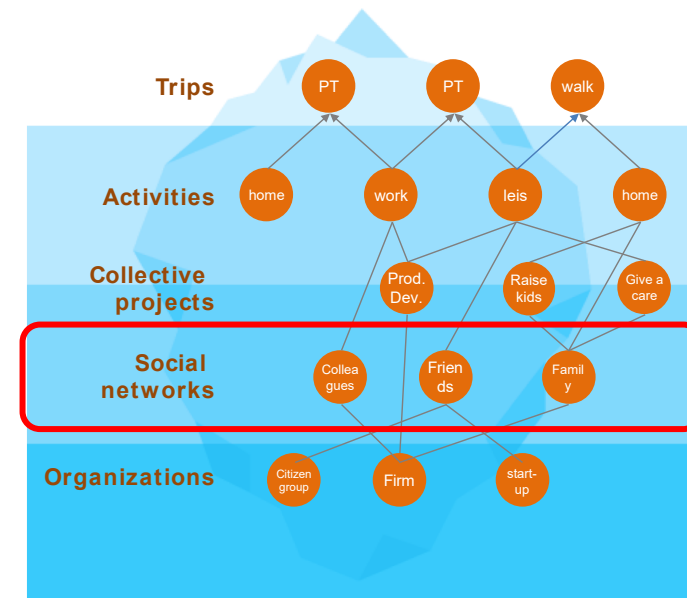
**Scenario 2**



**Scenario 3**

# Take away

- A-co-evolutionary simulation of social network and activity engagement:
  - **Activity-travel decisions**: Revision opportunity
  - **Tie retention decisions**: Revision protocol
- Possible extensions:
  - Embed “group decision-making” models for joint activities (Hafi).
  - Embed full activity-based models (Reem, Azwan).



Hafiyyan Hilmy Fawwaz



Azwan Nazamuddin



Reem Al Olabi

# Indonesian context: Informal ridesharing

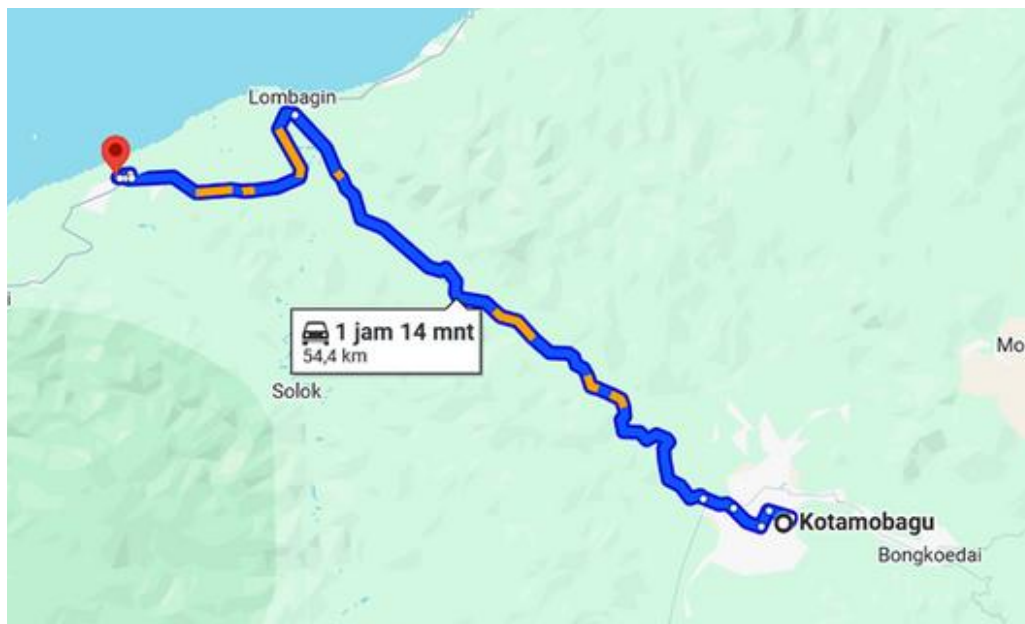
Informal ridesharing in Bolaang Mongondow, North Sulawesi

- Informal ridesharing serves not only as a mode of travel, but also as a means of fostering social networks.



Sitty Rukmini Mokobombang

Ridesharing route:



Beyond ridesharing, how can we capture everyday encounters and weak ties at scale?

# Mobility, daily encounters & social networks: A co-location analysis

Collaborators:



Azis Hakim Sjafruddin



Daisuke Kajiyama



Shouki Ichinose



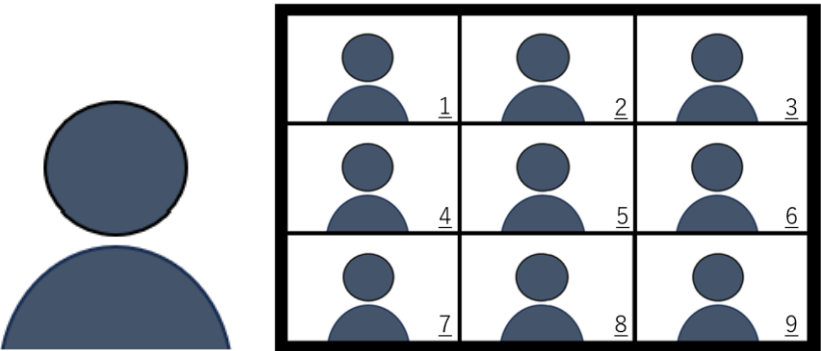
Karin Watanabe

## References:

- Kajiyama, D., & Chikaraishi, M. (2025). A Networked Social Ties and Co-Location (NEST-CL) Survey: A Novel Method for Capturing Complex Social Networks. Presented at the 16th EASTS.
- Other related drafts, in preparation for journal submission.

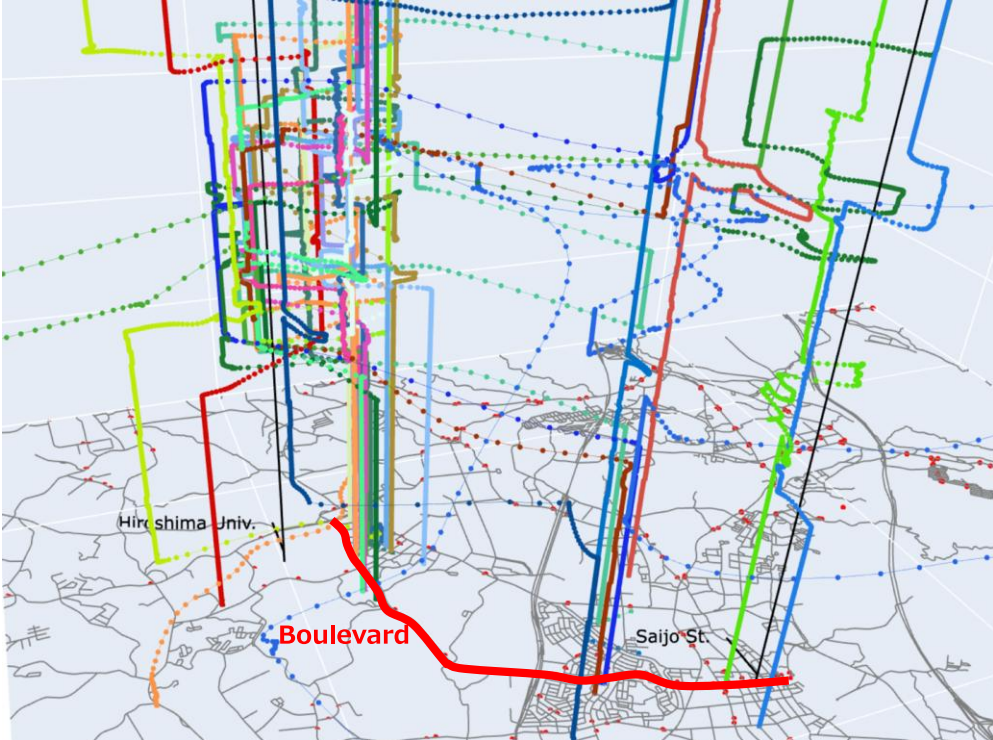
# Survey design: social ties (online) + co-location (GPS)

To capture **weak ties** and **SN structure**, we utilized an **online meeting tool**.



Stranger → Weak → Slightly Weak → Slightly Stronger → Strong

To observe **richer daily encounters**, we employed a **GPS-based survey**.



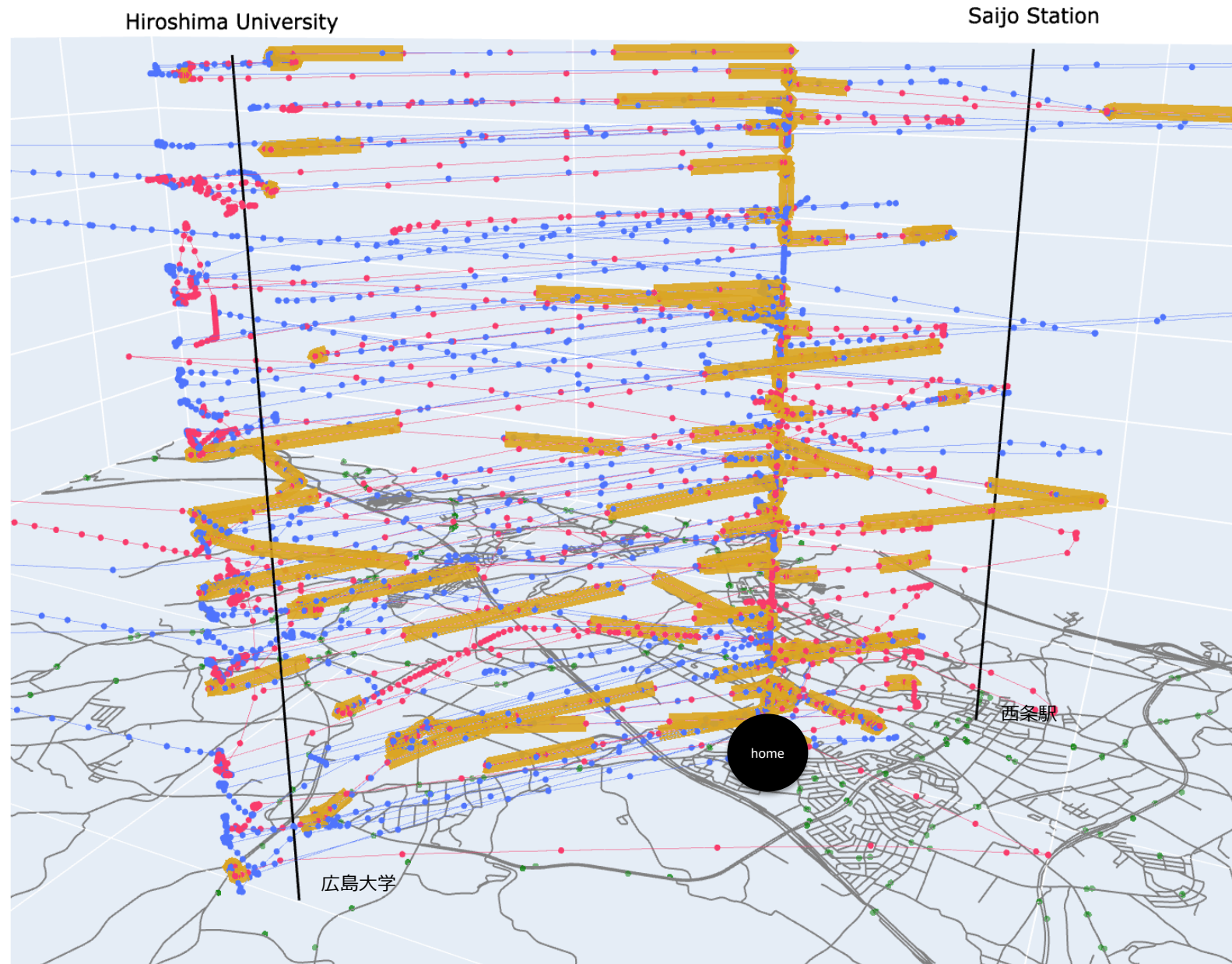
Example of GPS trajectories

*For details, please join Kajiyama's presentation on September 3, 9:00–10:30, Technical Session 6.*

# Identifying Co-location: co-stay and co-move

- **Co-stay**
  - Stay same location together
- **Co-move**
  - Travel together

The proposed scheme enables us to model social networks as a function of co-location, homophily, and spatial proximity.

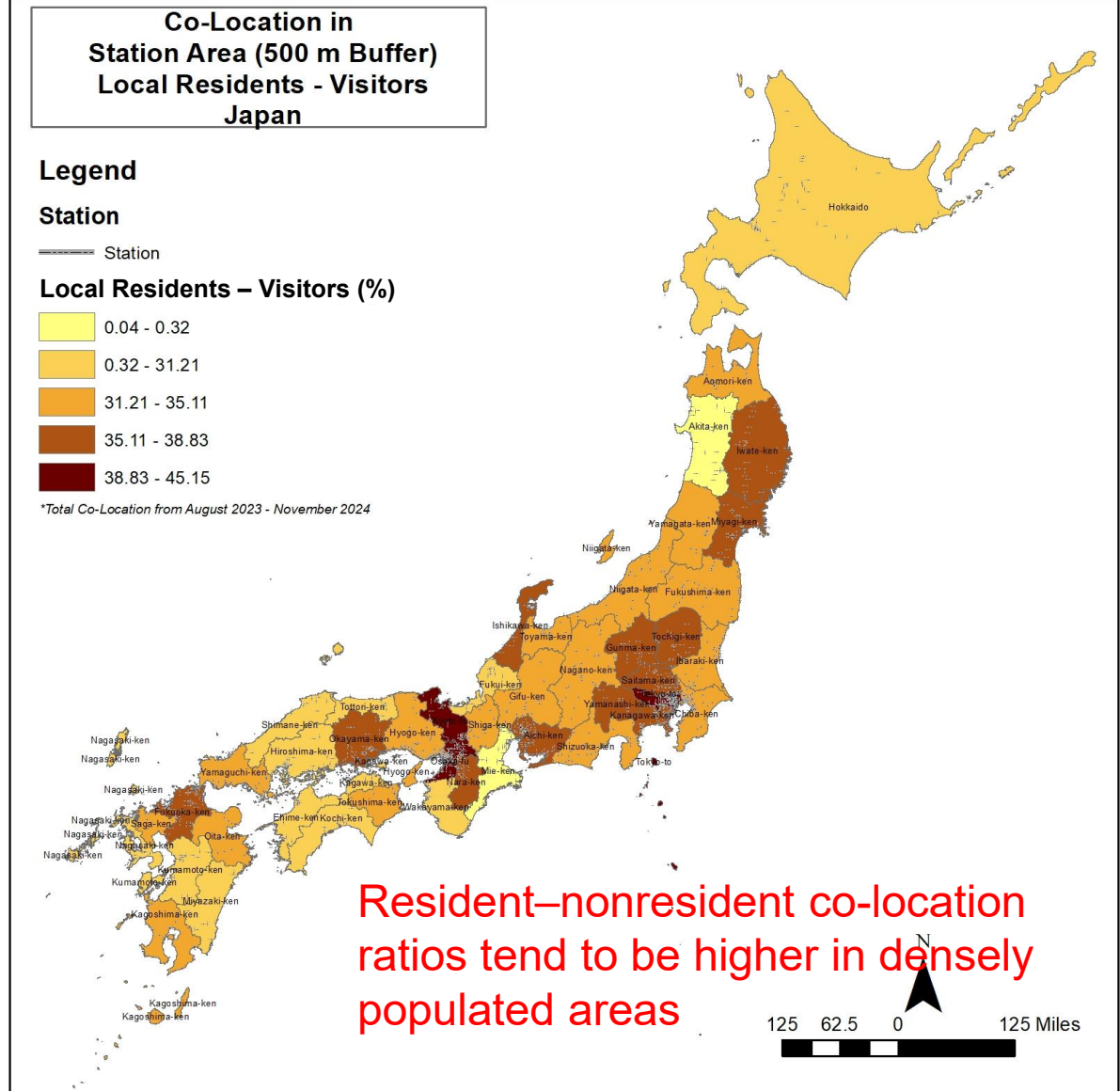
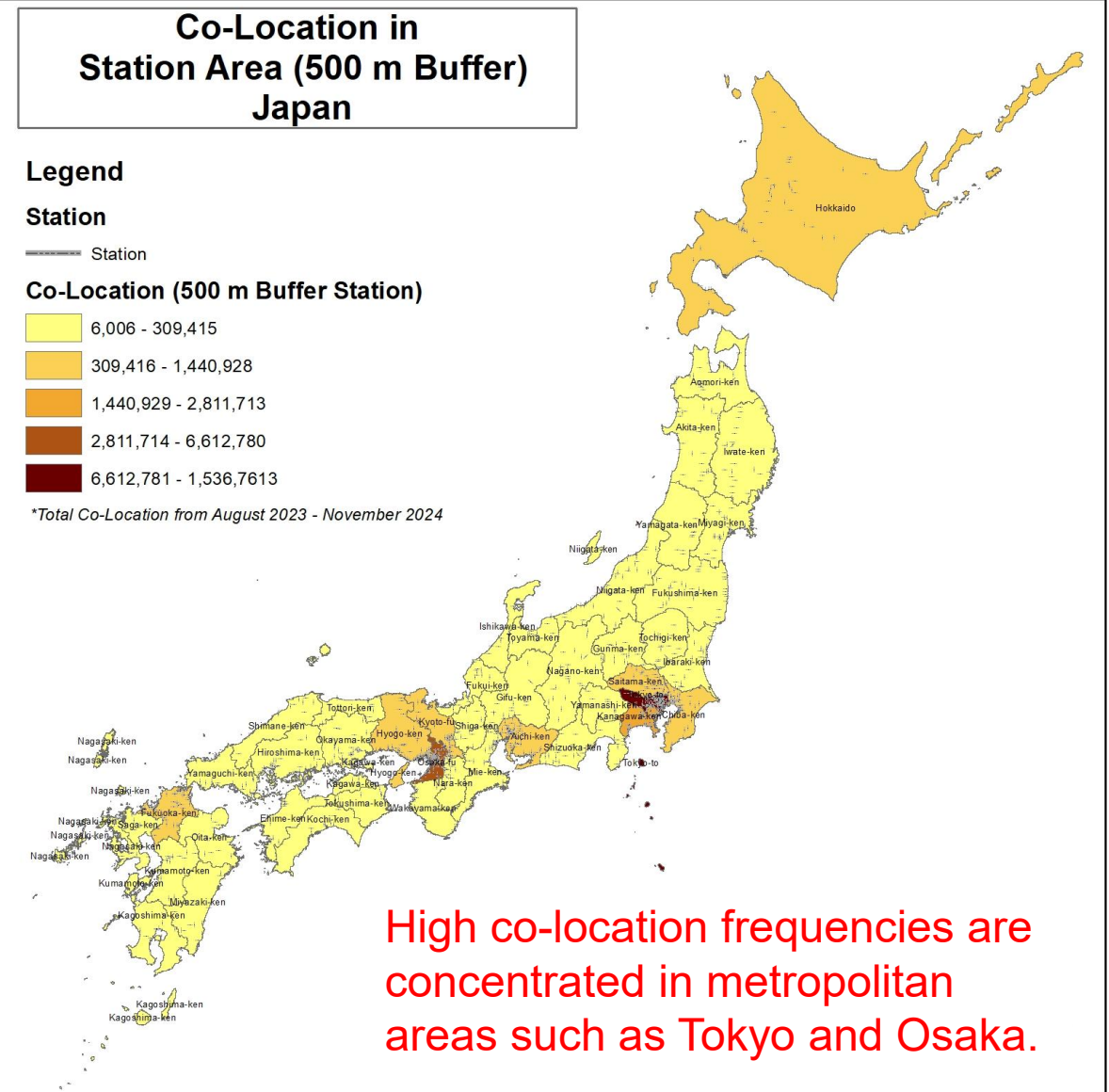


# Apply co-location functions to large-scale GPS

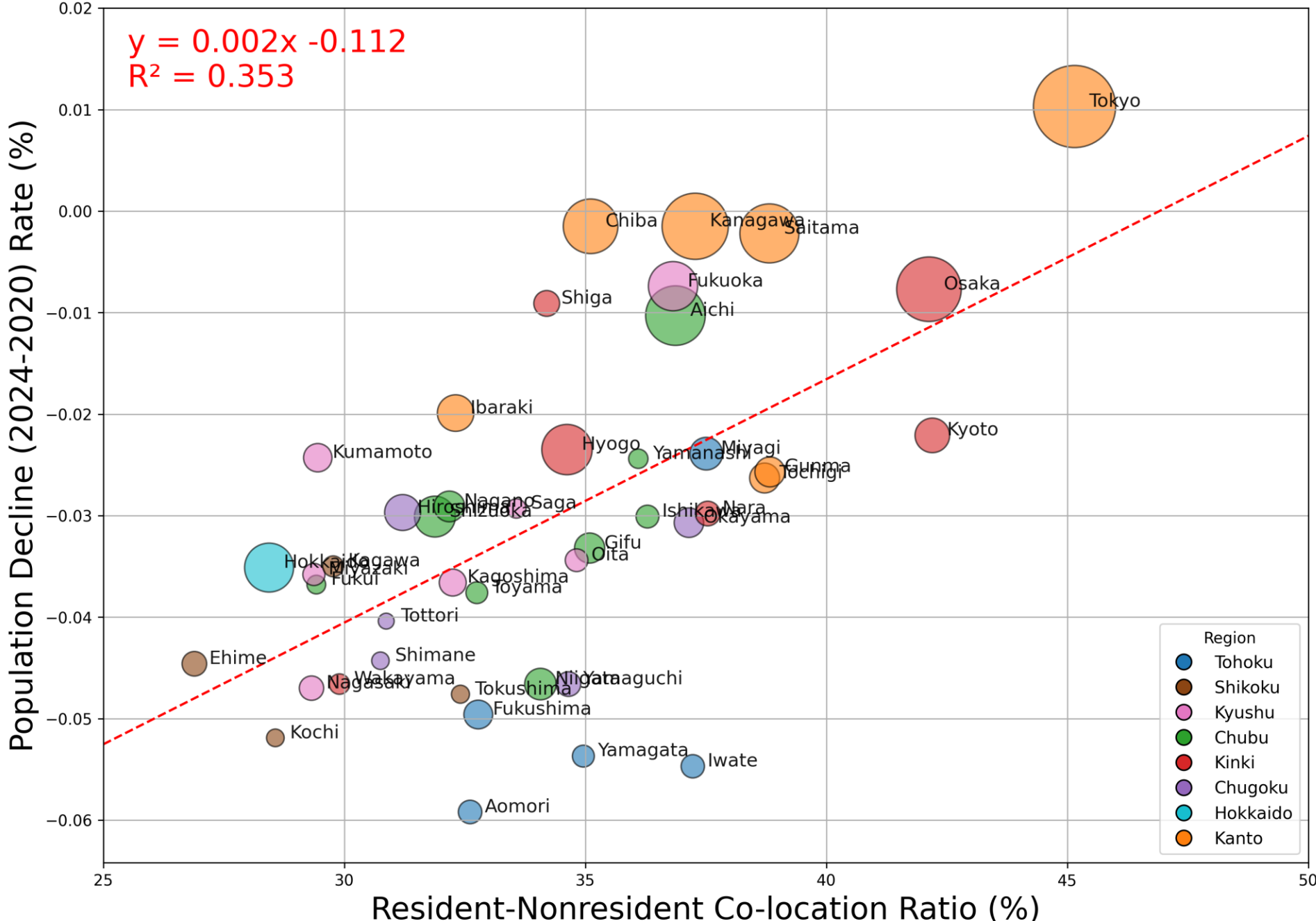
Once the function linking co-location to social networks is established, it can be applied to large-scale GPS data (in progress).

- Application to large-scale GPS collected via smartphone apps
  - **Period:** Aug 1, 2023 – Nov 30, 2024 (**nearly 500 days**)
  - **Total GPS points:** **30,995,934,897**
  - **Total trips/activities:** **1,107,637,307**
  - **Unique users:** **693,956**

# Co-location in station area



Resident–  
nonresident  
co-location  
may mitigate  
population  
decline



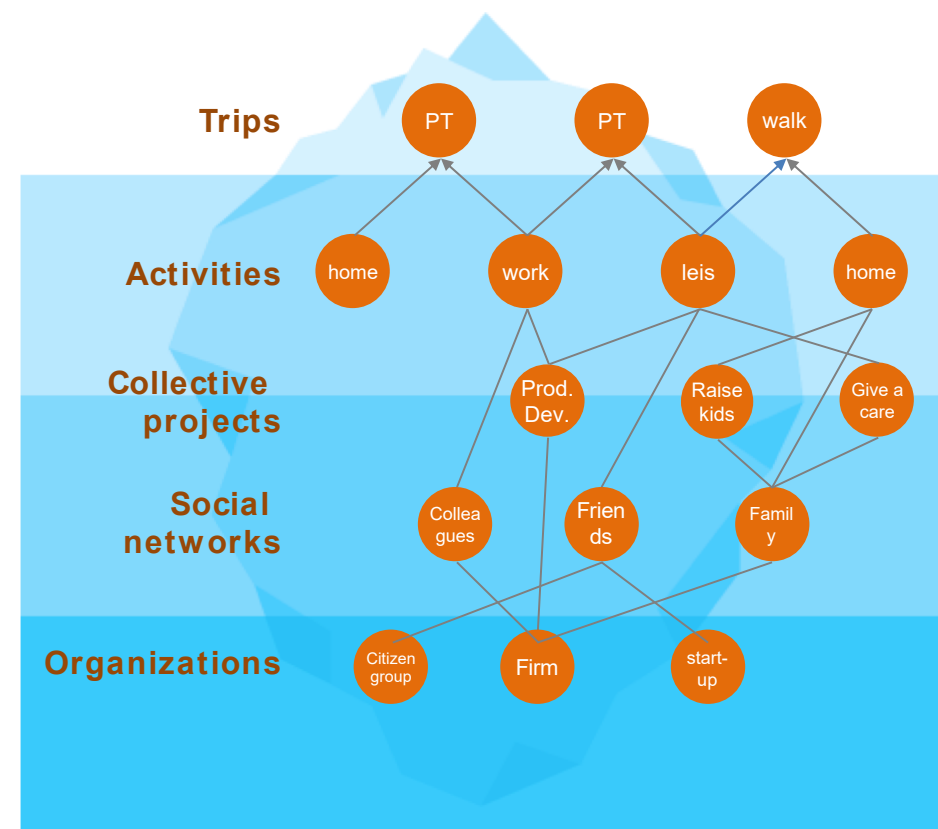
# Take away

- **Co-location and social networks**

- Capture both strong and weak ties through daily encounters
- Scale up the approach to large-scale GPS data to reveal broader dynamics

- **Possible extensions**

- Link co-location to macro-level indicators (e.g., population, start-ups)
- Connect findings to discussions on agglomeration and societal impacts



# A Joint model of pedestrian movers and stayers in urban public spaces

Collaborators:



Keishi Fujiwara



Yuki Oyama



Akimasa Fujiwara

## References:

- Fujiwara, K., Oyama, Y., Chikaraishi, M. and Fujiwara, A. (2025) A Joint Model of Pedestrian Movers and Stayers In Urban Public Spaces. Available at SSRN 5163637. (Presented at IATBR 2024)

# Essential functions of urban public space

Jones and Boujenko (2009)

**Travel function:** support various movements to destination

**Place function:** provide enough space for pedestrian activity



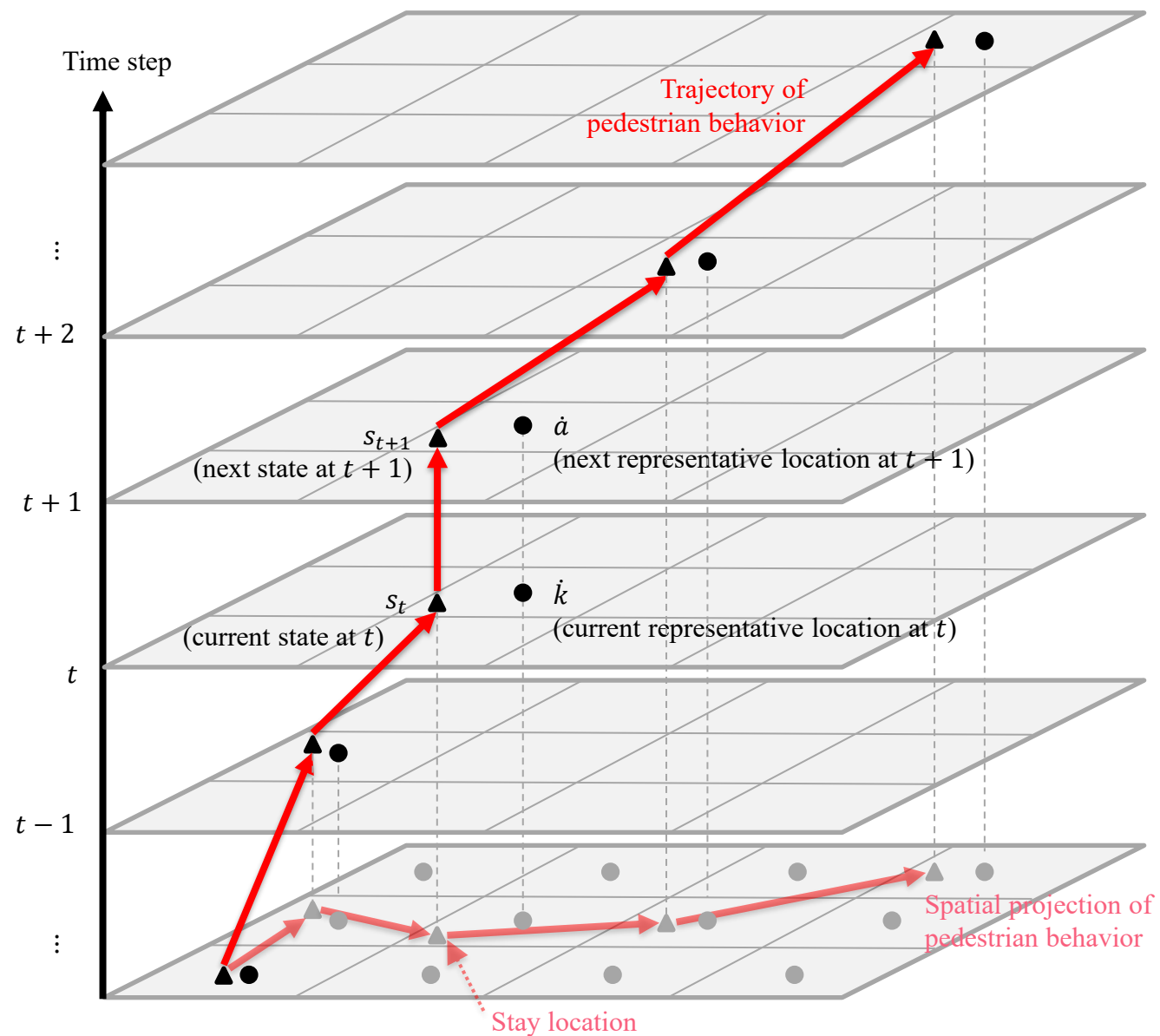
# Mover-stayer competition

The coexistence of movers and stayers in a finite space often results in competition, creating **trade-offs in space use between movers and stayers**



# Discretization

- Sojourners
  - both moving and staying
- Travelers
  - only moving



→ Use a dynamic discrete choice modeling (DDCM) framework

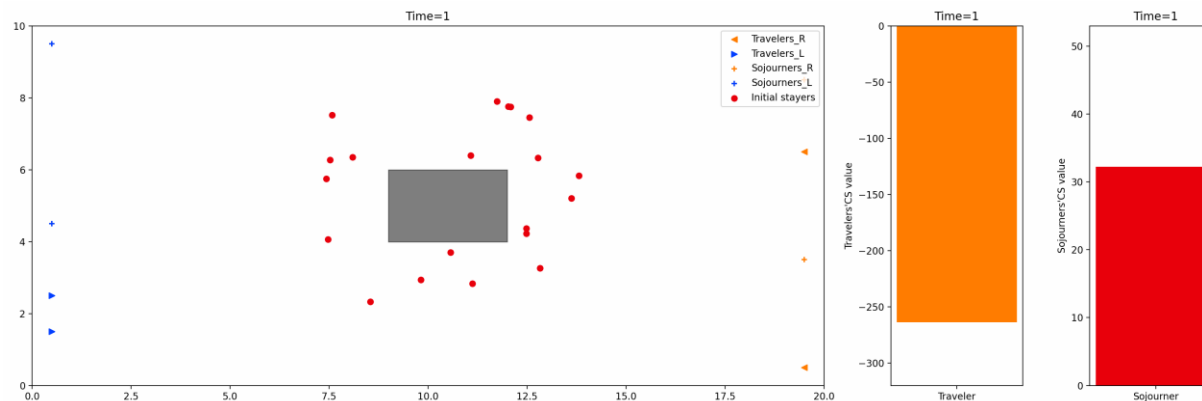
# Interactions considered

		Traveler	Sojourner	
		Move	Move	Stay
Traveler	Move	Collision avoidance Leader-follower	Collision avoidance Leader-follower	Decrease in walking service level
	Stay	Diminish the utility of staying	Diminish the utility of staying	Vibrant place
Sojourner	Move	Collision avoidance Leader-follower	Collision avoidance Leader-follower	Decrease in walking service level
	Stay	Diminish the utility of staying	Diminish the utility of staying	Vibrant place

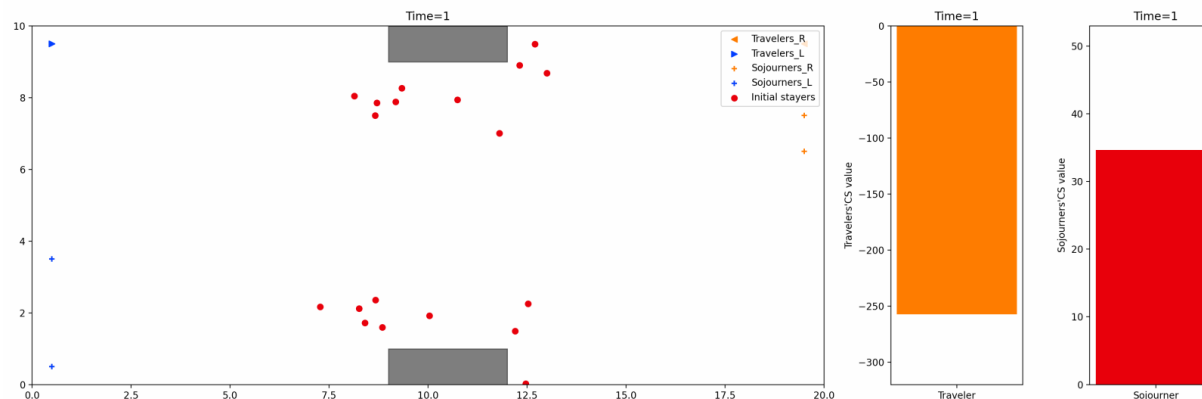
- : Internal interactions (interactions within movers/stayers)
- : External interactions (interactions between movers and stayers)

# Simulation results (example)

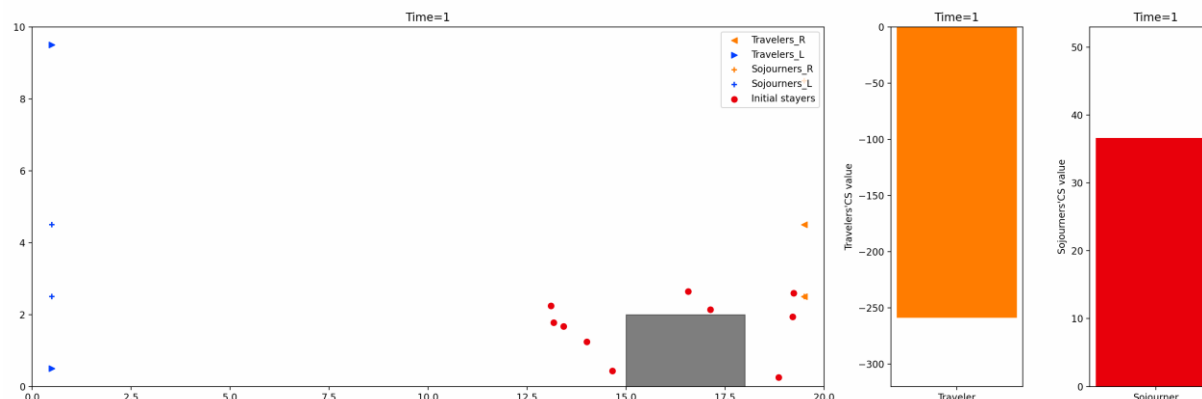
Object location: **Center**  
 The number of sojourners:  $N_S$ : 4  
 The number of travelers:  $N_T$ : 4



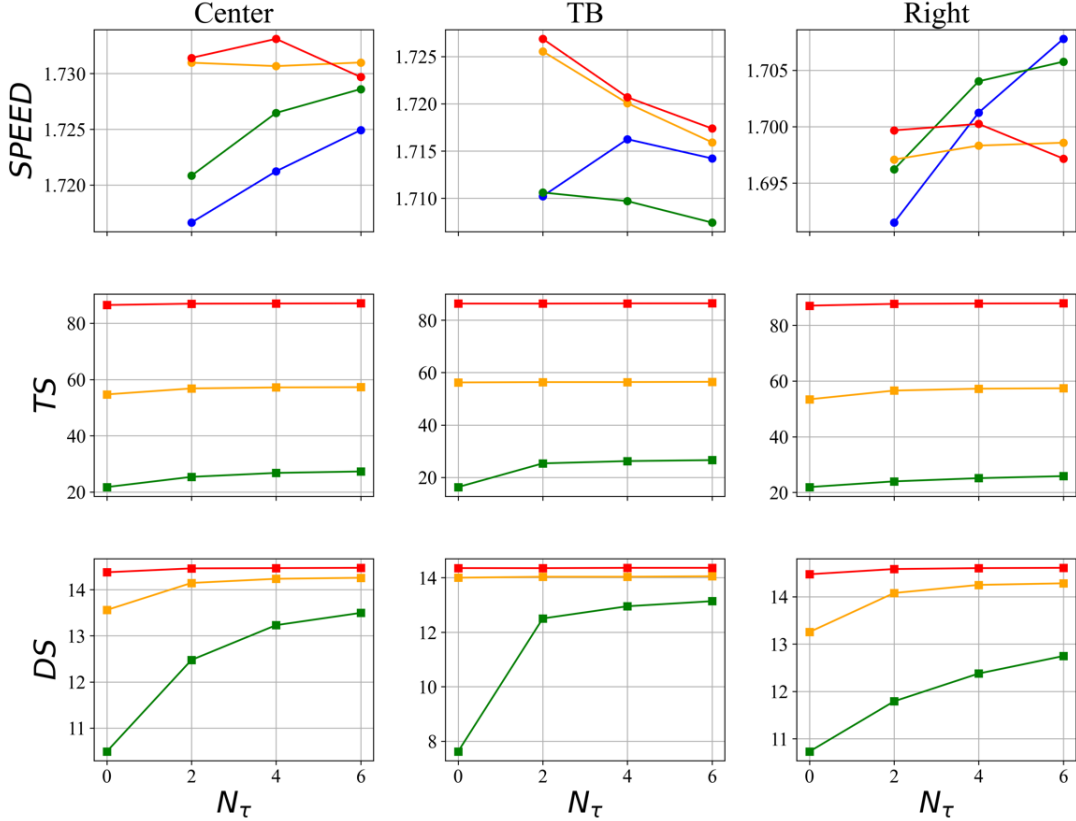
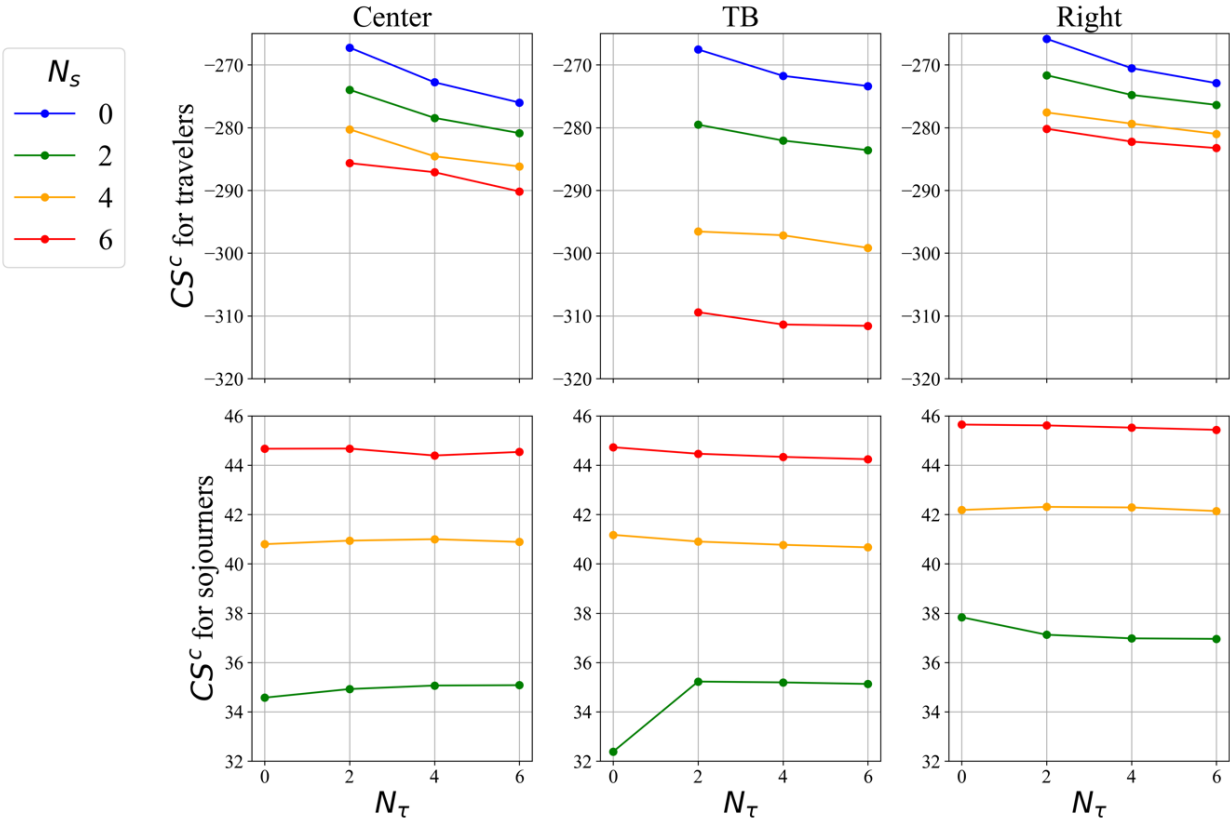
Object location: **Top and Bottom**  
 The number of sojourners:  $N_S$ : 4  
 The number of travelers:  $N_T$ : 4



Object location: **Right**  
 The number of sojourners:  $N_S$ : 4  
 The number of travelers:  $N_T$ : 4



# Simulation results

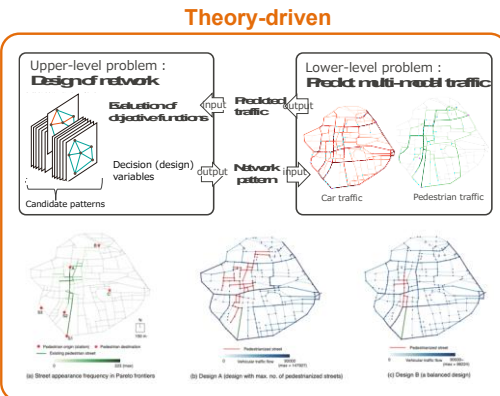


- “Right” is the best object location in terms of maximizing both travelers and sojourners CS.
- In the case of TB placement,  $CS^c$  are more sensitive to changes in  $N_s$
- $SPEED$  does not always decrease with an increase in  $N_\tau$  when  $N_s$  is small, while travelers’  $CS^c$  value decreases
- $TS$  and  $DS$  increase with an increase in  $N_\tau$  and  $N_s$ , while sojourners’  $CS^c$  value does not necessarily increase

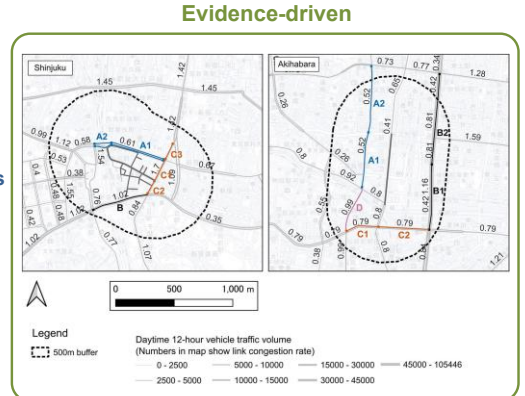
# On-going work: The JSCE Kathmandu Project

*Toward human-centric transport systems*

## [Methods]



Oyama et al. (2024)



Parady et al. (2025)

Consensus building (through workshop etc.)



## [Issues]

The Durbar Squares of the three former kingdoms of Malla Dynasty (1200-1769)...

1. Kathmandu Durbar Square
2. Patan Durbar Square
3. Bhaktapur Durbar Square

Collaborators:



Giancarlo Parady



Yuki Oyama



Hideki Yaginuma

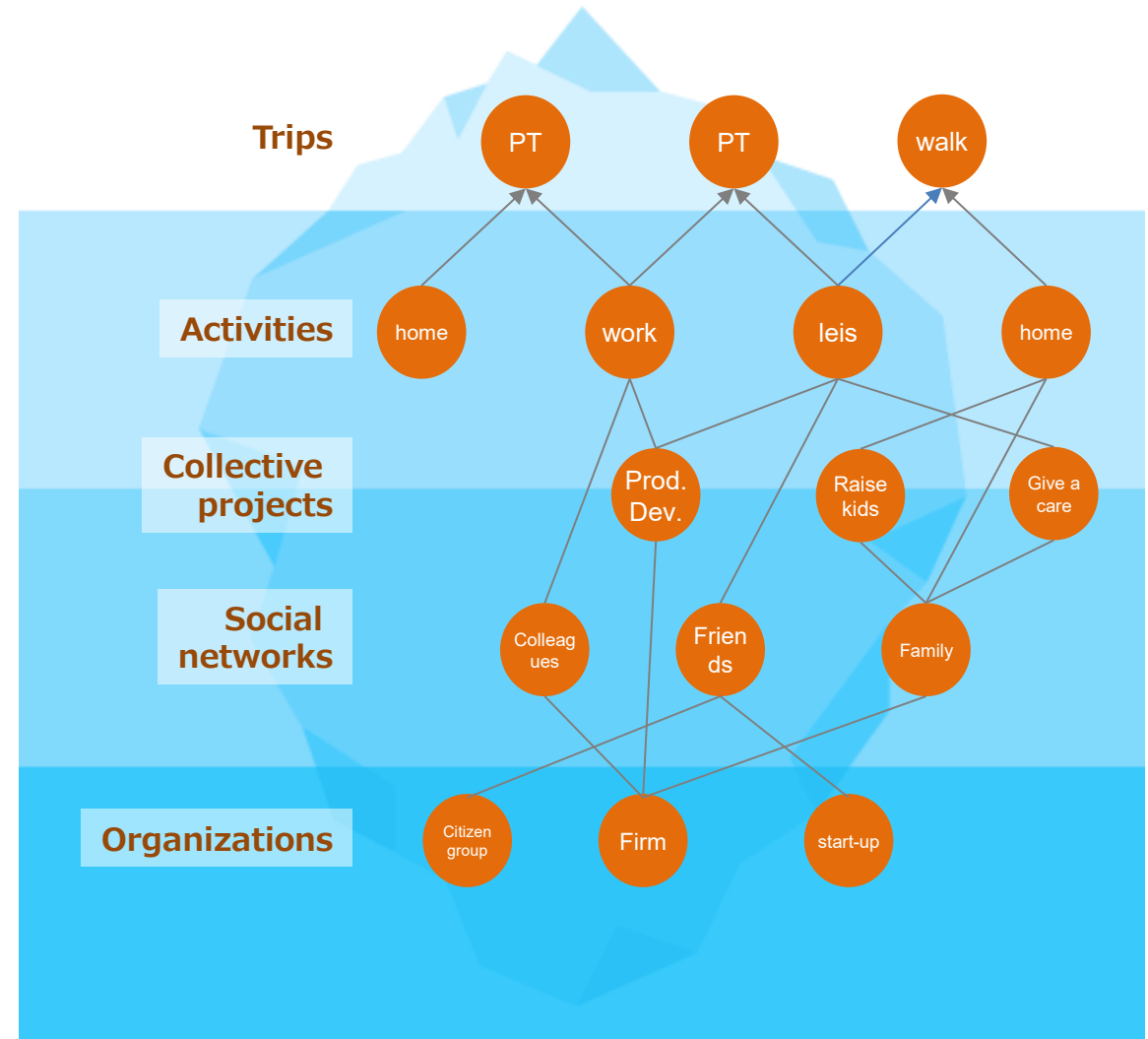


Rojee Pradhananga

with JICA, Nippon Koei, KMC

# Wrap up: Value of activity participation

- Jones (2009): Despite advances in activity-based models, the value of activity participation remains underexplored.
- Capturing the hidden layers helps us understand the true value of activity participation, including cultural values.
- Transport is not only about trips and flows, but about **shaping society**.



# THANK YOU

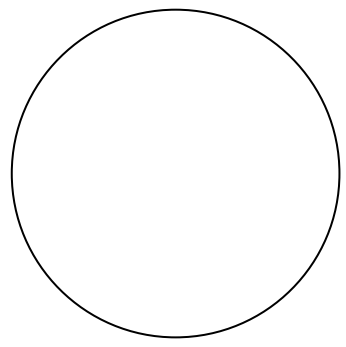
Makoto Chikaraishi, Hiroshima University

email: [chikaraishim@hiroshima-u.ac.jp](mailto:chikaraishim@hiroshima-u.ac.jp)

**This work was supported by:**

- ✓ JSPS, Japan KAKENHI Grants 18K04385, 21H01454, 23H01586, and 24K01001
- ✓ JST FOREST Program, Grant Number JPMJFR231G
- ✓ Cross-ministerial Strategic Innovation Promotion Program (SIP), the 3rd period of SIP “Smart Mobility Platform”, Grant Number JPNP23023 (Funding agency: NEDO).





# Research objectives

- Propose a dynamic framework of social network formation through activity engagement
  1. Develop a dynamic simulation framework linking activity participation and tie retention (**co-evolutionary process**)
  2. Demonstrate the framework using data from international students in Japan

# Steps

## 1. Data collection

- Social network survey + activity diary survey
  - Key items: joint activities, new encounters, tie retention

## 2. Model development

- Activity engagement model
- Tie retention model

## 3. Simulation algorithm

- Generate population-wide networks
- Incorporate clustering (transitivity)

## 4. Empirical application

- Case study of international students in Japan
- Scenario analysis (e.g., restrictions on activities)

# Data used in empirical analysis

- **Activity type**

- **Event** = {Events and Parties, Cultural activity}
- **Food** = {Bars and clubs, Café, Eating out/Drinking}
- **Socializing** = {Get together, Socialising}
- **Other** = {Hiking, Karaoke, Movies, Museums, Picnic, Shopping, Sightseeing, Sports, Walk, Others}

- **Sample size**

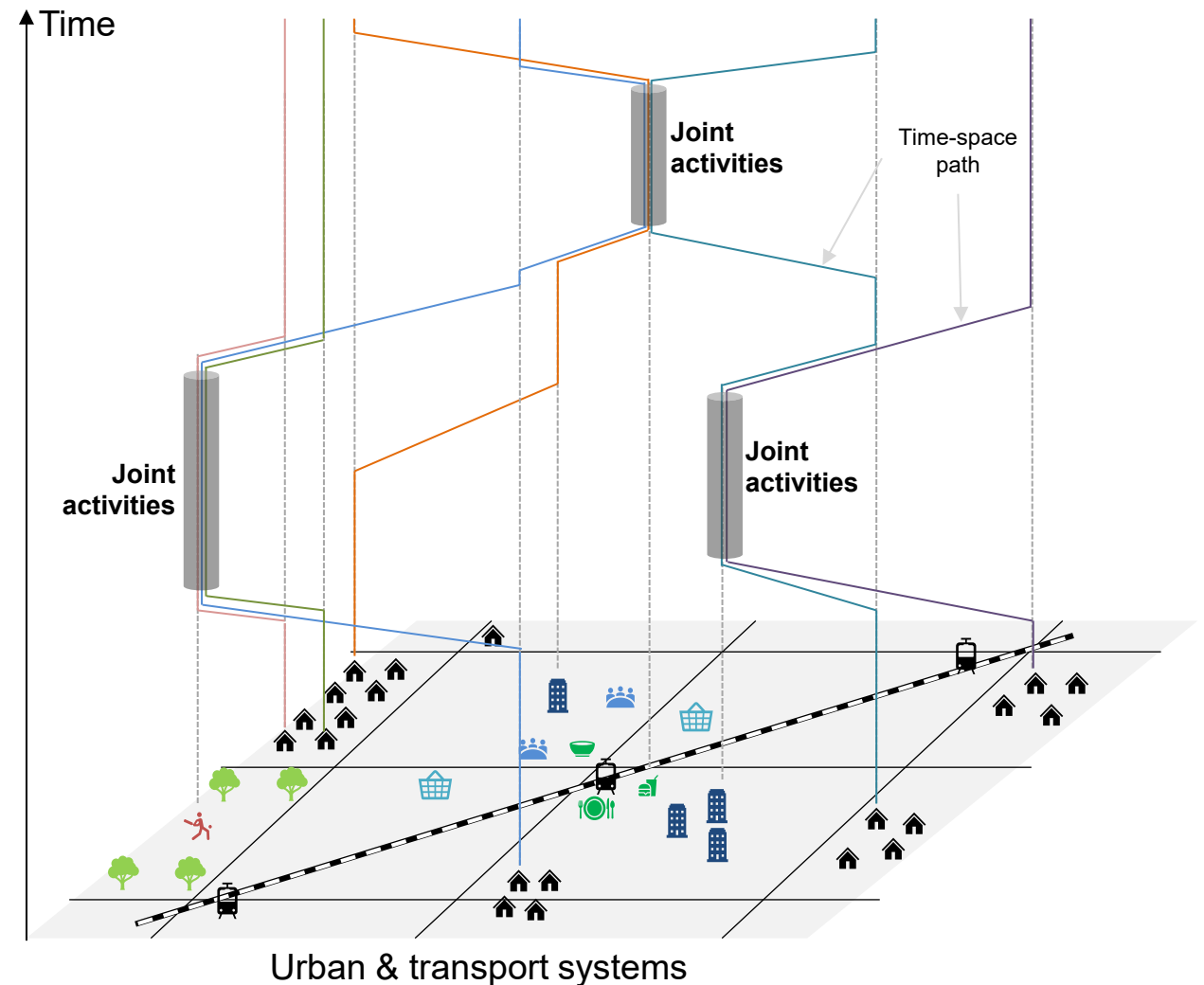
- **16 individuals**

- 1,344 joint activity opportunities (= 16 individuals  $\times$  4 activity type  $\times$  21 days)
- 435 joint activities were observed.
- Through 435 joint activities, 550 new encounters happened in total, and 183 (out of 550) new ties were added into their social network.

# Co-evolution of social networks & joint activities

Joint activities are a fundamental source of social development.

Social networks (SN) and joint activities **co-evolve**.



# Model estimation results: Activity participation and the number of individuals met

	Activity participation			# of persons met who are not in social network			# of persons met who are in social network		
	param	t-value		param	t-value		param	t-value	
<b>Fixed effects</b>									
Constant	-0.912	-4.271	**	-0.602	-1.839	+	1.369	2.474	*
Age	0.0	-		0.037	2.883	**	-0.039	-1.818	+
Gender (male 1; female 0)	0.0	-		0.038	0.807		0.194	2.354	*
Japanese language (OK 1; not OK 0)	-0.167	-1.141		0.103	1.906	+	-0.273	-2.919	**
Dorm dummy	0.209	1.108		0.498	5.984	**	-0.103	-0.795	
ln(# of friends+1)	0.127	1.633		-0.295	-6.882	**	0.355	7.318	**
Activity type = event	-0.660	-3.549	**	0.220	2.803	**	0.352	2.841	**
Activity type = food	-0.215	-1.199		0.104	1.538		-0.063	-0.55	
Activity type = socializing	0.767	4.334	**	0.111	1.904	+	0.036	0.343	
Activity type = other	0.0	-		0.0	-		0.0	-	
Inverse Mills ratio				0.029	0.58		-0.037	-0.64	
<b>Random effects (variance)</b>									
egoID × activity type	0.163			0.0078			0.0633		
Residual	-			0.1538			0.1829		
Sample size	1344			435			435		
MacFadden's rho squared	0.215								
Marginal R <sup>2</sup>				0.150			0.214		
Conditional R <sup>2</sup>				0.191			0.416		
Initial log-likelihood	-931.6								
Fin									

**Activity participation** : number of friends, Japanese language ability, living in dorm or not, does not have a significant effect on activity participation

# Model estimation results: Activity participation and the number of individuals met

	Activity participation			# of persons met who are not in social network			# of persons met who are in social network		
	param	t-value		param	t-value		param	t-value	
<b>Fixed effects</b>									
Constant	-0.912	-4.271	**	-0.602	-1.839	+	1.369	2.474	*
Age	0.0	-		0.037	2.883	**	-0.039	-1.818	+
Gender (male 1; female 0)	0.0	-		0.038	0.807		0.194	2.354	*
Japanese language (OK 1; not OK 0)	-0.167	-1.141		0.103	1.906	+	-0.273	-2.919	**
Dorm dummy	0.209	1.108		0.498	5.984	**	-0.103	-0.795	
ln(# of friends+1)	0.127	1.633		-0.295	-6.882	**	0.355	7.318	**
Activity type = event	-0.660	-3.549	**	0.220	2.803	**	0.352	2.841	**
Activity type = food	-0.215	-1.199		0.104	1.538		-0.063	-0.55	
Activity type = socializing	0.767	4.334	**	0.111	1.904	+	0.036	0.343	
Activity type = other	0.0	-		0.0	-		0.0	-	
Inverse Mills ratio				0.029	0.58		-0.037	-0.64	
<b>Random effects (variance)</b>									
egoID × activity type	0.163			0.0078			0.0633		
Residual	-			0.1538			0.1829		
Sample size	1344			435			435		
MacFadden									
Marginal R									
Conditional									
Initial log-									
Final log-l									

- # of persons met**
1. Japanese language ability, living in dorm would help to meet with persons who are not in social network.
  2. Students tend not to meet with persons who are not in social network with the increase in the size of social network.

## Model estimation results: tie retention model

	param	t-value	
<b>Fixed effects</b>			
Constant	0.356	1.033	
Age gap between ego and alter	-0.005	-0.265	
Nationality (1 different nationality; 0 otherwise)	-0.588	-3.728	**
Gender (1 different gender; 0 otherwise)	0.007	0.058	
ln(# of friends+1)	-0.343	-3.038	**
Activity type = event	0.0	-	
Activity type = food	0.559	2.100	*
Activity type = socializing	0.623	2.698	**
Activity type = other	0.379	1.381	
<b>Random effects (variance)</b>			
egoID × activity type	0.169		
Sample size	550		
Initial log-likelihood	-381.2		
Final log-likelihood	-325.7		

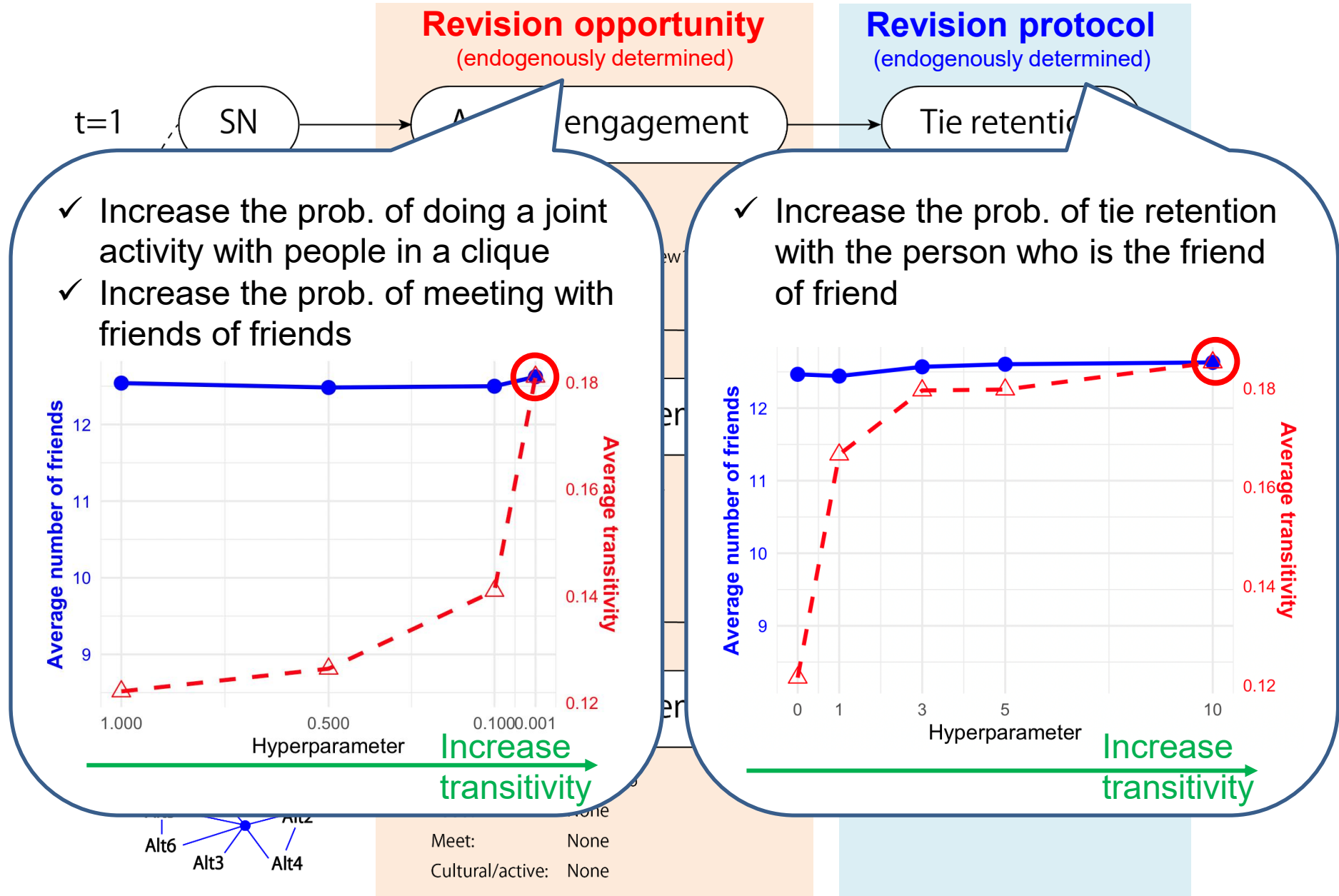
1. Tie tends to be retained when they have the same nationality, and when they met for “food” and “meet”.
2. Tie retention probability goes down with the increase in the size of social network.

# Simulation analysis: baseline setting

Assume that there are **200 international students** who

1. came from 10 countries (equally distributed across countries)
2. are female (50%) and male (50%)
3. are 20 to 40 years old (equally distributed across ages)
4. can speak Japanese (50%)
5. live in the dorm (50%)

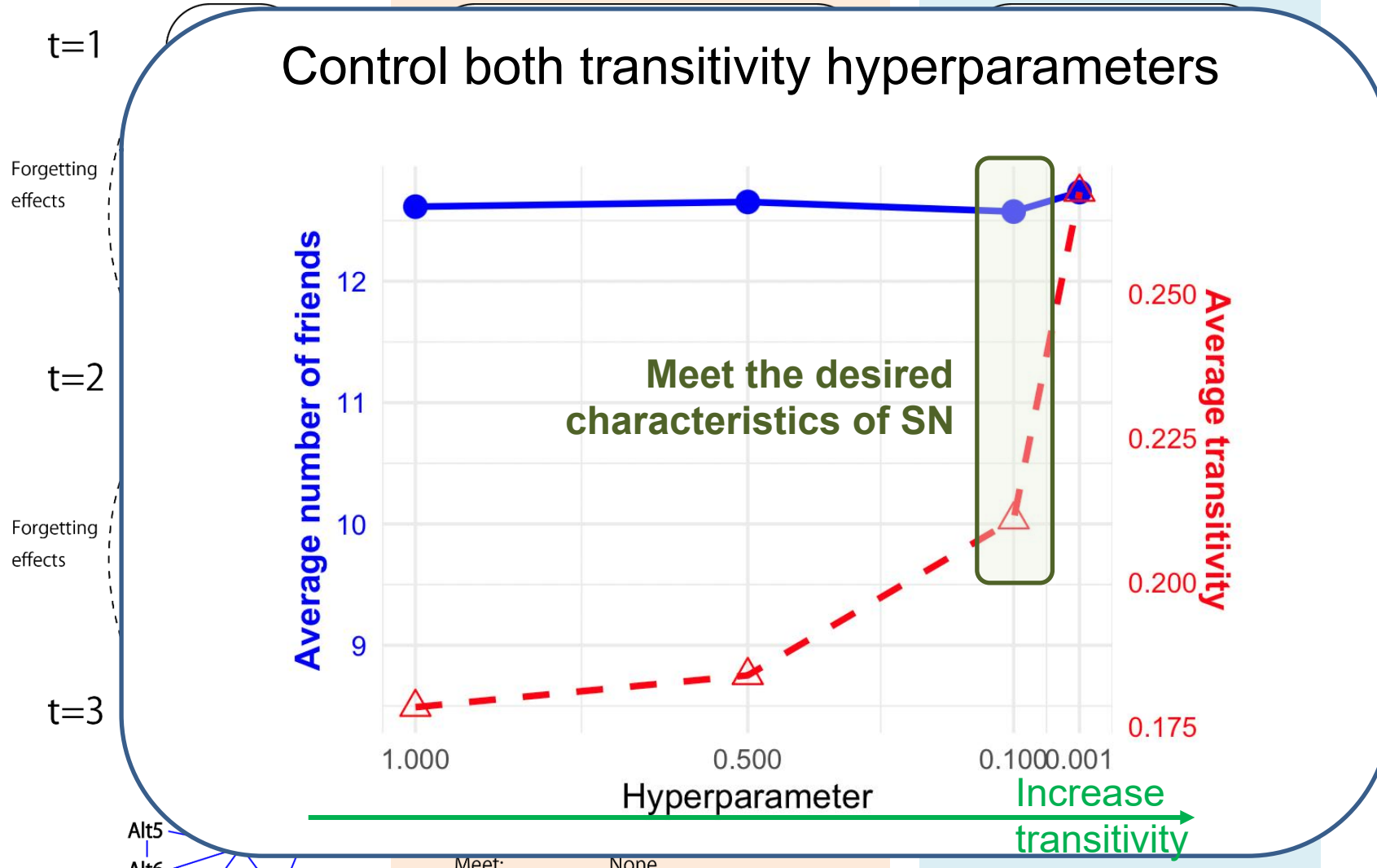
# Tuning hyperparameters for transitivity



# Tuning hyperparameters for transitivity

**Revision opportunity**  
(endogenously determined)

**Revision protocol**  
(endogenously determined)

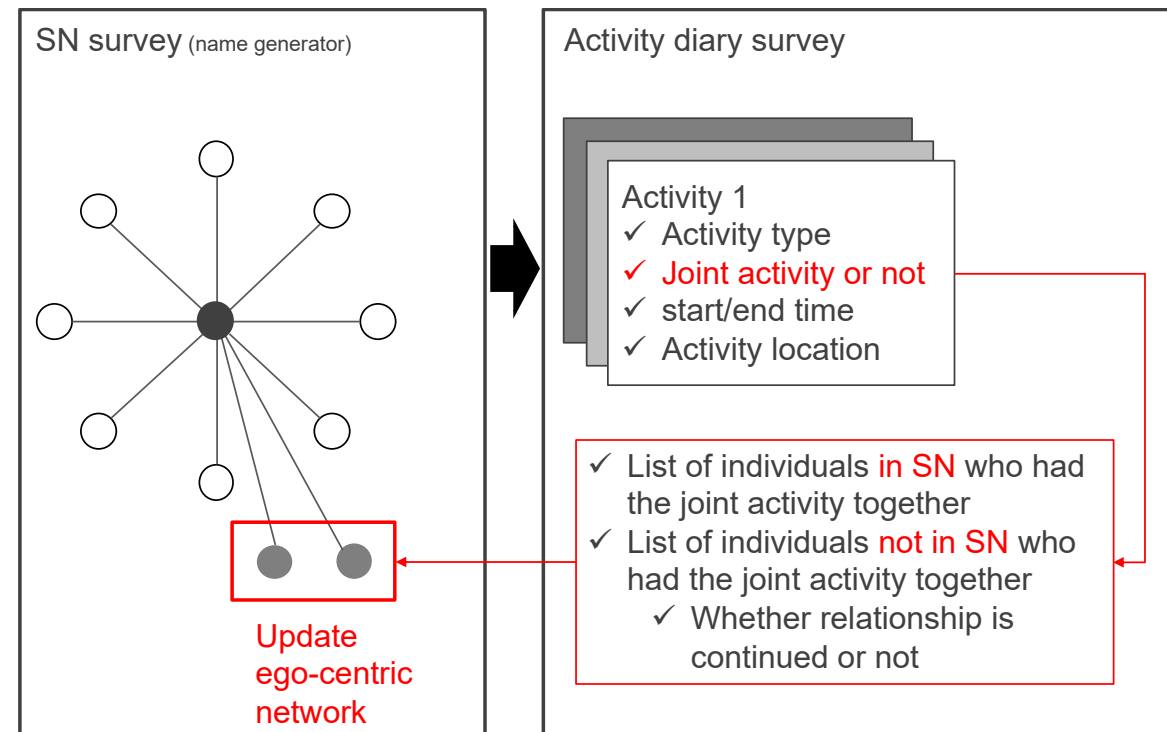


**We could add transitivity in revision opportunity, revision protocol, or both.**

# Limitations of joint activity surveys

Conducting a joint activity survey in combination with a social network survey is very expensive and has the following limitations:

1. ignores weak ties and casual encounters
2. focuses only on planned / intentional activities
3. cannot capture opportunities for serendipitous interactions



# Estimation of unknown pairs including homophily and affiliation specific attribute

	Predict_tie 1	Predict_tie 2	Predict_tie 3	Predict_tie 4	Predict_tie 5	Total
Hiroshima University	354	12	34	0	17084	17484
FukkenCo., Ltd	136	142	2816	20	846	3960
Higashi- Hiroshima City	42	84	746	2	688	1562
Total	532	238	3596	22	18618	23006

# A Challenge

Interactions can become highly complex when both movers and stayers coexist, potentially **leading to multiple equilibria**

1. Theoretically elucidating the properties of the model, for example, using evolutionary game theory (e.g., Iryo and Watling, 2020)
  - Deterministic approximation of stochastic evolutionary process
  - Not be appropriate for the modeling pedestrian behavior
2. **Explore model behavior through simulation (e.g., Asano et al., 2009)**
  - Use simulation to understand the behavior of the consequences of complex interactions

# Performance indicators

## 1. Consumer surplus $CS^{ltsc}$

$l$ (location): 20 starting points

$t$ (time): 600 time steps

$s$ (trial): 50 trials

$c$ (scenario): 45 scenarios

## 2. Other behavioral indicators:

***SPEED***: speed per traveler (over space, 600 time steps, and 50 trials)

***DS***: time agents spent for staying (over space, 600 time steps, and 50 trials)

***TS***: the number of stayers (over space, 600 time steps, and 50 trials)

# Conditions

## Scenario setting (45 scenarios in total)

Object location	The number of sojourners: $N_s$	The number of travelers: $N_t$
Center	{0, 2, 4, 6} [persons/s]	{0, 2, 4, 6} [persons/s]
Top-and-Bottom	{0, 2, 4, 6} [persons/s]	{0, 2, 4, 6} [persons/s]
Right	{0, 2, 4, 6} [persons/s]	{0, 2, 4, 6} [persons/s]

## Parameters used for simulation

Sojourners:  $[\gamma^{cam}, \gamma^{le}, \gamma^{cas}, \gamma^{sa}, \gamma^{as}, \beta^{so}, \beta^{cao}, \beta^{td}, \beta^{stm}, \beta^{mts}]$   
 $= [-1.0, 0.1, -1.2, -1.0, 1.2, 1.0, -0.1, -0.1, -0.1, -0.1]$

Travelers:  $[\gamma^{cam}, \gamma^{le}, \gamma^{cas}, \gamma^{td}, \beta^{cao}, \beta^{stm}] = [-10, 10, -10, -10, -10, -10]$

# Algorithm

---

**LET**  $N_t$  is a set of travelers and sojourners in the space at time  $t$  ( $|N_1| = 0$ )  
1  $IN_t$  is a set of travelers and sojourners who just depart from the origin at  $t$  ( $|IN_1| = 0$ )  
 $OUT_t$  is a set of travelers and sojourners who just arrived at destination at  $t$  ( $|OUT_1| = 0$ )  
 $S$  is the maximum number of steps to the destination

2 **SET**  $t = 1$

3 **WHILE TRUE**

4 **COMPUTE**  $N_t \leftarrow N_{t-1} \cup IN_t \setminus OUT_{t-1}$

5 **FOR**  $n = 1, \dots, |N_t|$  **DO**

6 **COMPUTE**  $M$  and  $\tilde{M}$

7 **COMPUTE**  $z_T$  (i.e.,  $z_{T,d} = 1, z_{T,k} = 0, \forall k \neq d$ )

8 **FOR**  $i = T - 1, \dots, 1$  **DO**

**COMPUTE**  $z_i \leftarrow M_i \circ z_{i+1}$

9 **COMPUTE**  $P(s_{n,i}) \leftarrow \frac{\tilde{M}_{i,s_i} \circ z_i^T}{\tilde{M}_{i,s_i} z_i}$

10 **END FOR**

11 **COMPUTE**  $a \sim P(a|s_{n,t})$

12 **COMPUTE**  $s_{n,t+1} \sim q(a, s_{n,t})$

13 **END FOR**

14 **COMPUTE**  $OUT_t$

15 **INCREMENT**  $t$

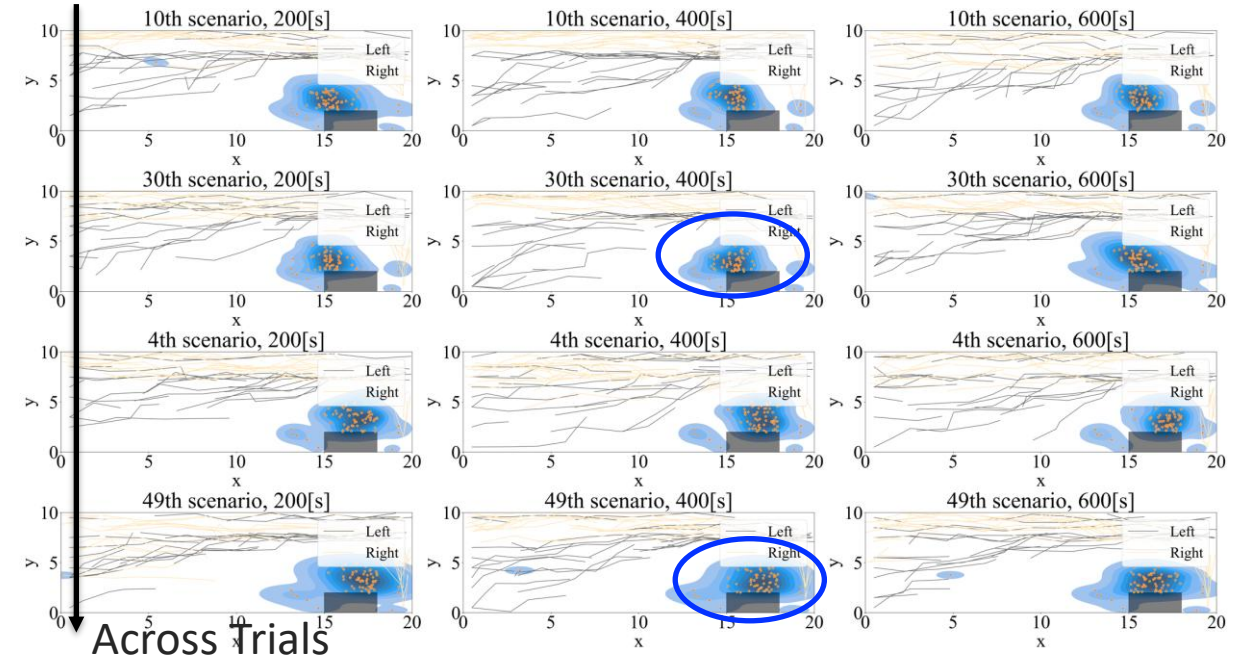
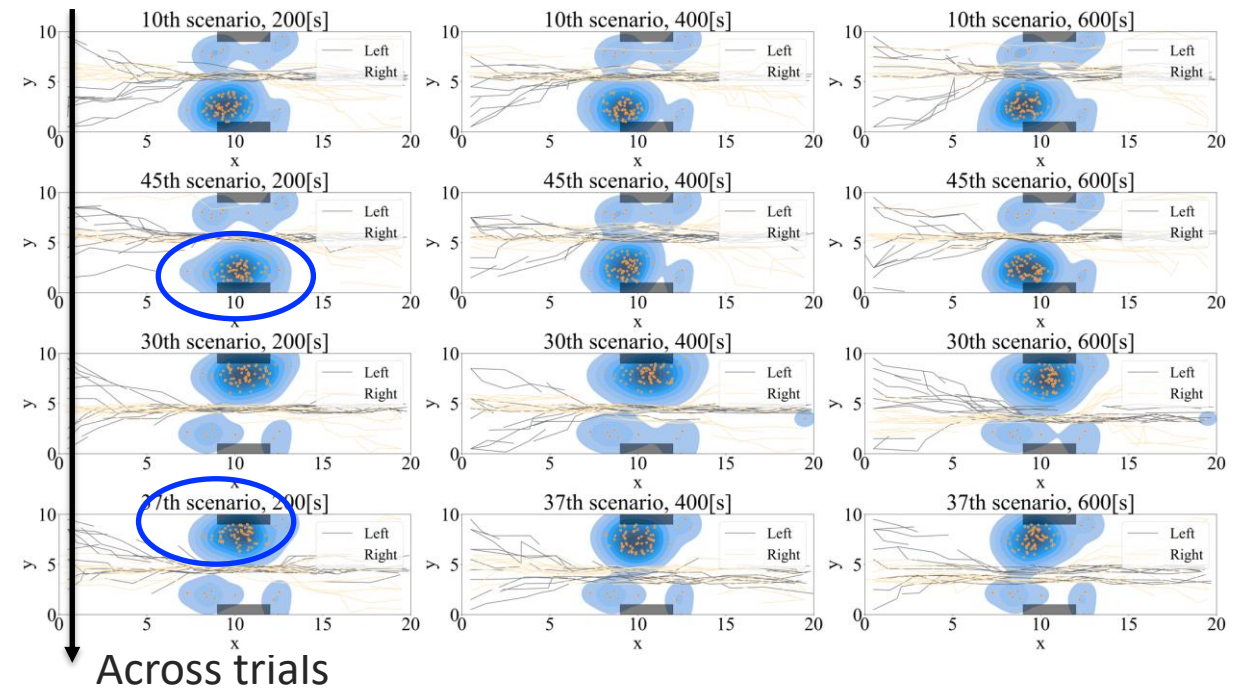
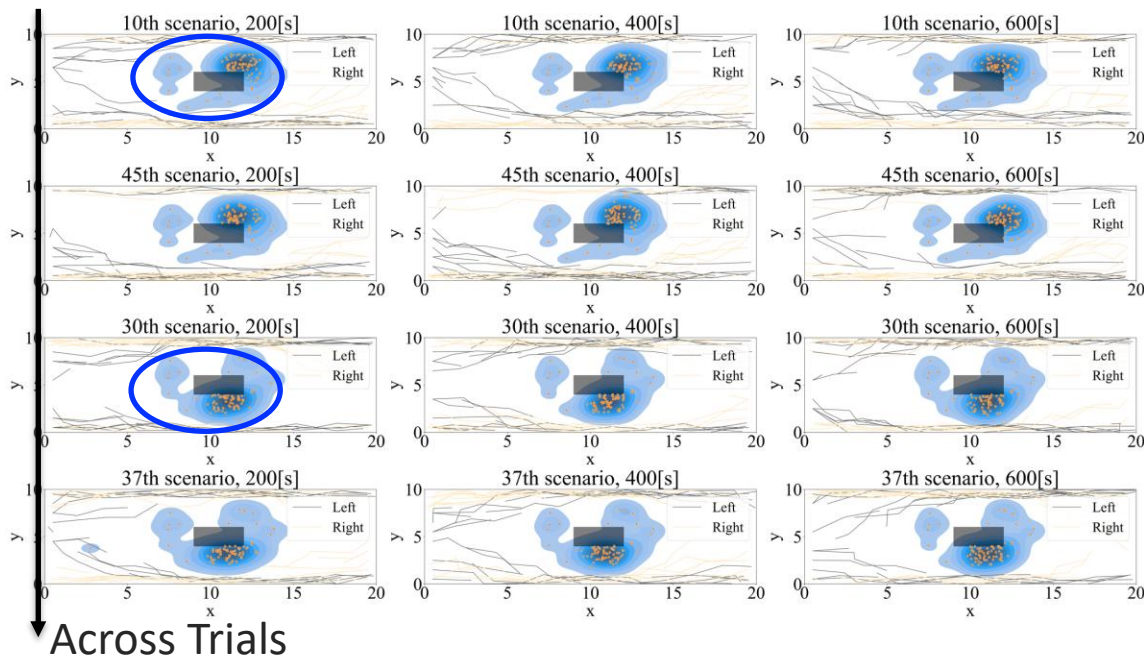
16 **END WHILE**

---

In each simulation, we simulate pedestrian behavior for 1000 seconds  
(only utilize 200-800 in making inferences)

# Stationary states of pedestrian behavior

Multiple equilibria (e.g., different locations of concentrating stayers) across trials occur



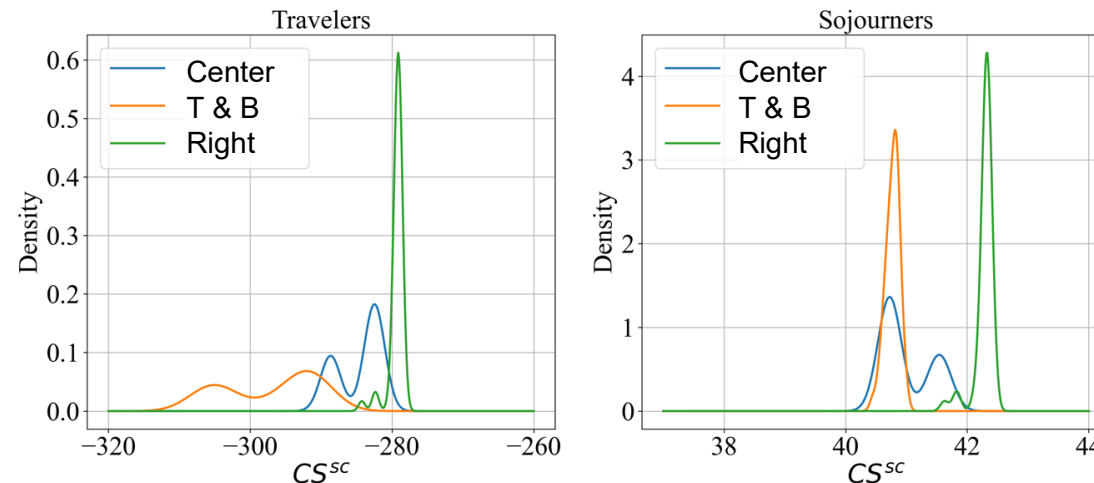
# Stationary States of CS Values

## Result of ADF test on $CS$

	Travelers			Sojourners		
Significance levels	$\leq 1\%$	$\leq 5\%$	$> 5\%$	$\leq 1\%$	$\leq 5\%$	$> 5\%$
Center	50	0	0	50	0	0
Top-and-Bottom	49	1	0	50	0	0
Right	48	2	0	50	0	0

→  $CS$  values ultimately fall within a specific range.

## Distribution of the average $CS$ across 50 trials

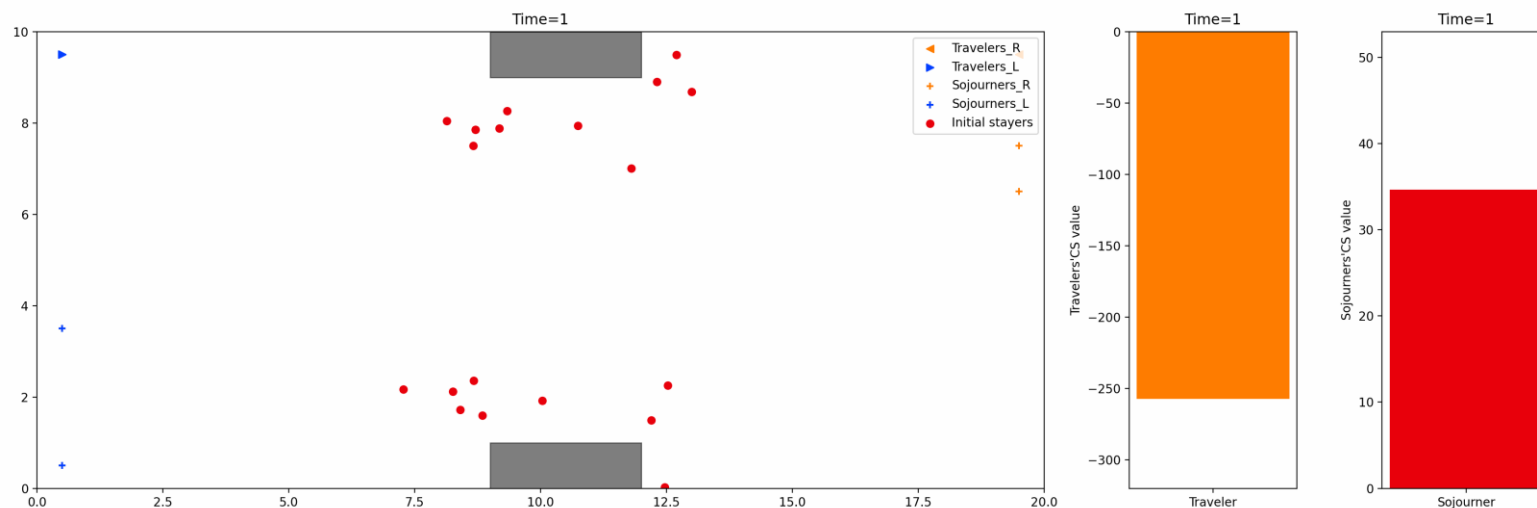


→  $CS$  are significantly different across three object location settings. 57

# Research objective

Propose a pedestrian model with mover-stayer competition based on the dynamic discrete choice modeling framework (DDCM).

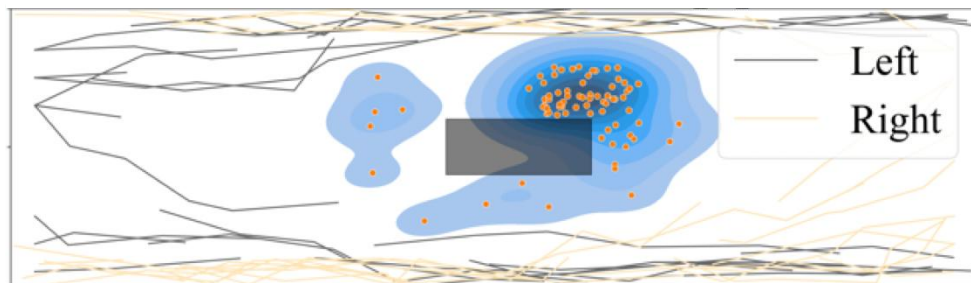
1. Model the competition between movers and stayers
2. Derive **consumer surplus** as an evaluation index for urban public space
3. Reflect **various interactions between movers and stayers**



# Advantages of using DDCM

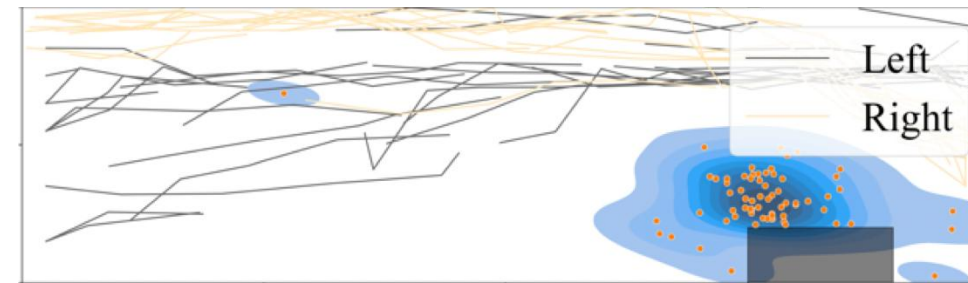
- Dynamic discrete choice model (DDCM) is consistent with the random utility maximization theory, enabling the calculation of consumer surplus (CS) as a performance indicator of the space.

Object location: Center



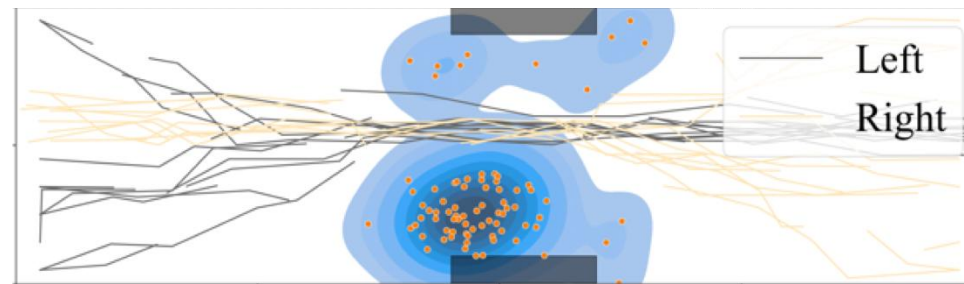
CS = ???

Object location: Right



CS = ???

Object location: Top-and-Bottom



CS = ???

# Pedestrian behavior using DDCM

## Action

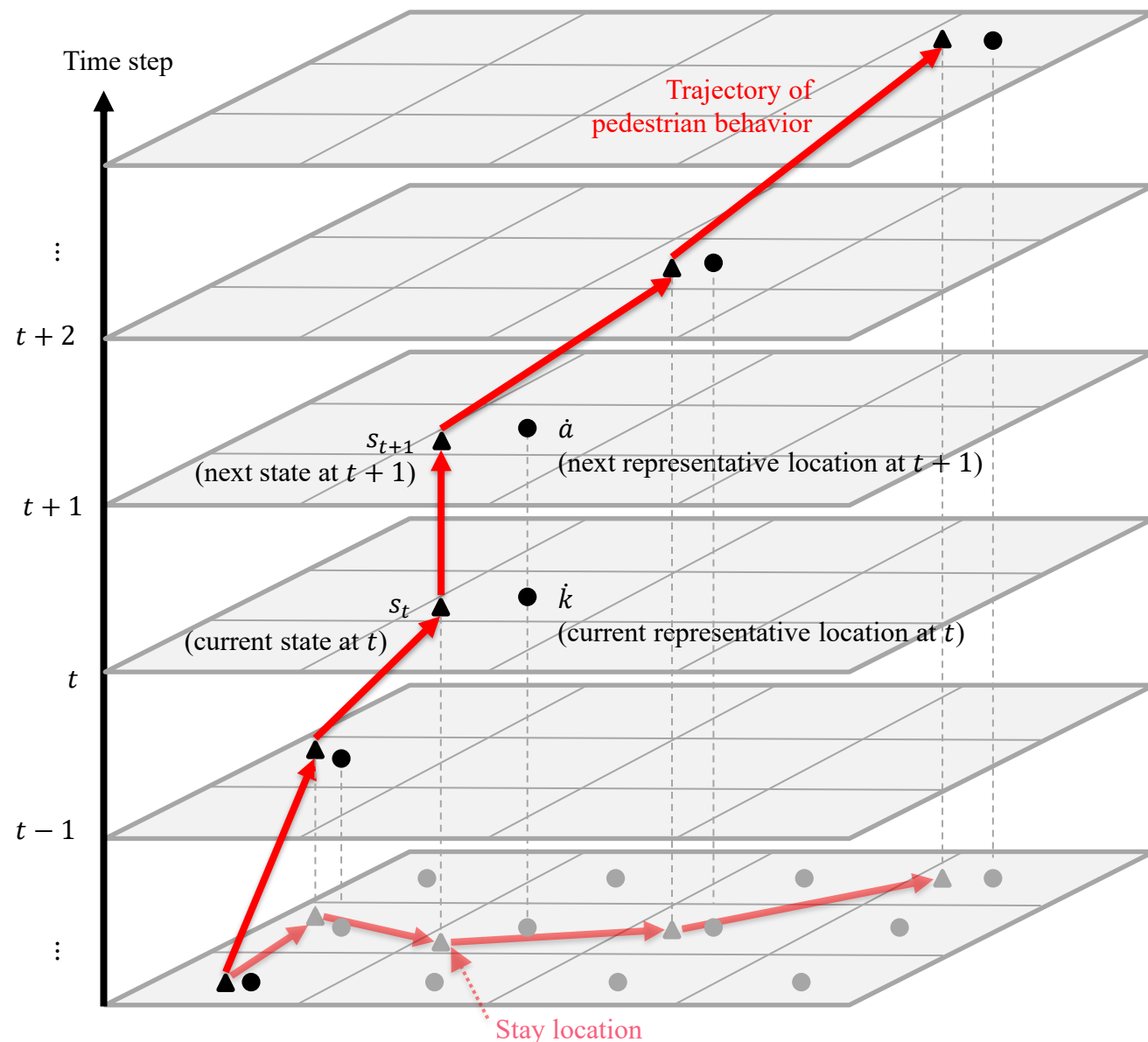
- At  $s_t$ , pedestrian chooses next action  $a$  maximizing the sum of instantaneous utility and value function

## State transition

- Move action:**
  - $s_{t+1}$  is determined stochastically in continuous using  $q_t(s_{t+1}|s_t, a)$
- Stay action:**
  - $s_{t+1}$  is determined without  $q_t(s_{t+1}|s_t, a)$

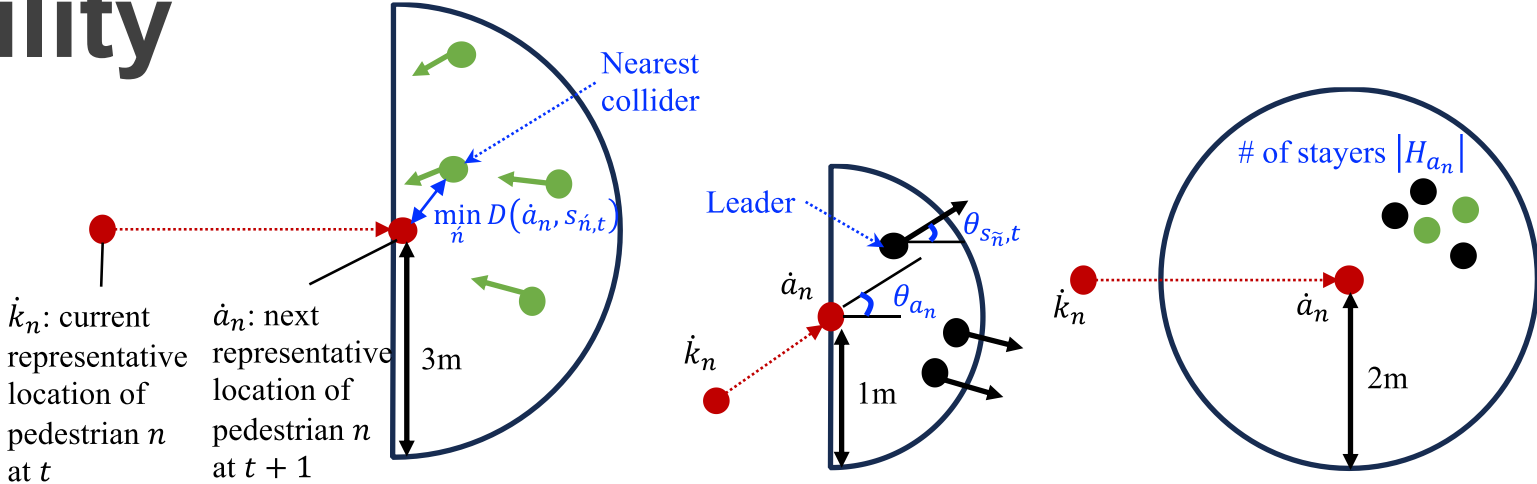
## Value function

- $V_t(a)$  is computed only in discrete approximation space  
(equivalent to consumer surplus)



# Instantaneous utility

When  $a$  is move action:



$$v_t(a|s_t) = \beta^{cao} x^{cao}(a|s_t) + \beta^{td} x^{td}(a|s_t) + \beta^{stm} x^{stm}(a|s_t) + \gamma^{cam} w^{cam}(a|s_t) + \gamma^{le} w^{le}(a|s_t) + \gamma^{cas} w^{cas}(a|s_t)$$

Collision avoidance from fixed object(s)

Tendency to avoid objects

1: start new move  
0: continue to move

Cost of shifting from stay to move

Collision avoidance with other movers

Tendency to avoid collision with other movers

1: leader present  
0: no leader

Tendency to follow the leading pedestrian

# of stayers within two meters

Collision avoidance with stayers

Travel distance per unit time

Tendency to choose the shortest route

Exogeneous variables

Endogenous variables

# Instantaneous utility

When  $a$  is move action:

$$v_t(a|s_t) = \beta^{cao} x^{cao}(a|s_t) + \beta^{td} x^{td}(a|s_t) + \beta^{stm} x^{stm}(a|s_t) + \gamma^{cam} w^{cam}(a|s_t) + \gamma^{le} w^{le}(a|s_t) + \gamma^{cas} w^{cas}(a|s_t)$$

Collision avoidance from fixed object(s)

Tendency to avoid objects

Travel distance per unit time

Tendency to choose the shortest route

1: start new move  
0: continue to move

Cost of shifting from stay to move

Negative interactions with other movers

Positive interactions with other movers

Negative interactions with other stayers

1: leader present  
0: no leader

Tendency to follow the leading pedestrian

# of stayers within two meters

Collision avoidance with stayers

Collision avoidance with other movers

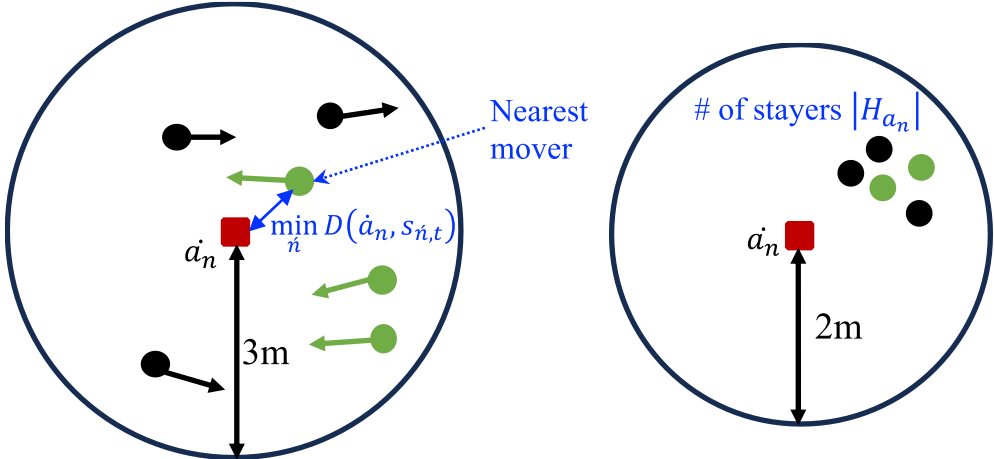
Tendency to avoid collision with other movers

Exogeneous variables

Endogenous variables

# Instantaneous utility

When  $a$  is stay action:



$$v_t(a|s_t) = \underbrace{\beta^{so} x(a|s_t)} + \underbrace{\beta^{mts} x^{mts}(a|s_t)} + \underbrace{\gamma^{sa} w^{sa}(a|s_t)} + \underbrace{\gamma^{as} w^{as}(a|s_t)}$$

Distance from the object

attractiveness of object

1: start new stay  
0: continue to stay

Cost of shifting from move to stay

distance from movers

Tendency to avoid collision with movers

# of stayers within two meters

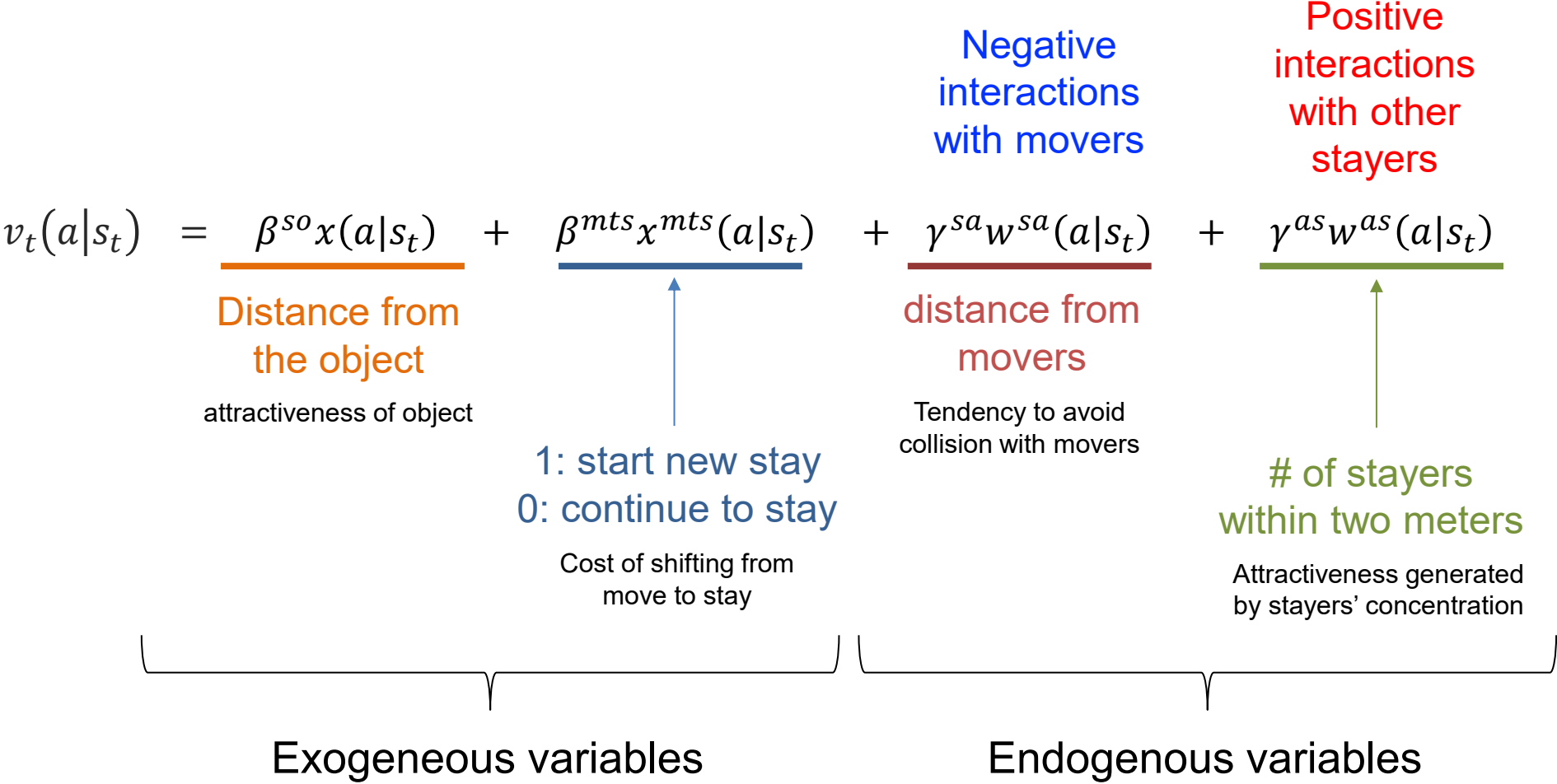
Attractiveness generated by stayers' concentration

Exogeneous variables

Endogenous variables

# Instantaneous utility

When  $a$  is stay action:

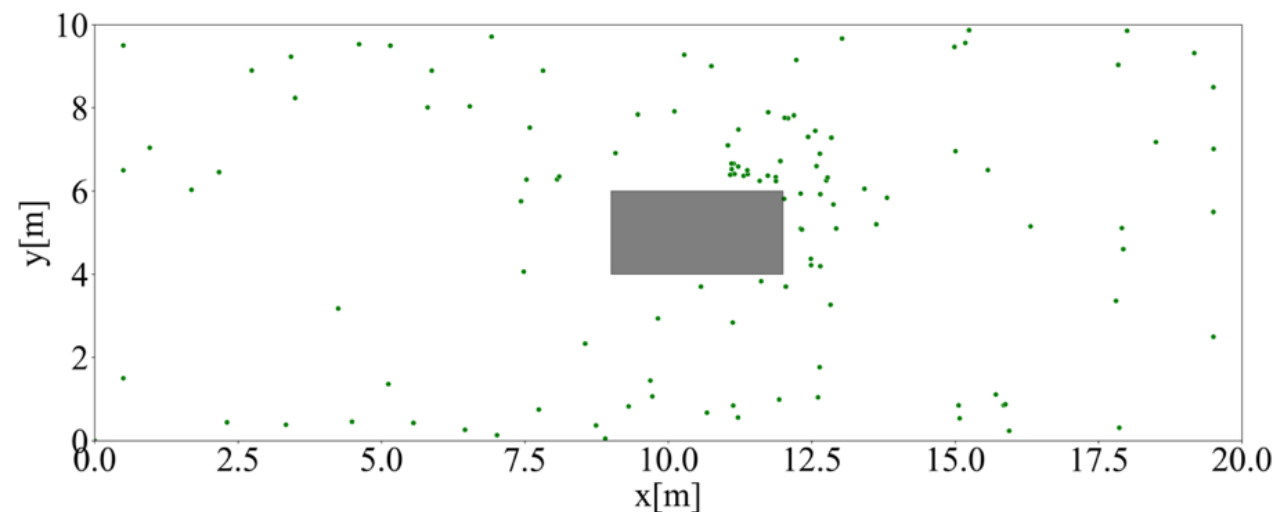


# Numerical simulation

**Main Objective:** To examine how urban public space design influences competition and overall performance

**Simulation Setting:**

- 10m × 20m which has 200 cells
- Flow in/out from both sides
- Start randomly from 10 cells on each side
- Each pedestrian' action every 1.0 [s]
- 20 stayers randomly placed within 2m of objects



# Conclusions

Develop pedestrian simulation model with mover-stayer competition based on the dynamic discrete choice modeling framework

## Key observation from numerical simulation

1. While multiple equilibria emerge across trials, the corresponding CS value remains within a certain range
  - Calculate relatively stable performance indicators
2. An increase in the number of travelers does not necessarily decrease traveler speed in some scenarios
  - Contradict the implications of pedestrian fundamental diagram
3. Consolidating object on one side is a better strategy to maximize CS

# Nusantara: Beyond trips and flows

- Massive investment in transport infrastructure
- Although visions highlight social cohesion, limited concrete attention has been paid to how transport weaves social networks and cultural values.



**Key question: Are we designing for flows, or for society?**

This is where our community can contribute:  
**bringing the social fabric into transport design.**