7th International Conference on Geographical Information Systems Theory, Applications and Management (GISTAM 2021): 24 April 2021, online streaming event

Keynote Lecture

Integration of Multiple Spatiotemporal Demographic Data and Its Applications for Disaster Mitigation Planning

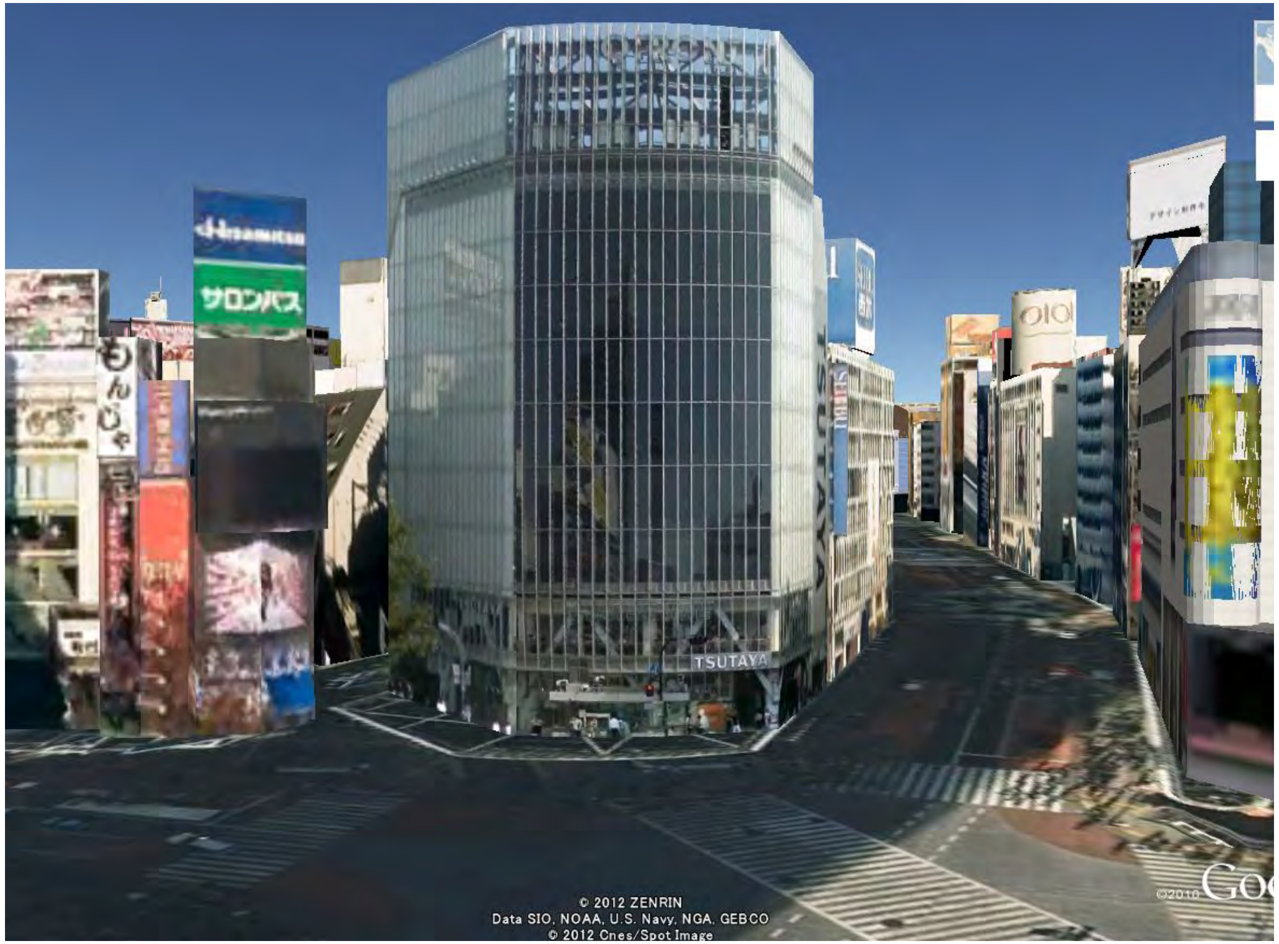
Tokyo Tech

Toshihiro OSARAGI
Tokyo Institute of Technology

Outline

- ✓ Background & Motivation
- ✓ Spatiotemporal Demographic Data
  (its potential and limitation)
- ✓ Integration Method (1) for Demographic data
  (building use / purpose / attribute)
- ✓ Integration Method (2) for Demographic data
  (inflow / outflow / static)
- ✓ Applications for Disaster Mitigation Planning
- ✓ Summary and Conclusions

Shibuya City in Tokyo



A picture taken from a model produced by Google Earth

Shibuya City in Tokyo

Background

Ordinal modeling techniques of environment and urban systems based only on static physical objects do not always describe a certain aspects of their realities

The next step in modeling of the urban environment is to take people into account

In order to consider people in spatial models, it would be a possible means to use spatially referenced demographic data (Census Data)

Background

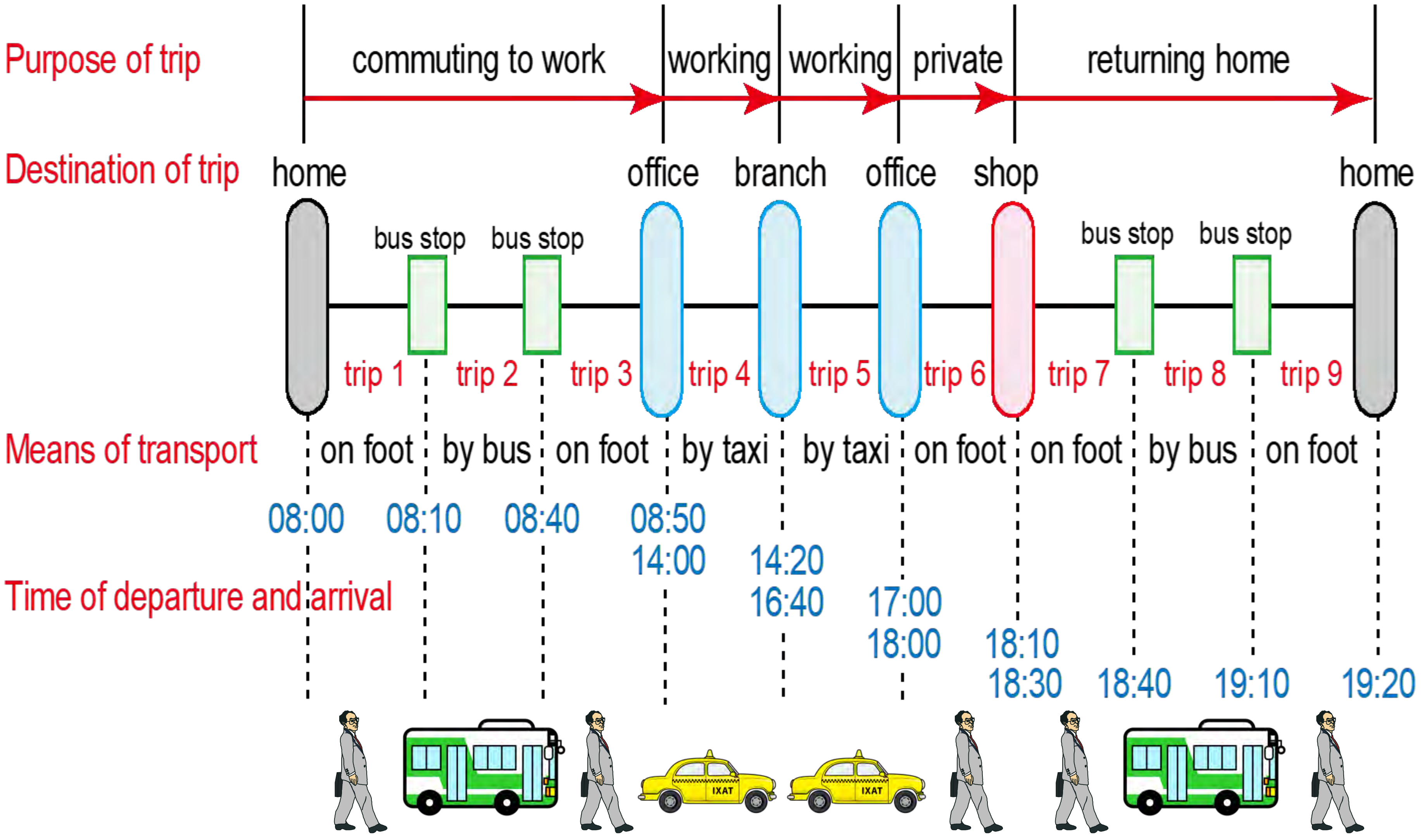
Most estimates of human activities have been estimated based on static population distributions (Census Data)

However

The actual spatial distribution of people changes by the hour, or even by the minute, since they are travelling for a variety of purposes over long distances

Person-Trip Survey Data (PT Data) can provide us the information about the dynamically varying spatiotemporal distribution of people

Person Trip Survey Data (PT Data)

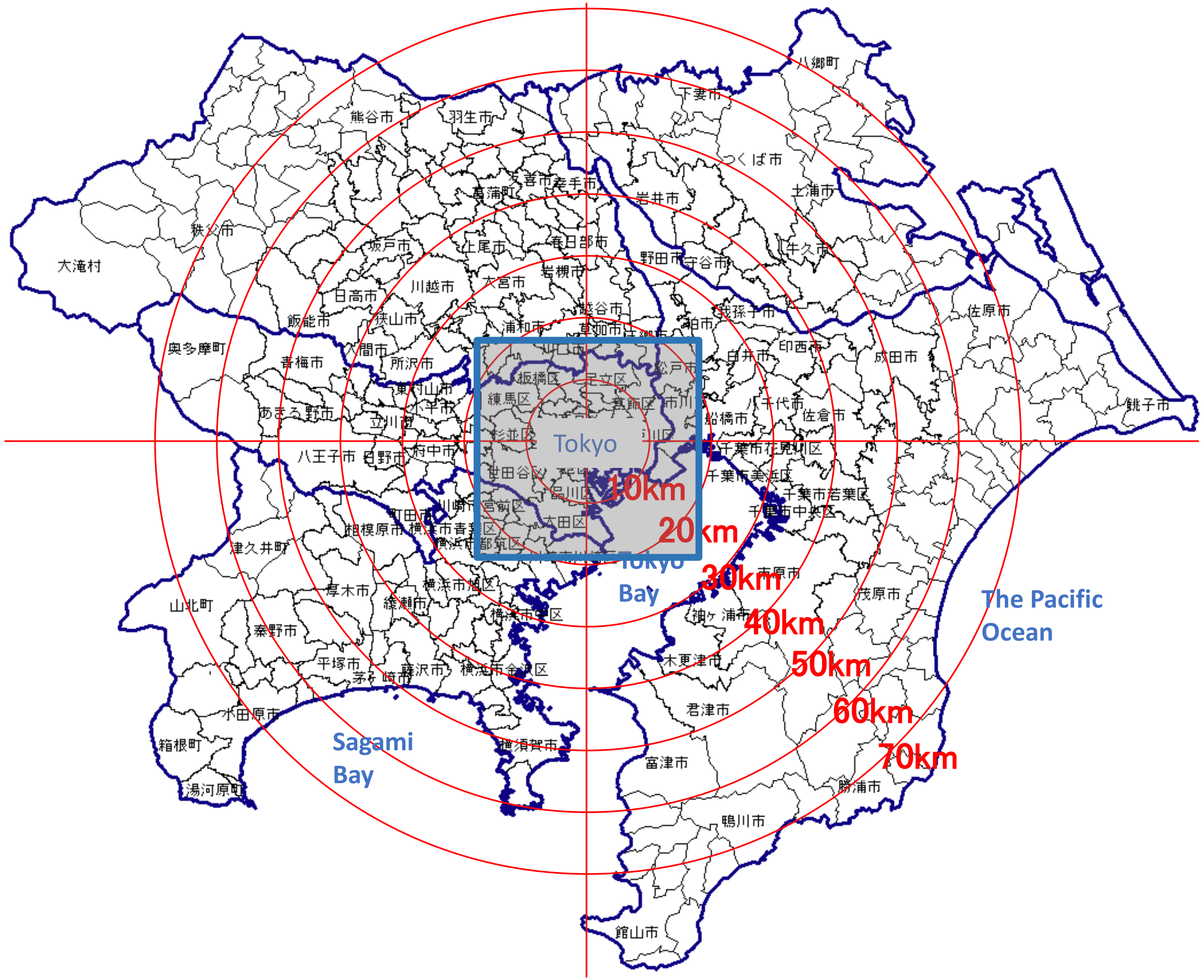


Overview of PT Data

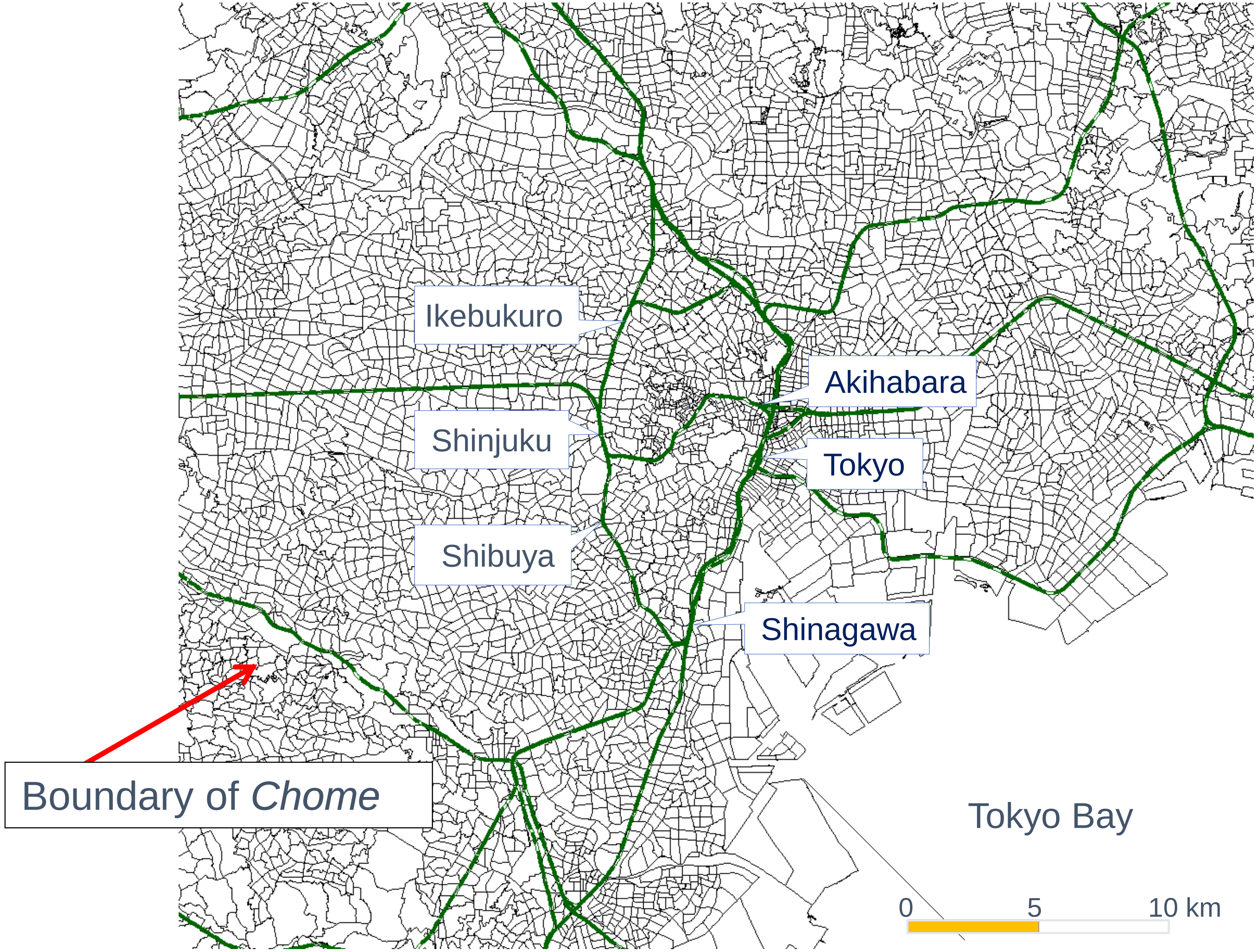
Questionnaire-based survey

- Regions:
  Greater Tokyo Metropolitan Area
- Sampling:
  Random sampling based on census data
  (1,235,883 persons from 32,896,705 persons)
- Valid data:
  883,044 samples
  sampling ratio = 2.68 %
  (= 883,044 / 32,896,705)
- Contents:
  Personal attributes, Departure/ Arrival Location and Time, Purpose of trip, Means of trip, … etc.

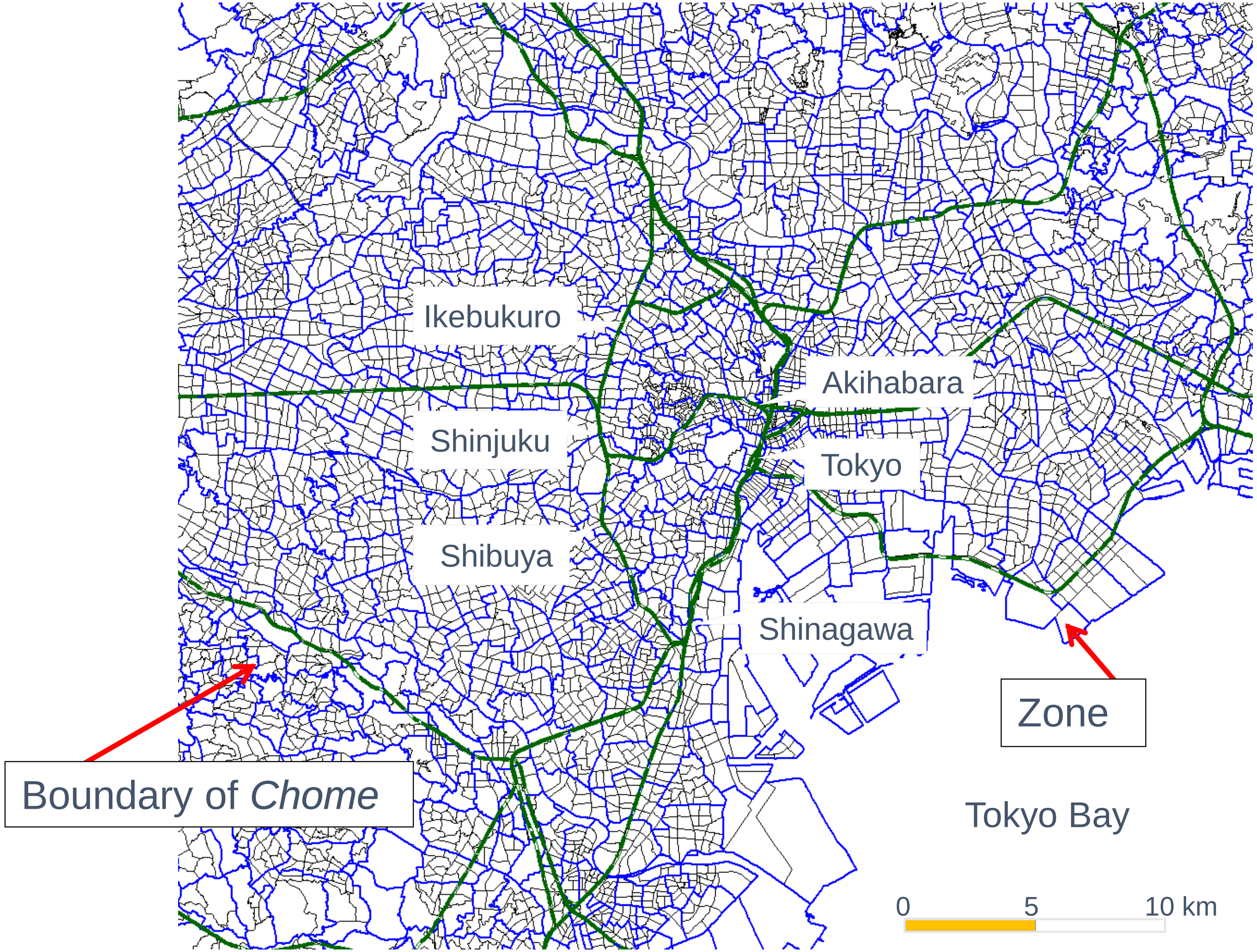
Survey Area of PT Data



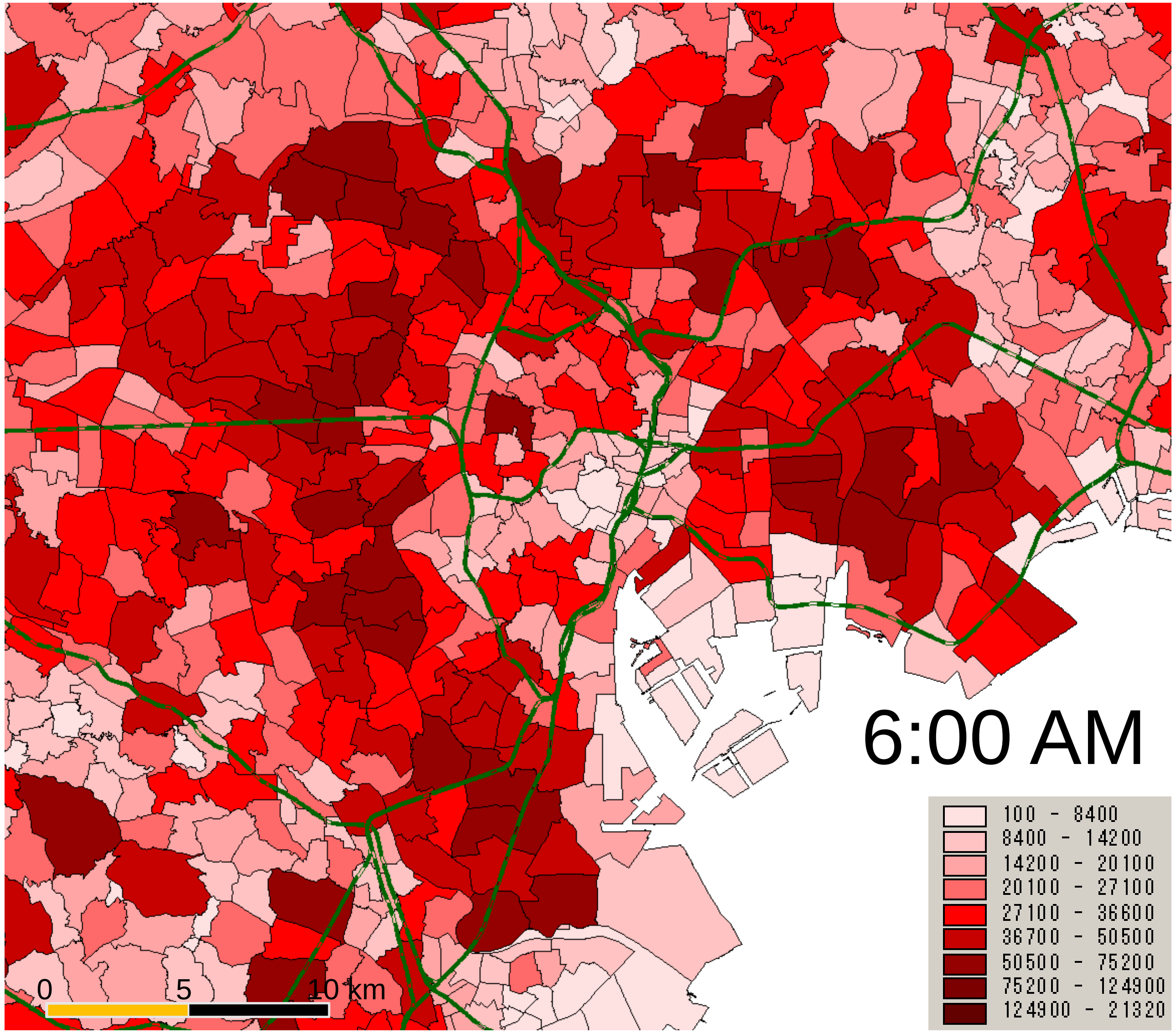
Numbered Subdivision of Area for Address



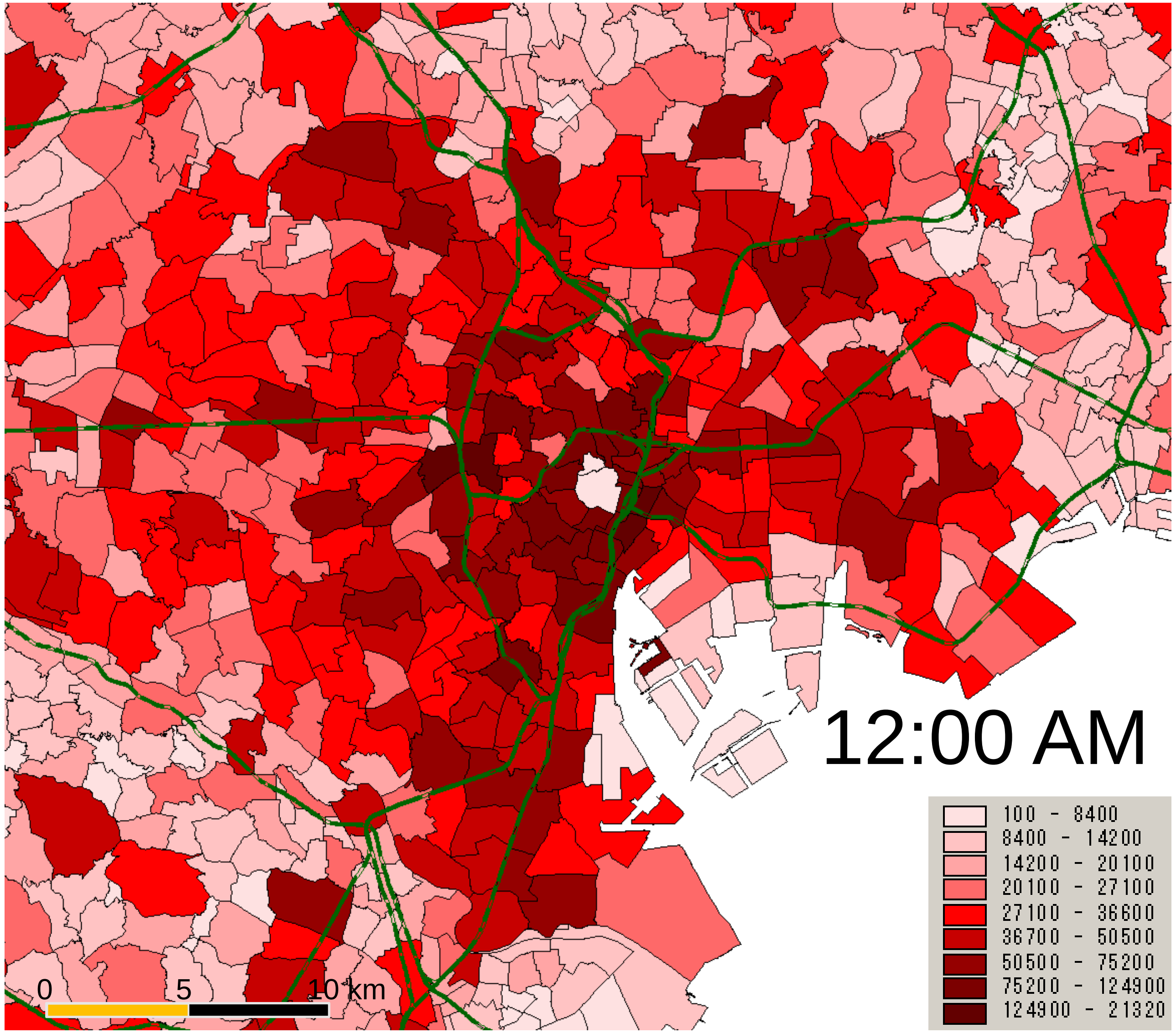
Zone of PT Data



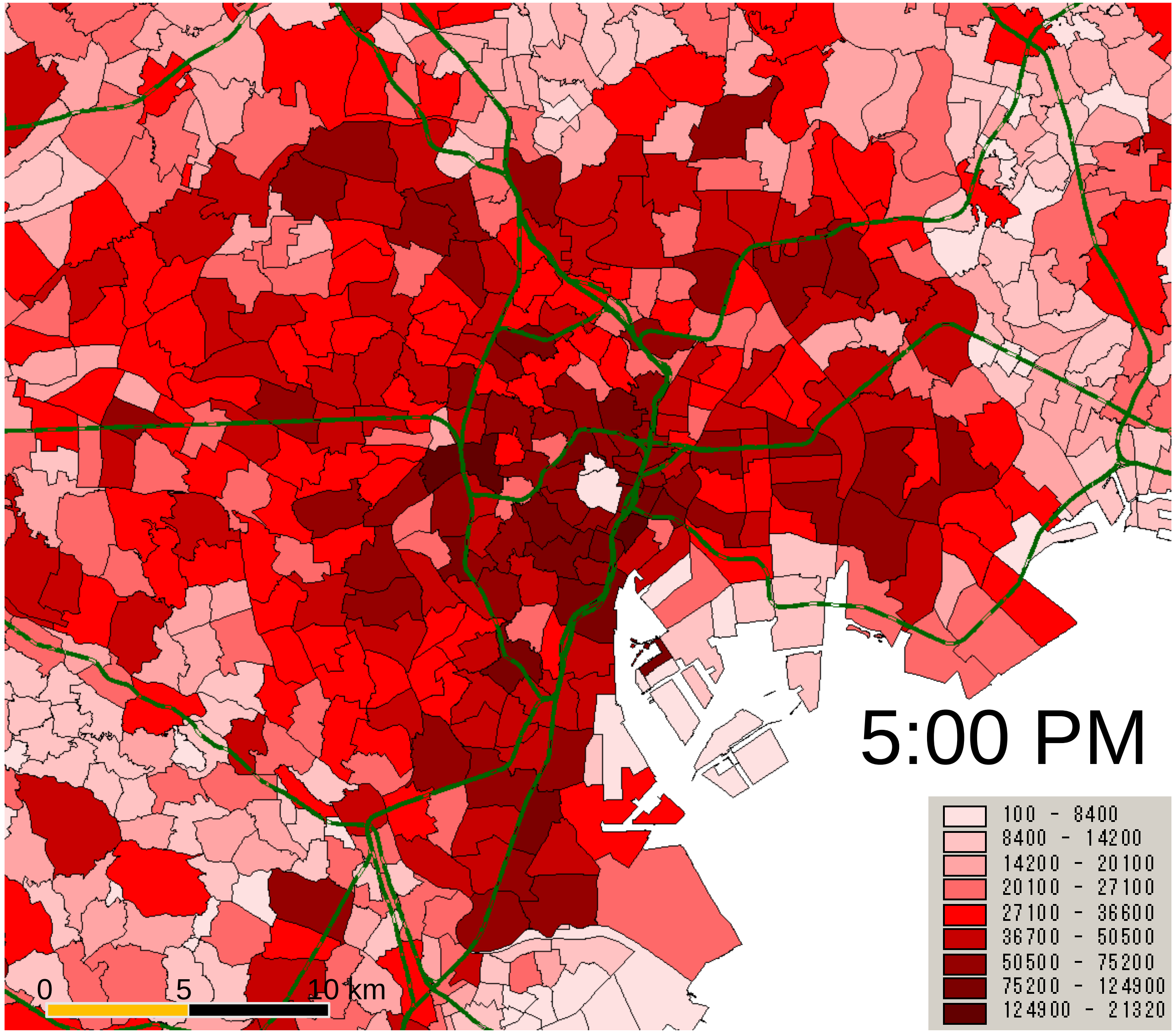
Spatiotemporal Distribution of People inside Buildings



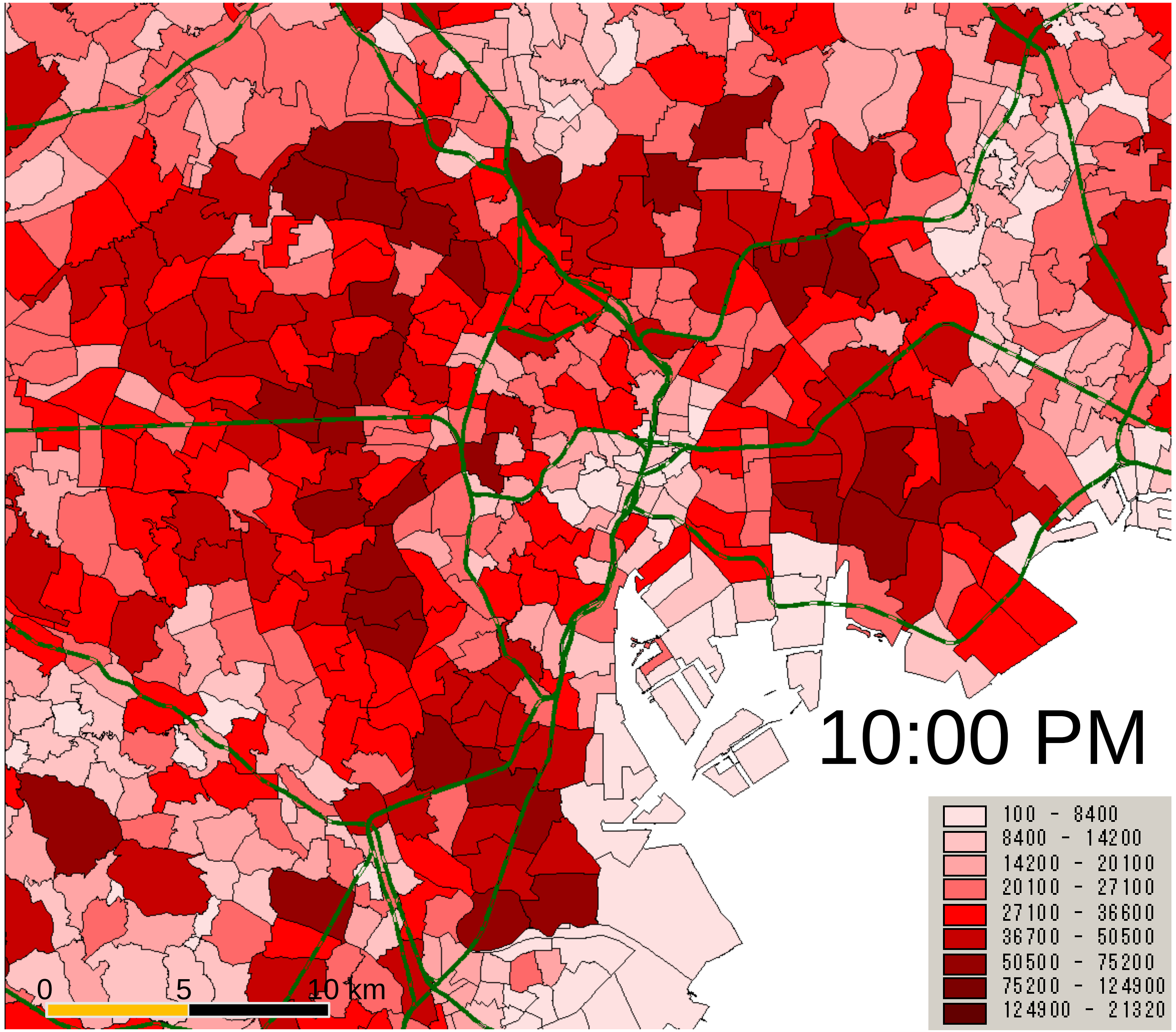
Spatiotemporal Distribution of People inside Buildings



Spatiotemporal Distribution of People inside Buildings



Spatiotemporal Distribution of People inside Buildings



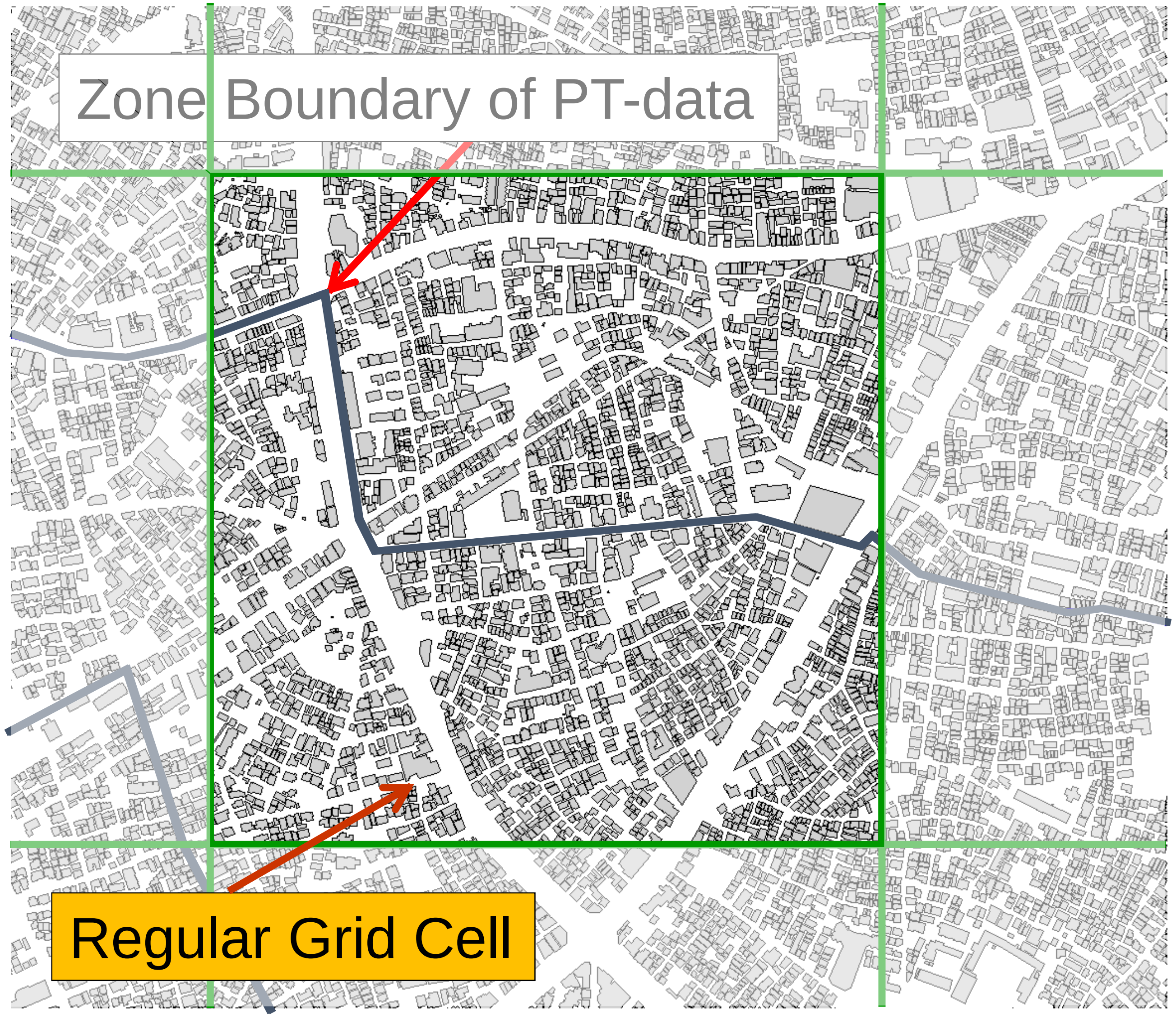
Background / Motivation

Person-Trip Survey Data (PT Data) provide us the information about the dynamically varying spatiotemporal distribution of people.

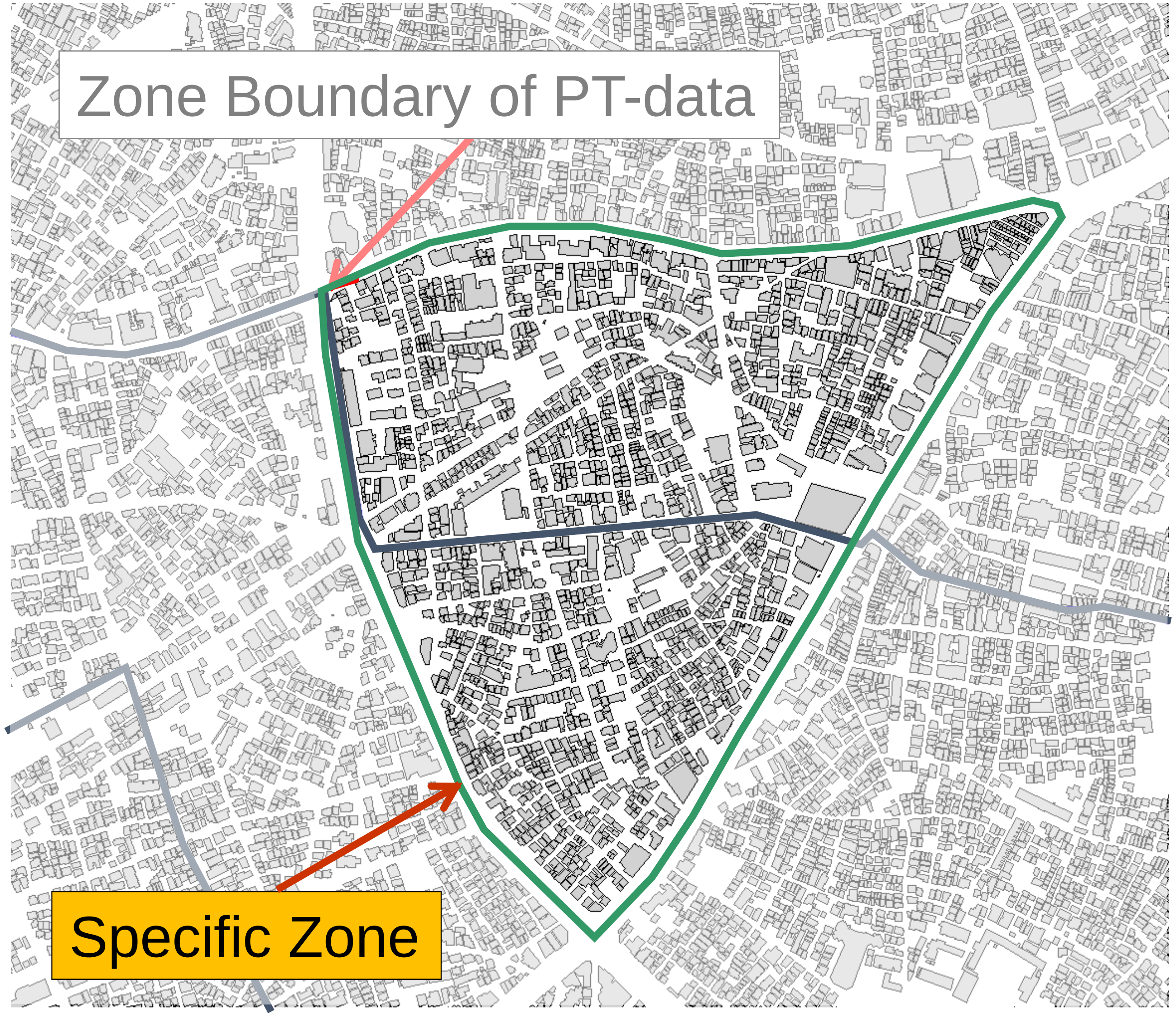
However

The problem with "zone" is that they are not regular in size making inter-comparisons very difficult.

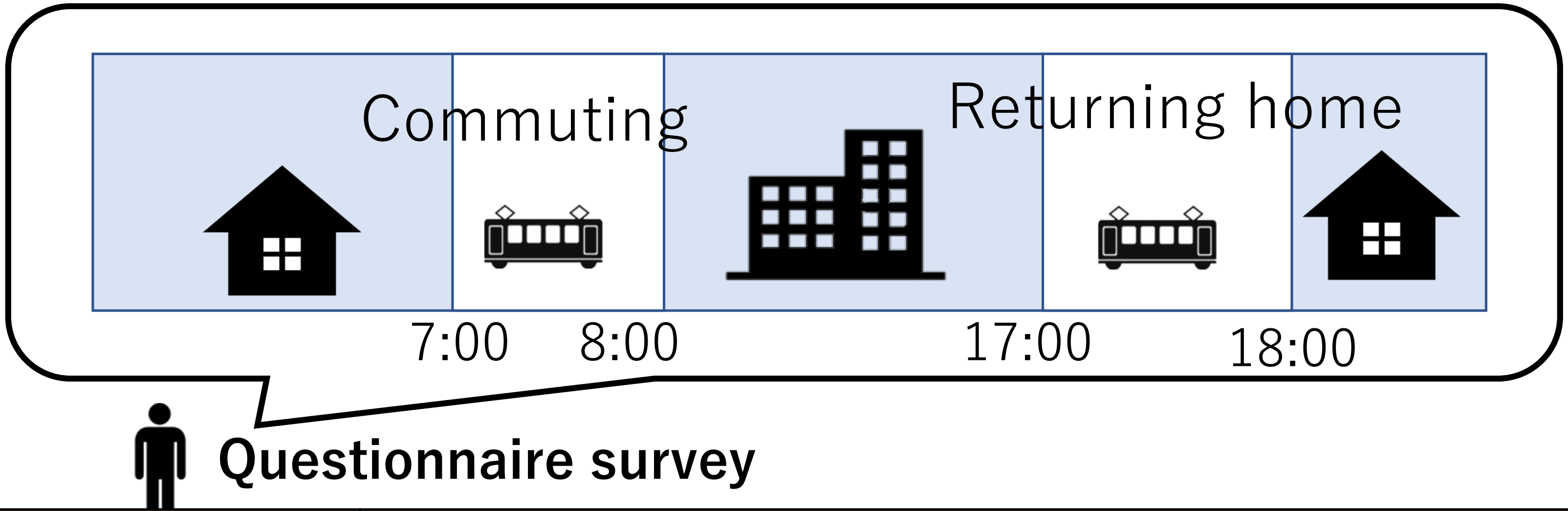
Limitation of PT-data (1)



Limitation of PT-data (2)

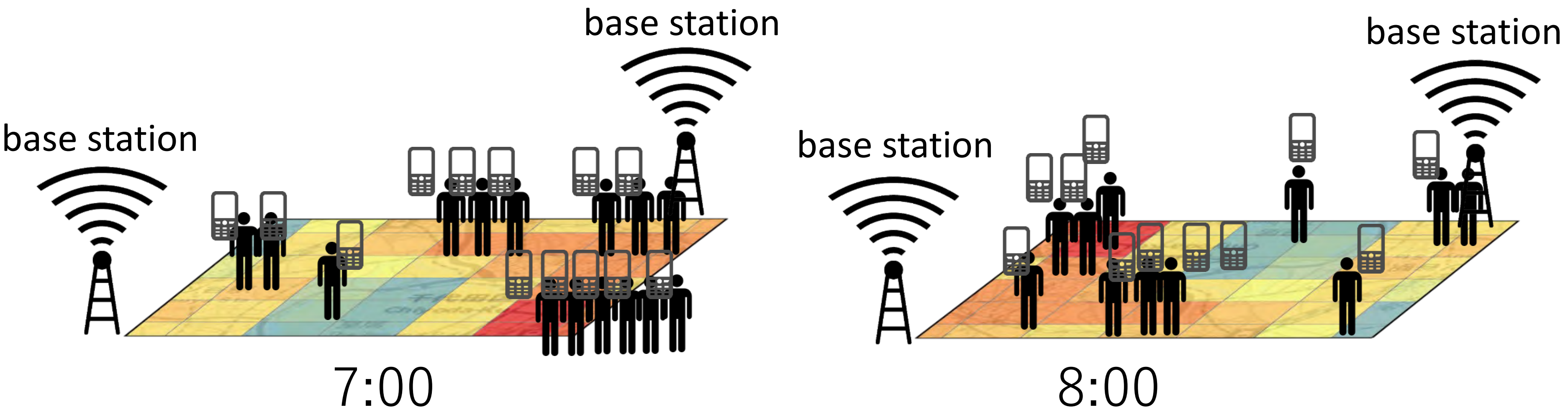


Person Trip Survey Data (PT Data)



Strengths	**Detailed behavior** (purpose of trip, location/time information of trip, means of transportation etc.)
	Many kinds of attributes (age, gender, occupation, residence etc.)
Limitations	**Low frequency of survey** (**once every 10 years**)
	Low sample rate (**2～3%**)
	Not regular in size

Mobile Spatial Statistics (MSS) data

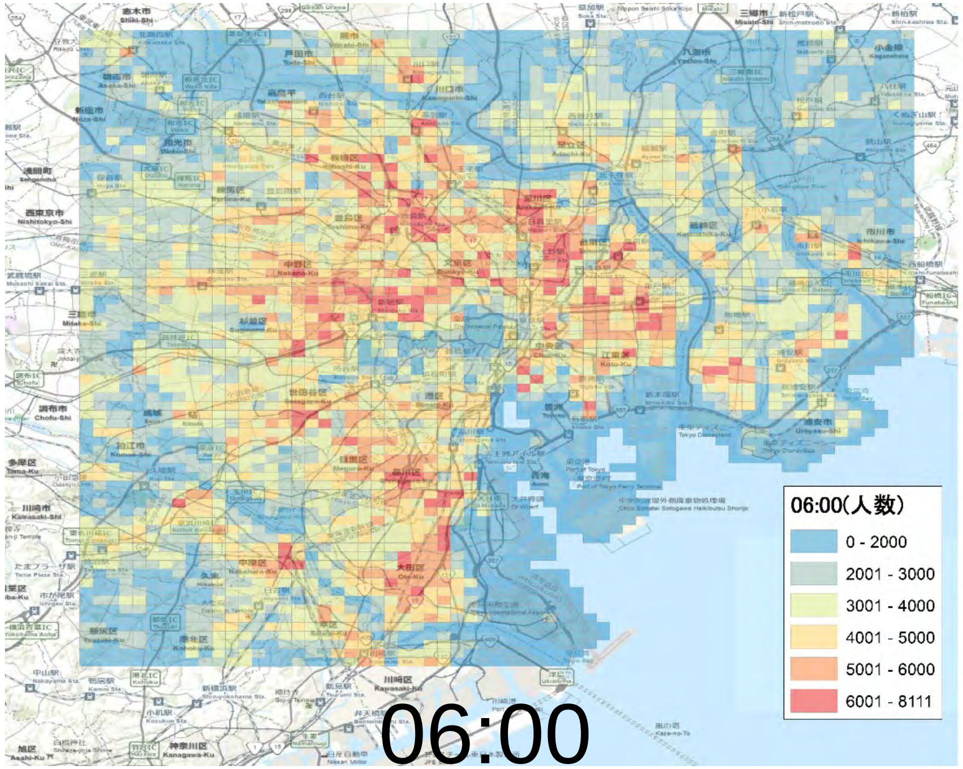


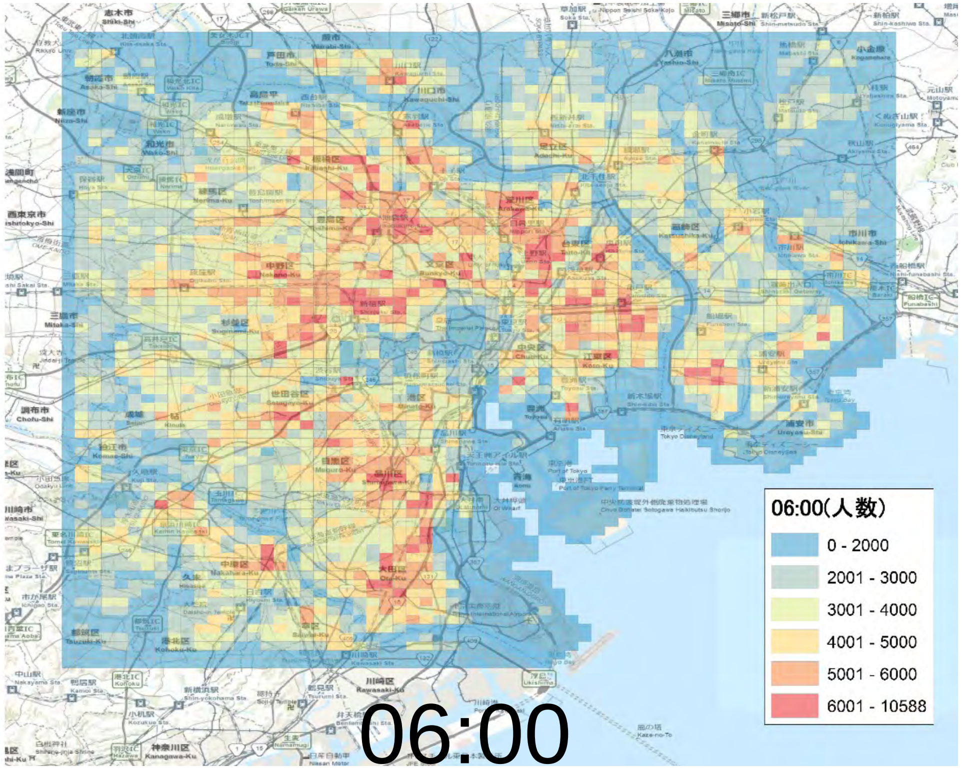
Strengths	Able to grasp distribution of people with **small spatial unit** (**250m or 500m grids**)
	Able to grasp population **every hour**
	High sample rate (penetration) (**around 40 %**)
Limitations	Unable to distinguish people **staying inside buildings or moving outside**
	Few kinds of attributes (age, gender, residence)

Mobile Spatial Statistics (MSS) data

Tuesday (Oct.20, 2015)

Sunday (Oct.18, 2015)

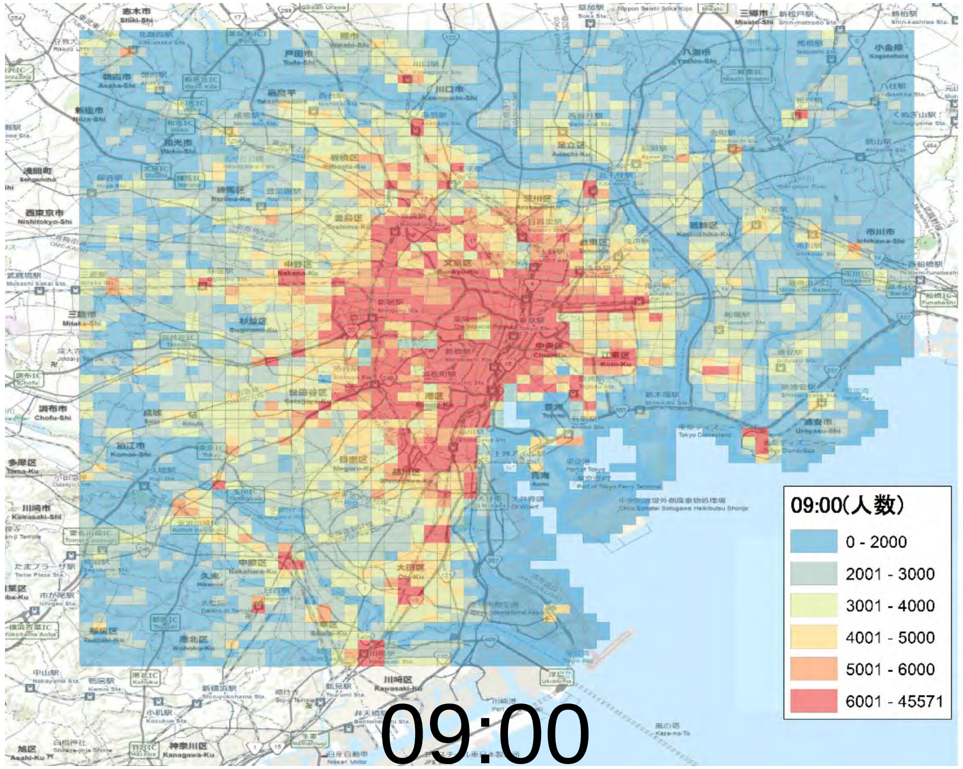




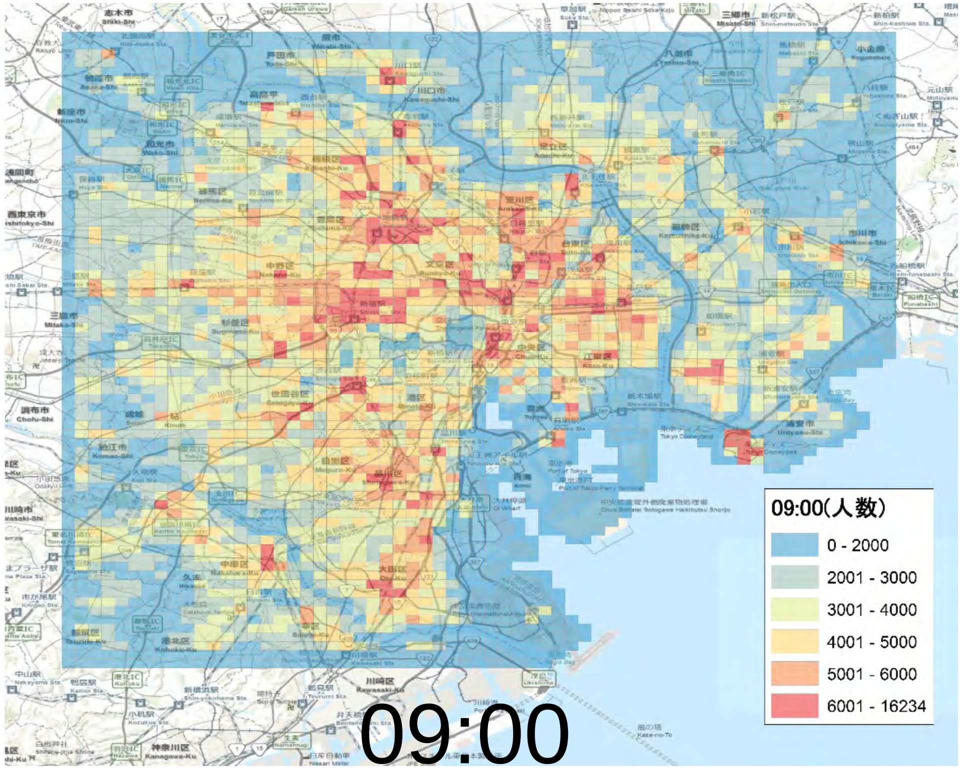
Mobile phone : DoCoMo (Nippon Telegraph and Telephone Corporation)
Grid size : 500 m (250 m in highly populated area)

Mobile Spatial Statistics (MSS) data

Tuesday (Oct.20, 2015)



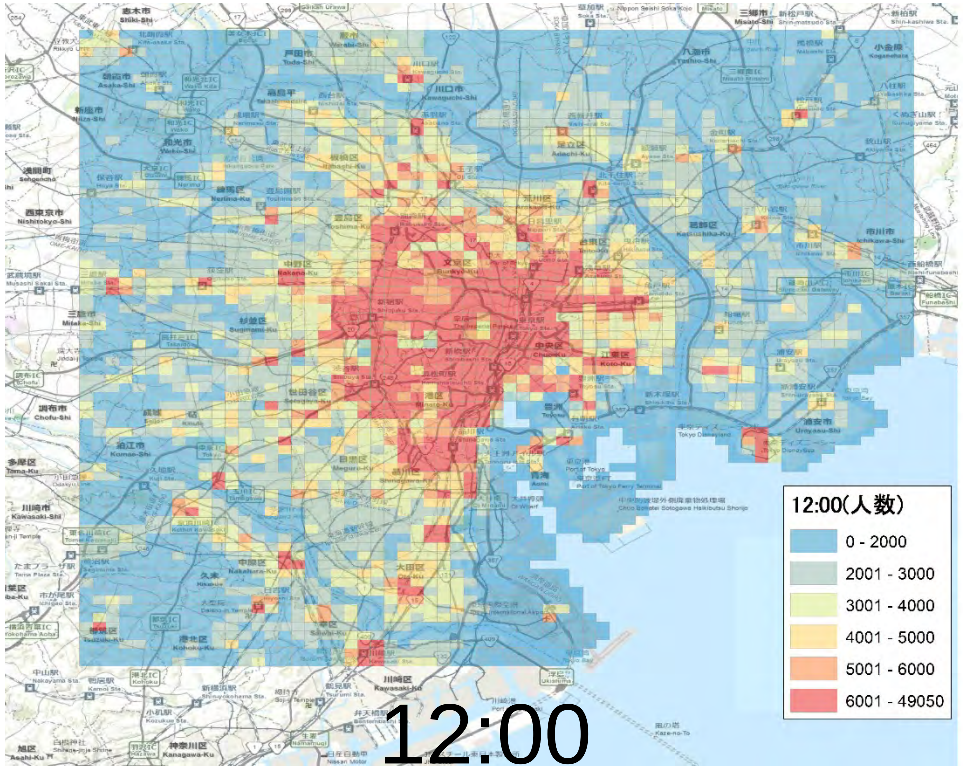
Sunday (Oct.18, 2015)



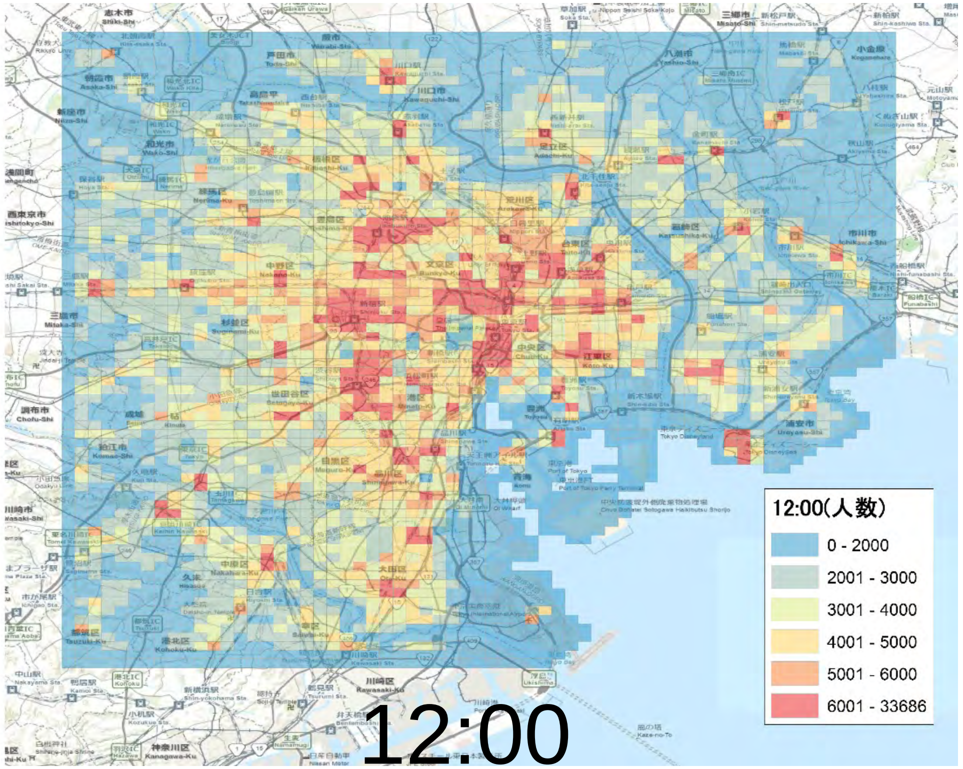
Mobile phone : DoCoMo (Nippon Telegraph and Telephone Corporation)
Grid size : 500 m (250 m in highly populated area)

Mobile Spatial Statistics (MSS) data

Tuesday (Oct.20, 2015)



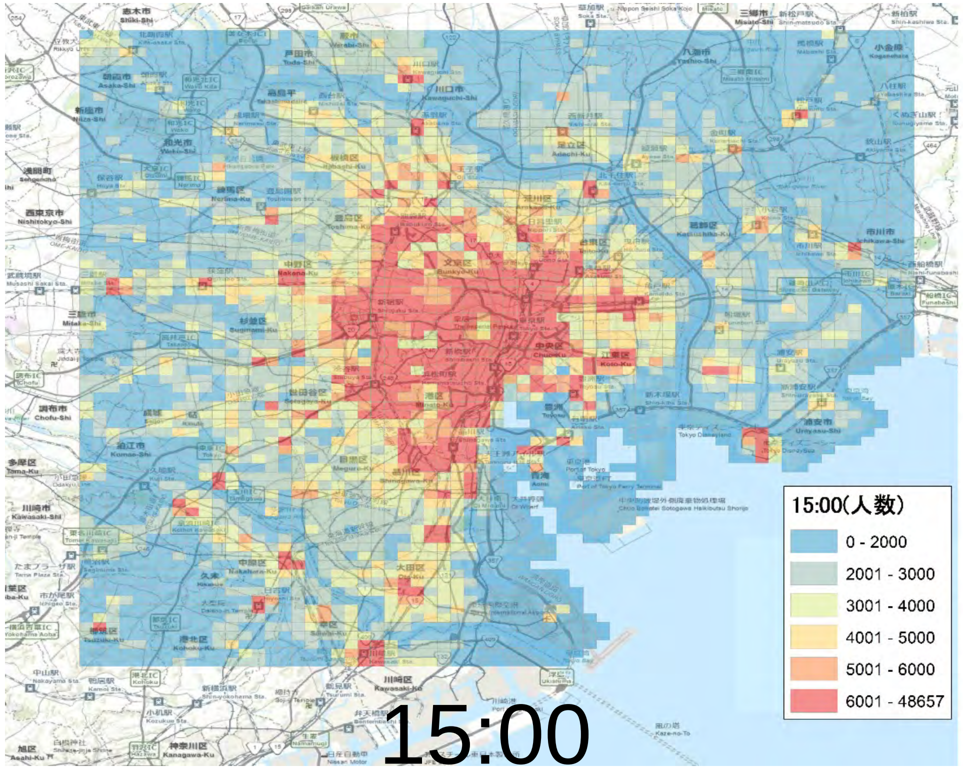
Sunday (Oct.18, 2015)



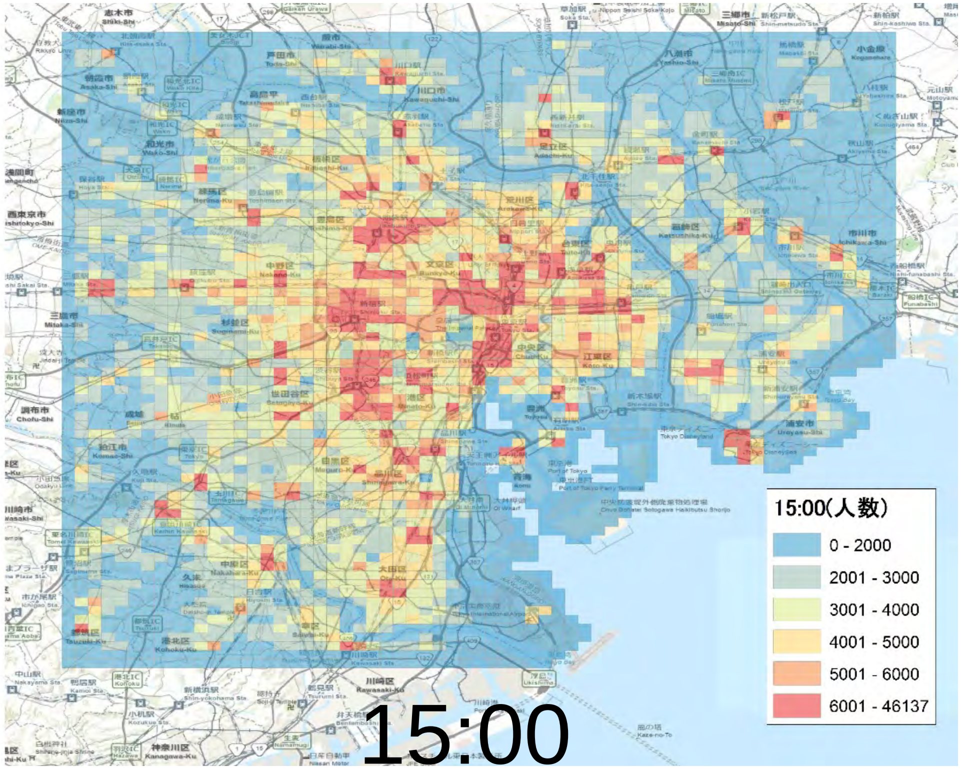
Mobile phone : DoCoMo (Nippon Telegraph and Telephone Corporation)
Grid size : 500 m (250 m in highly populated area)

Mobile Spatial Statistics (MSS) data

Tuesday (Oct.20, 2015)



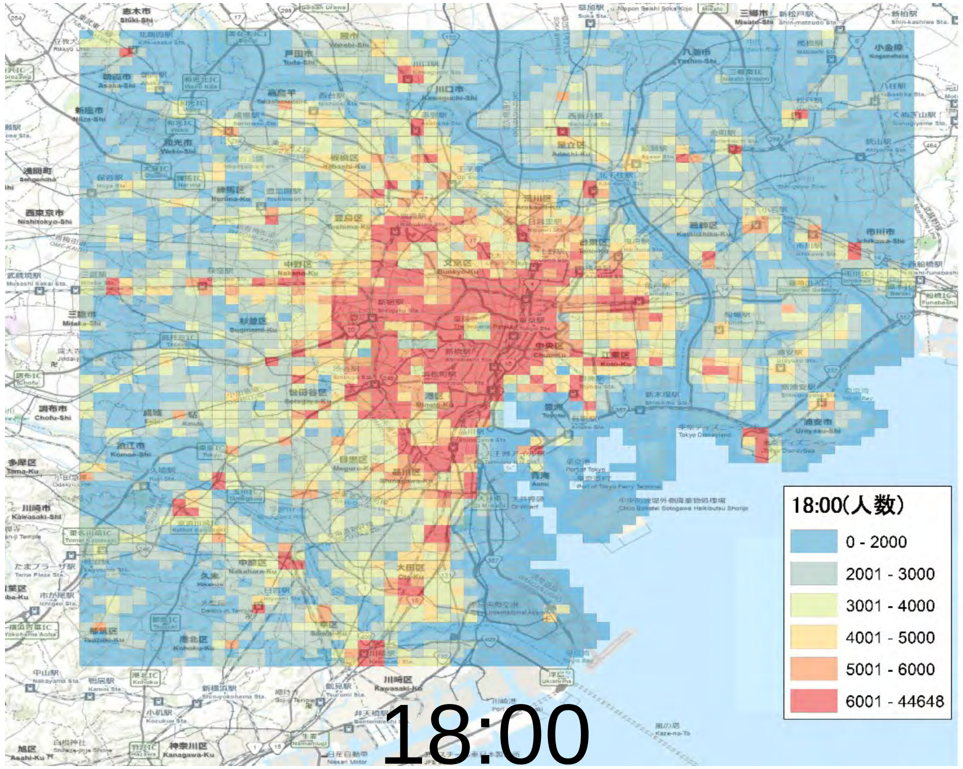
Sunday (Oct.18, 2015)



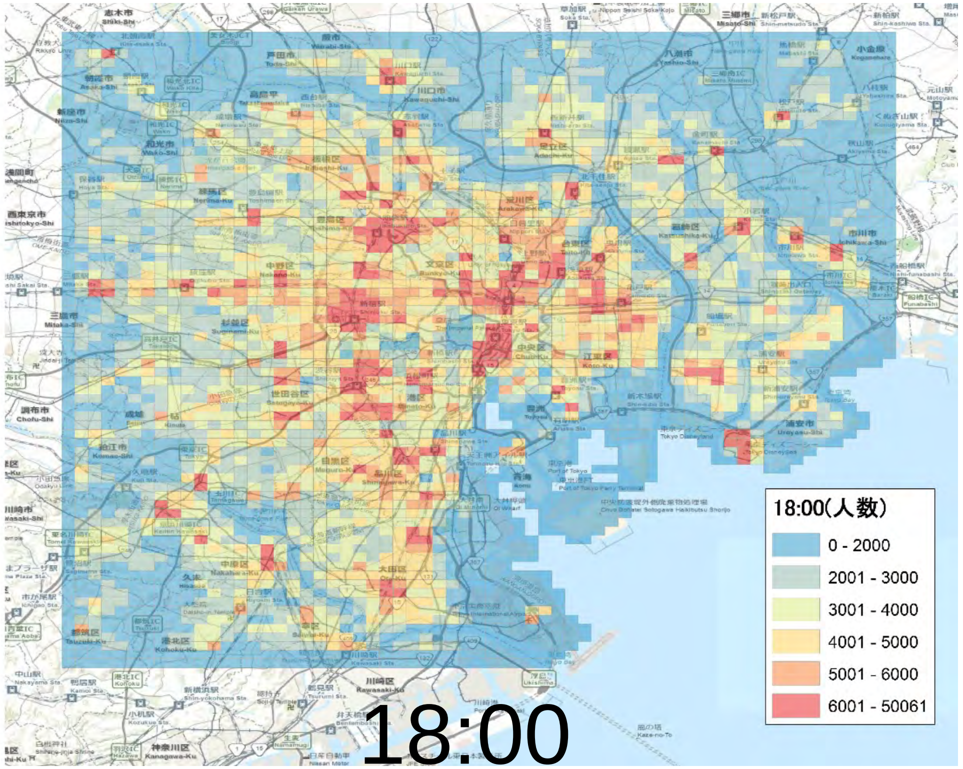
Mobile phone : DoCoMo (Nippon Telegraph and Telephone Corporation)
Grid size : 500 m (250 m in highly populated area)

Mobile Spatial Statistics（MSS) data

Tuesday (Oct.20, 2015)



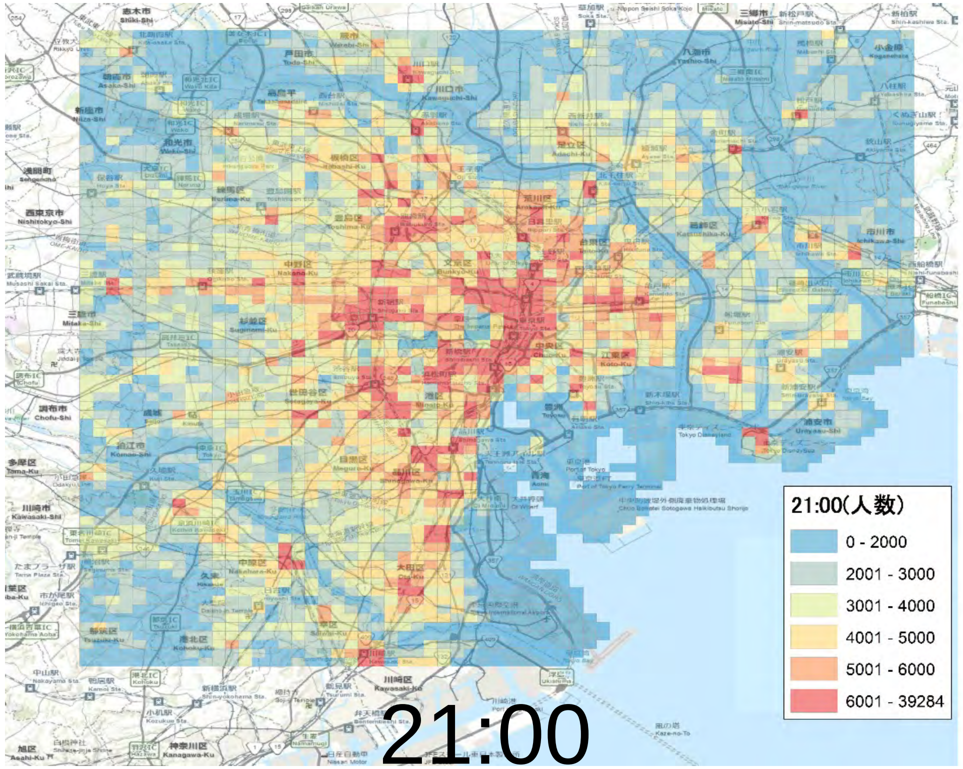
Sunday (Oct.18, 2015)



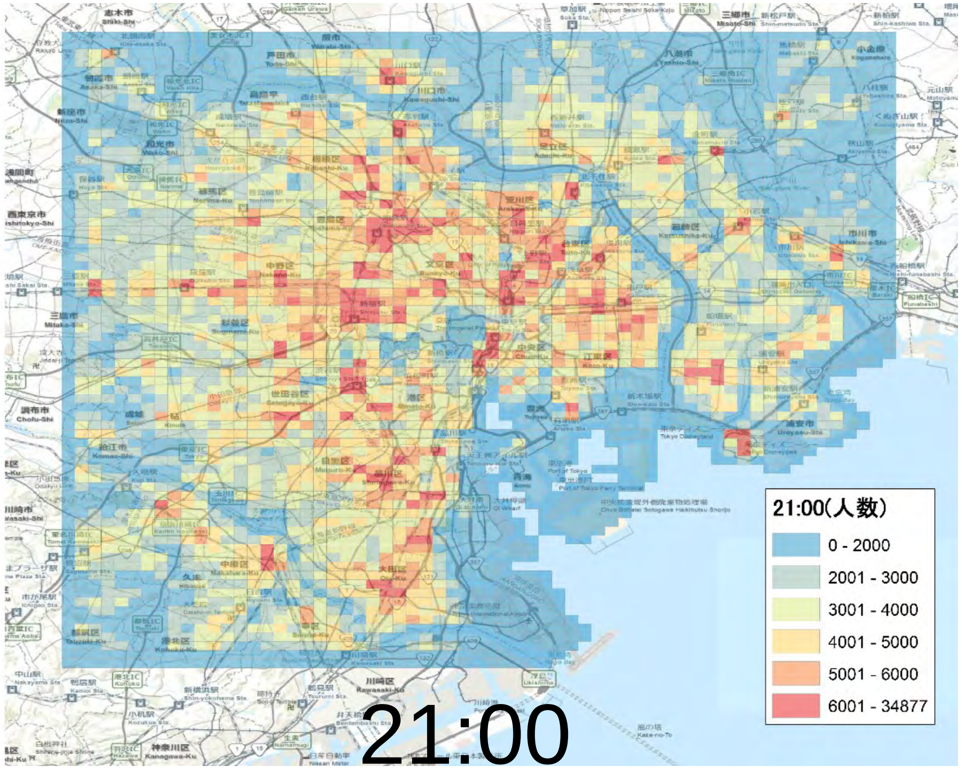
Mobile phone : DoCoMo (Nippon Telegraph and Telephone Corporation)
Grid size : 500 m (250 m in highly populated area)

Mobile Spatial Statistics (MSS) data

Tuesday (Oct.20, 2015)

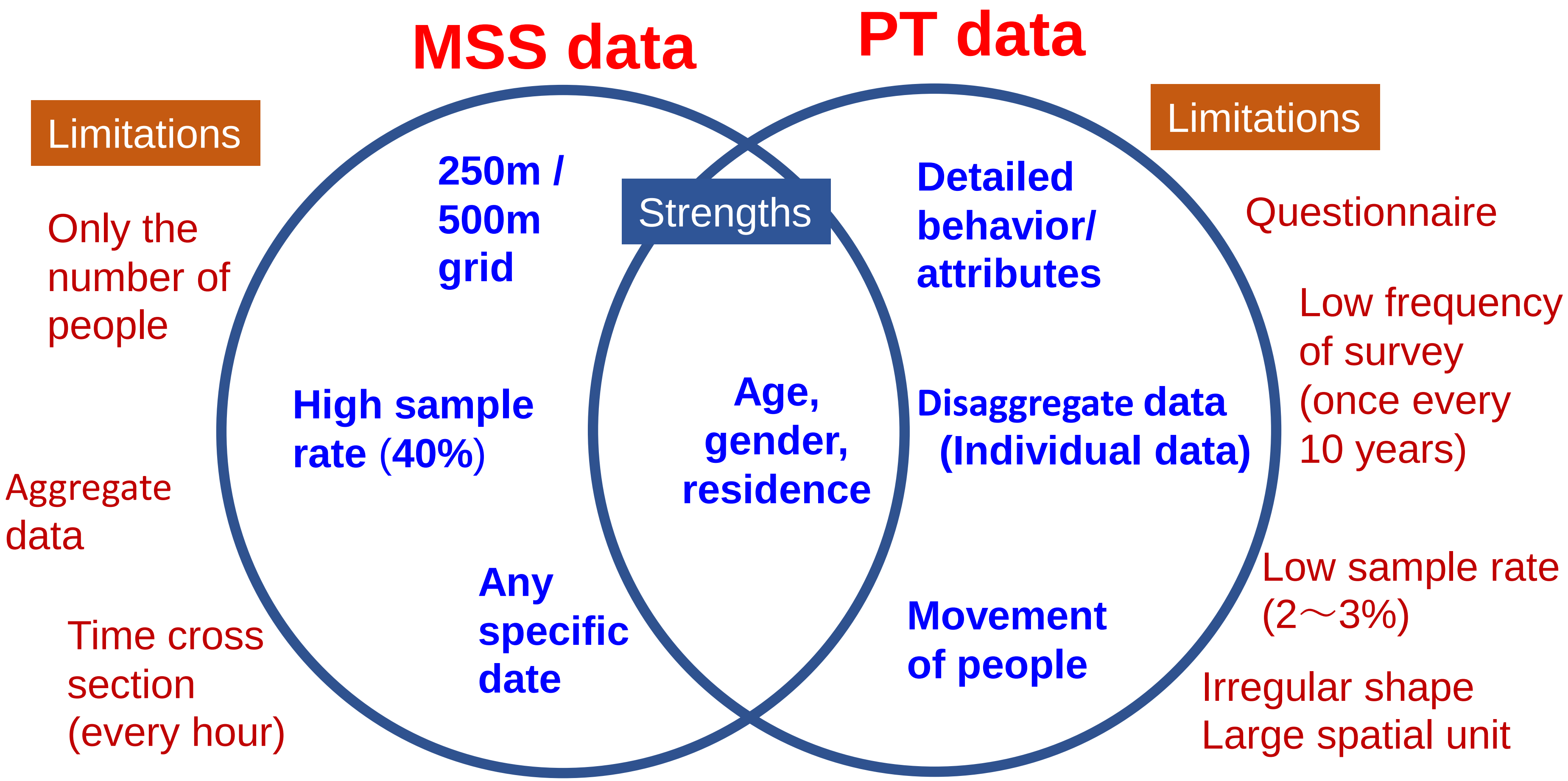


Sunday (Oct.18, 2015)



Mobile phone : DoCoMo (Nippon Telegraph and Telephone Corporation)
Grid size : 500 m (250 m in highly populated area)

Summary of Strengths / Limitations



Enhance these urban demographic big-data by complementing the disadvantages and utilizing the advantages

Outline

- ✓ Background & Motivation
- ✓ Spatiotemporal Demographic Data
  (its potential and limitation)
- ✓ Integration Method (1) for Demographic data
  (building use / purpose / attribute)
- ✓ Integration Method (2) for Demographic data
  (inflow / outflow / static)
- ✓ Applications for Disaster Mitigation Planning
- ✓ Summary and Conclusions

Attribute/ Purpose of Stay/ Building use

MSS data

Precise Spatiotemporal distribution of population

Decomposed into each building use

Building use
Day of week
Time of the day
Location

School

Office

Restaurant

Shop

Hospital

Amusement

Bar

Estimating Number of People by Each Building Use

The number of people

The number of people in building use j

i : cell

j : building use

t : time

$$y_i^t = \sum_j y_{ij}^t$$

MSS data

$$= \sum_j D_{ij}^t \; x_{ij}$$

GIS data

Density of people

Floor-area of buildings

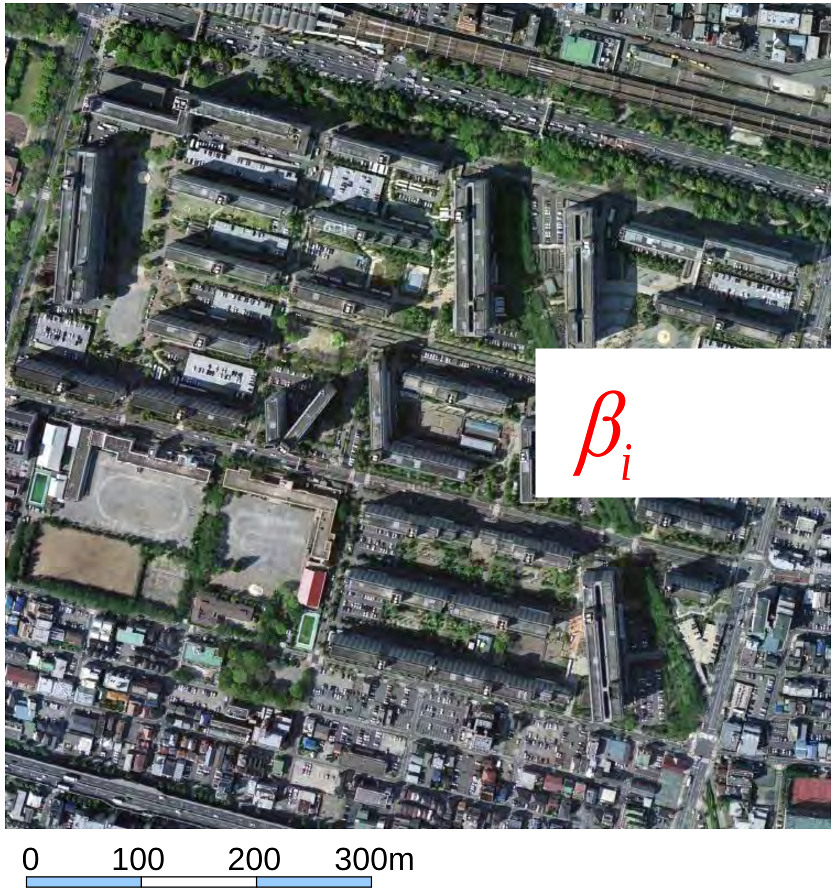
$$= \sum_j \alpha_j^t \beta_i \; x_{ij}$$

Time fluctuation factor (Temporal Change)

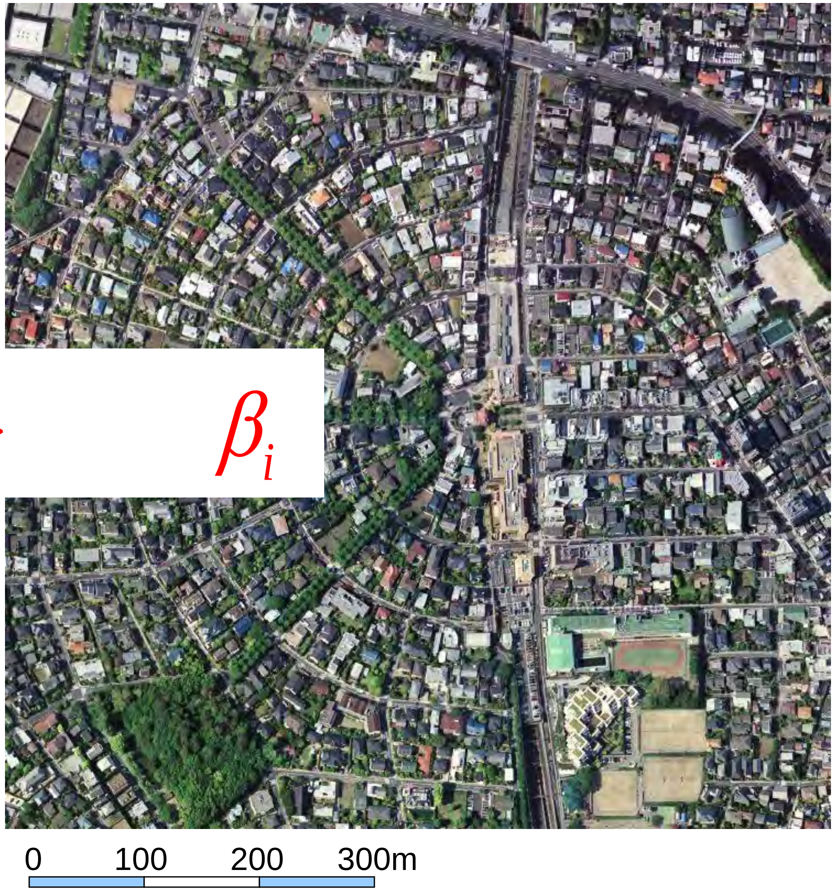
Location factor (Average Density)

Location Characteristic Factor

High density housing estate | Low density detached house



$$\beta_i > \beta_i$$



Location Characteristic Factor

High density housing estate

Flats in business district

$$\beta_i > \beta_i$$

0 100 200 300m

0 100 200 300m

Generalization of Model

Descriptive model

The number of people | Average density = unique parameter for each zone i

$$y_i^t = \beta_i \sum_j \alpha_j^t x_{ij}$$

Temporal changes

i : cell

j : building use

t : time

$$\frac{1}{N}\sum_{t=1}^{N} \beta_i = 1$$

Predictive model

General explanatory variables of available data

$$y_i^t = \left(\sum_k \gamma_k z_{ik}\right)\left(\sum_j \alpha_j^t x_{ij}\right)$$

Calibration Method of Model

$$\gamma_k = 1 \quad for\ all\ k$$

MSS data

GIS data

$$y_i^t = \left(\sum_k \gamma_k z_{ik}\right)\left(\sum_j \alpha_j^t x_{ij}\right)$$

GIS data

$$\frac{1}{N}\sum_{t=1}^{N}\left(\sum_k \gamma_k z_{ik}\right) = 1$$

$$\left|\frac{{}_n\alpha_j^t - {}_{n-1}\alpha_j^t}{{}_{n-1}\alpha_j^t}\right| \leq 0.01\%$$

$$\left|\frac{{}_n\gamma_k - {}_{n-1}\gamma_k}{{}_{n-1}\gamma_k}\right| \leq 0.01\%$$

$$y_i^t = \left(\sum_k \gamma_k z_{ik}\right)\left(\sum_j \alpha_j^t x_{ij}\right)$$

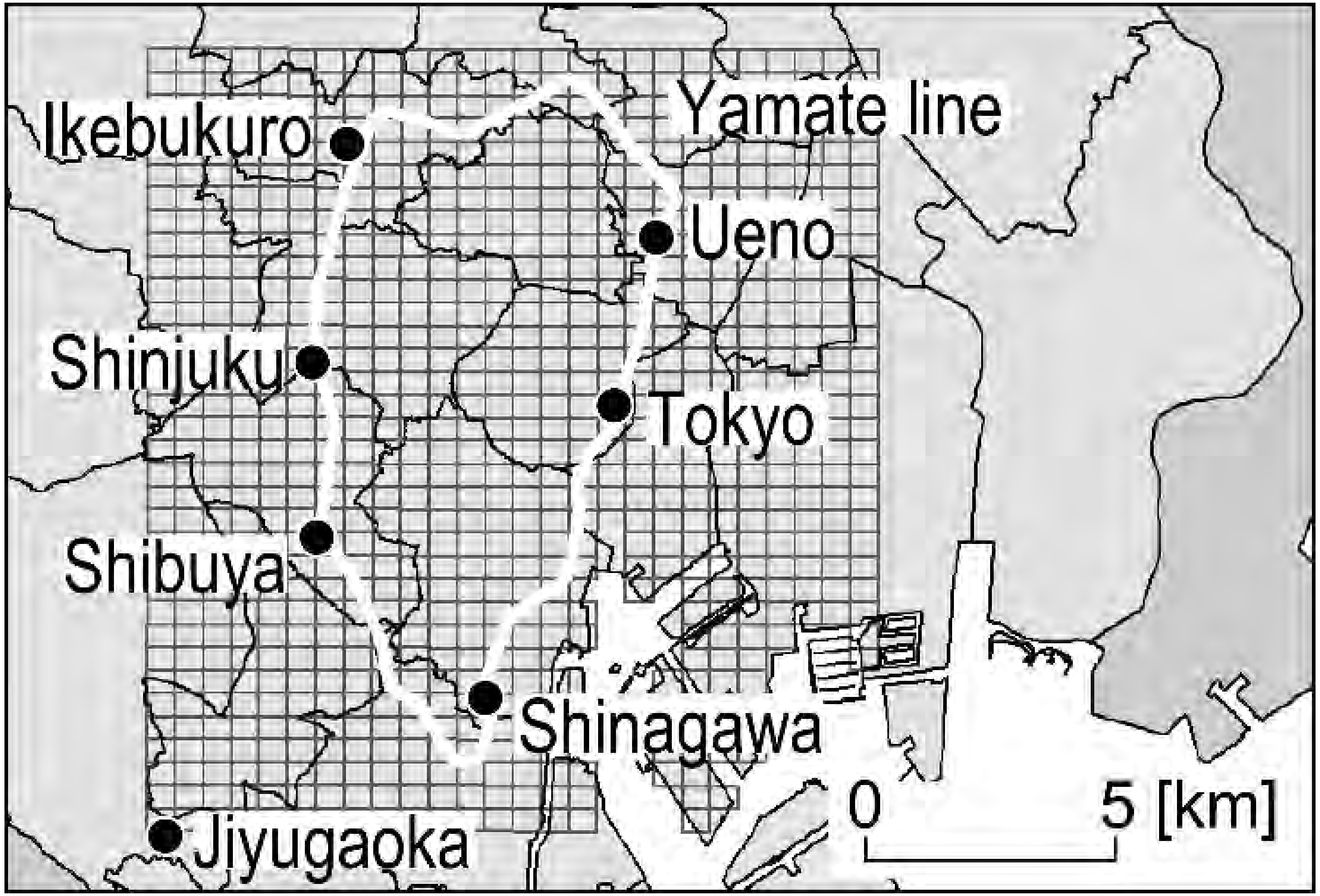
Explanatory Variables

No.	Building use	Examples
1	Public / Religious facility	Government office, Museum, Temple and shrine
2	Educational facility	Elementary/junior high/high school, University, Vocational school, Study cram school
3	Medical / welfare facility	Hospital, Nursing care welfare facility, etc.
4	Office	Logistics, Post office, Finance, Insurance, Real estate, Industry
5	Restaurant / Bar	Home delivery, Restaurant
6	Commercial facility	Service, Sales business, Automobile industry (including automobile repair business)
7	Mass retailer	Supermarket, Department store, Large store, etc.
8	Hotel	Hotel, Inn
9	Sports / Entertainment facilities	Sports facility, Entertainment
10	Apartment house	Flat, Apartment house, Dormitory, Company house
11	Detached house	Detached house
12	Railway station	The number of railways (FY2005 National Land Numerical Data)
13	Park (outside buildings)	Area of park (Land Use Current State Survey Data, 2011)

Explanatory Variables (Predictive model)

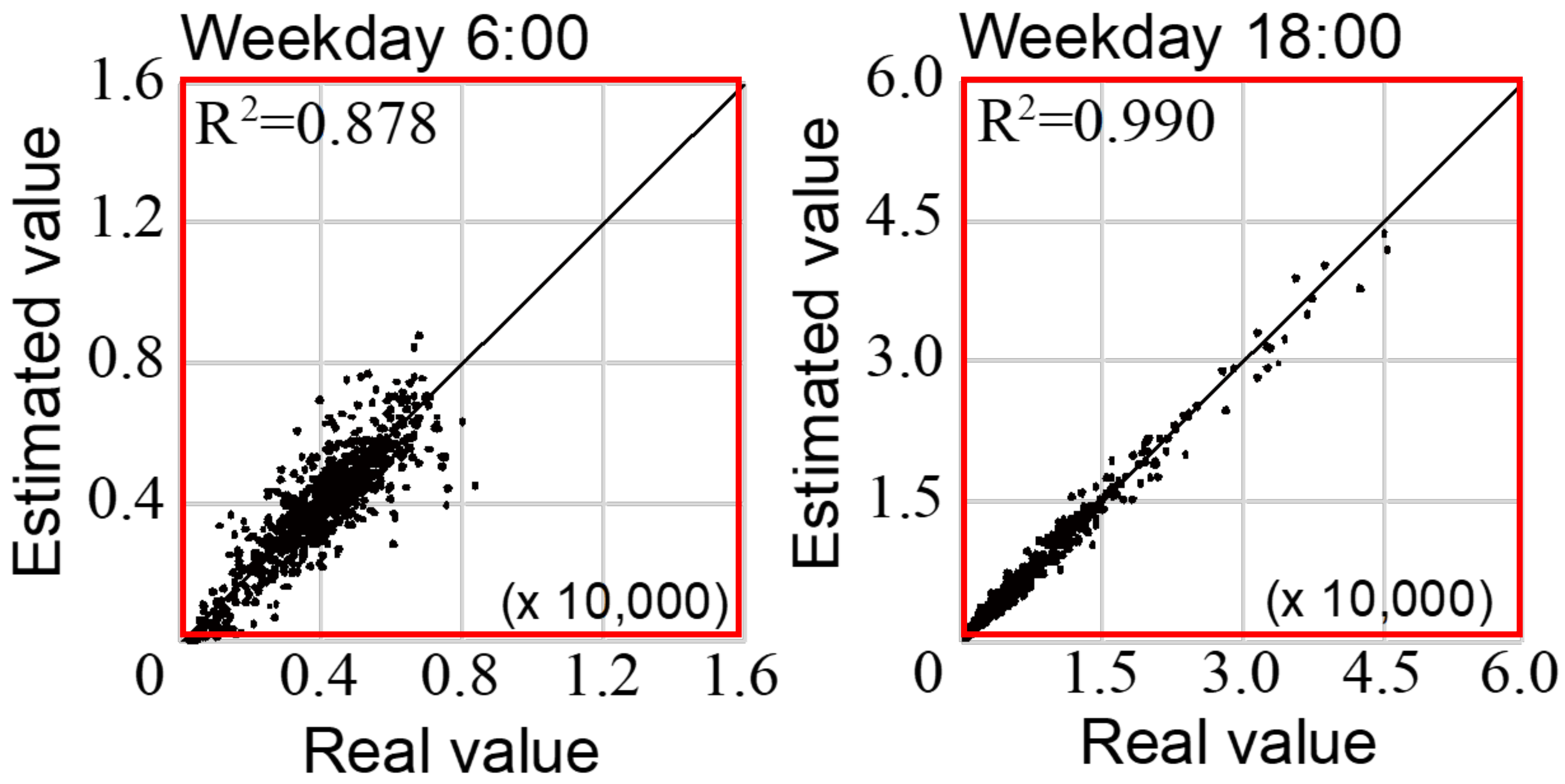
	No.	Building use	Size of building		
			Small	Medium	Large
Single building use	1	Public / Religious facility	～150 m^2	150～600 m^2	600 m^2～
	2	Educational facility	～700 m^2	700～3300 m^2	3300 m^2～
	3	Medical / welfare facility	～175 m^2	175～350 m^2	350 m^2～
	4	Office	～80 m^2	80～210 m^2	210 m^2～
	5	Restaurant / Bar	～75 m^2	75～150 m^2	150 m^2～
	6	Commercial facility	～105 m^2	105～225 m^2	225 m^2～
	7	Mass retailer	～190 m^2	190～360 m^2	360 m^2～
	8	Hotel	～550 m^2	550～1600 m^2	1600 m^2～
	9	Sports / Entertainment facilities	～260 m^2	260～840 m^2	840 m^2～
	10	Apartment house	～200 m^2	200～500 m^2	500 m^2～
	11	Detached house	～80 m^2	80～160 m^2	160 m^2～
	12	Railway station	The number of railways (FY2005 National Land Numerical Data)		
	13	Park (outside buildings)	～330 m^2	330～1120 m^2	1120 m^2～
Compound building use	14	Commercial based complex (1)	～260 m^2	260～540 m^2	540 m^2～
	15	Commercial based complex (2)	～210 m^2	210～710 m^2	710 m^2～
	16	Office based complex (1)	～240 m^2	320～770 m^2	770 m^2～
	17	Office based complex (2)	～330 m^2	240～870 m^2	870 m^2～

Study Area

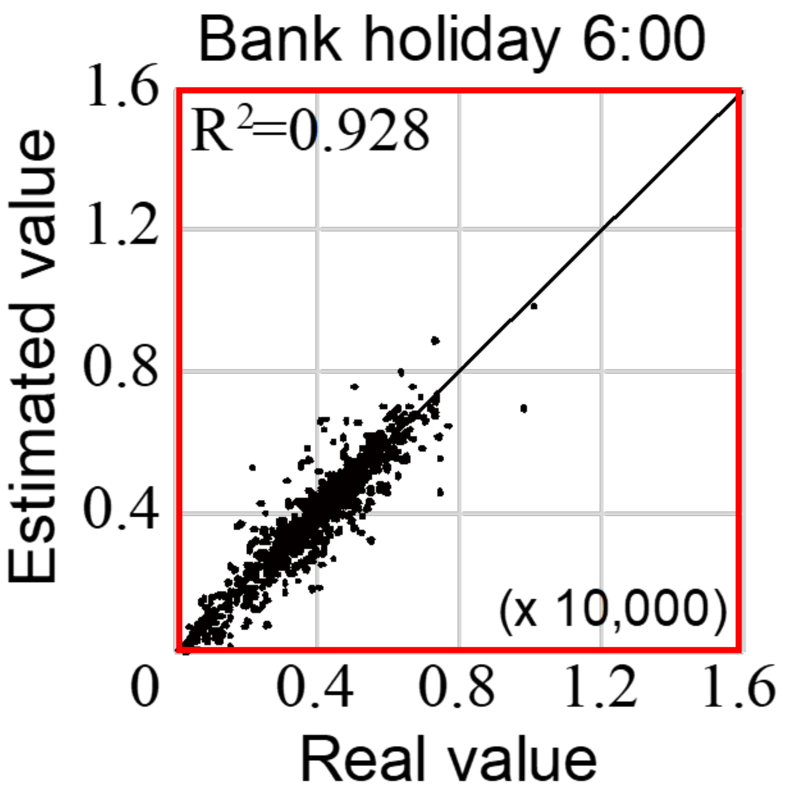


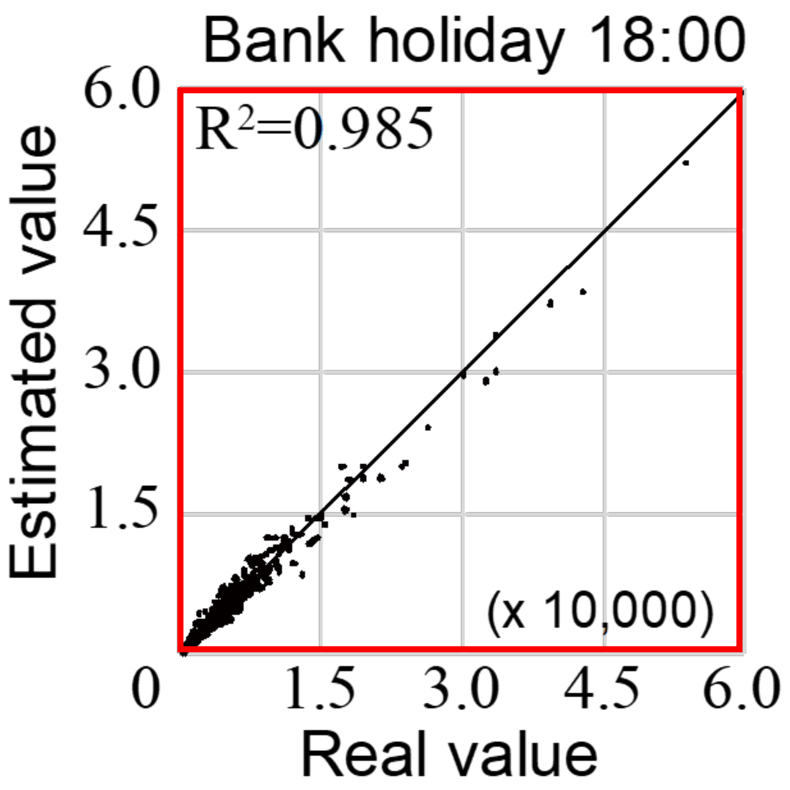
(500 m by 500 m grid cell, the total number of cells is 806)

Validation of Descriptive Model

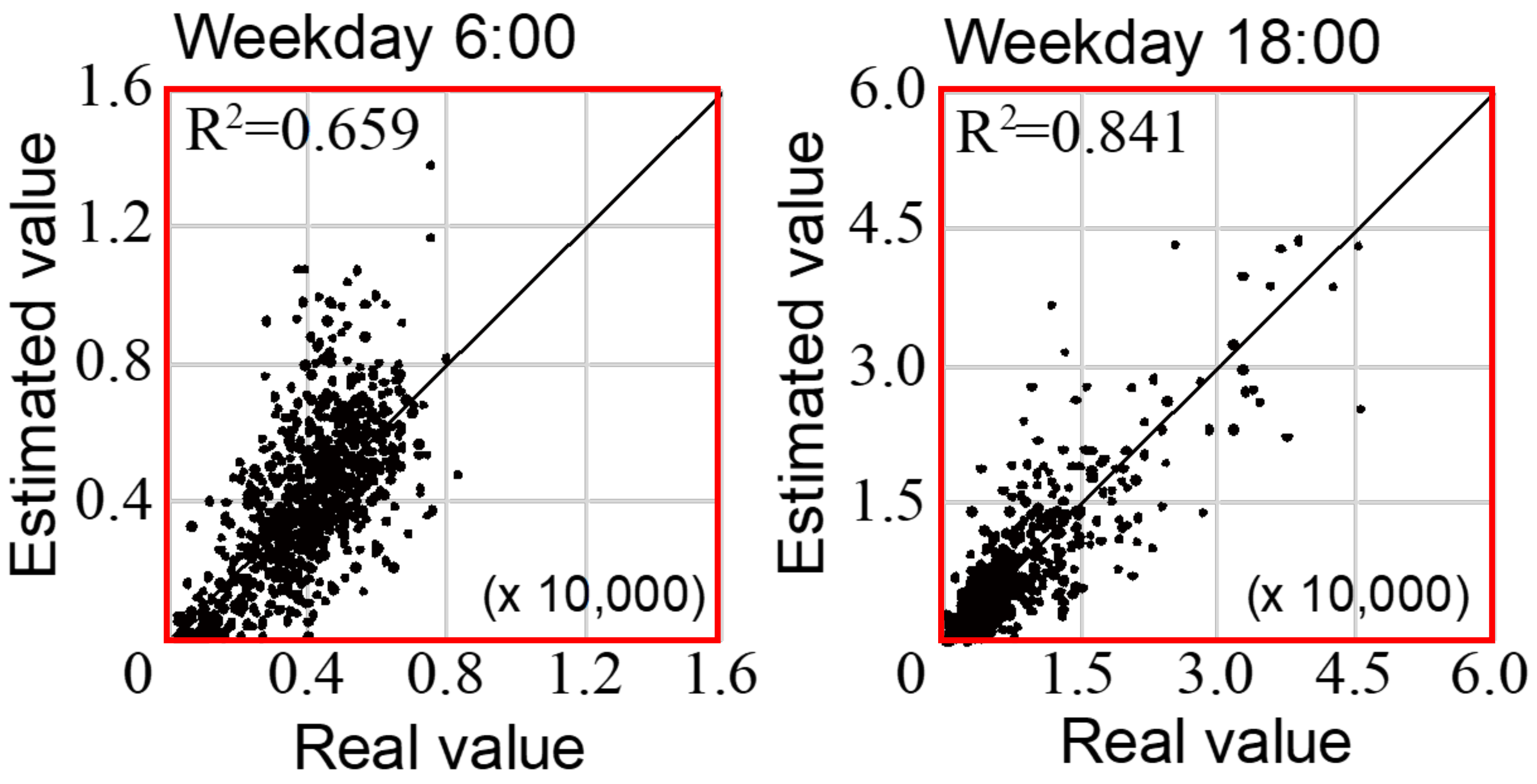


Validation of Descriptive Model

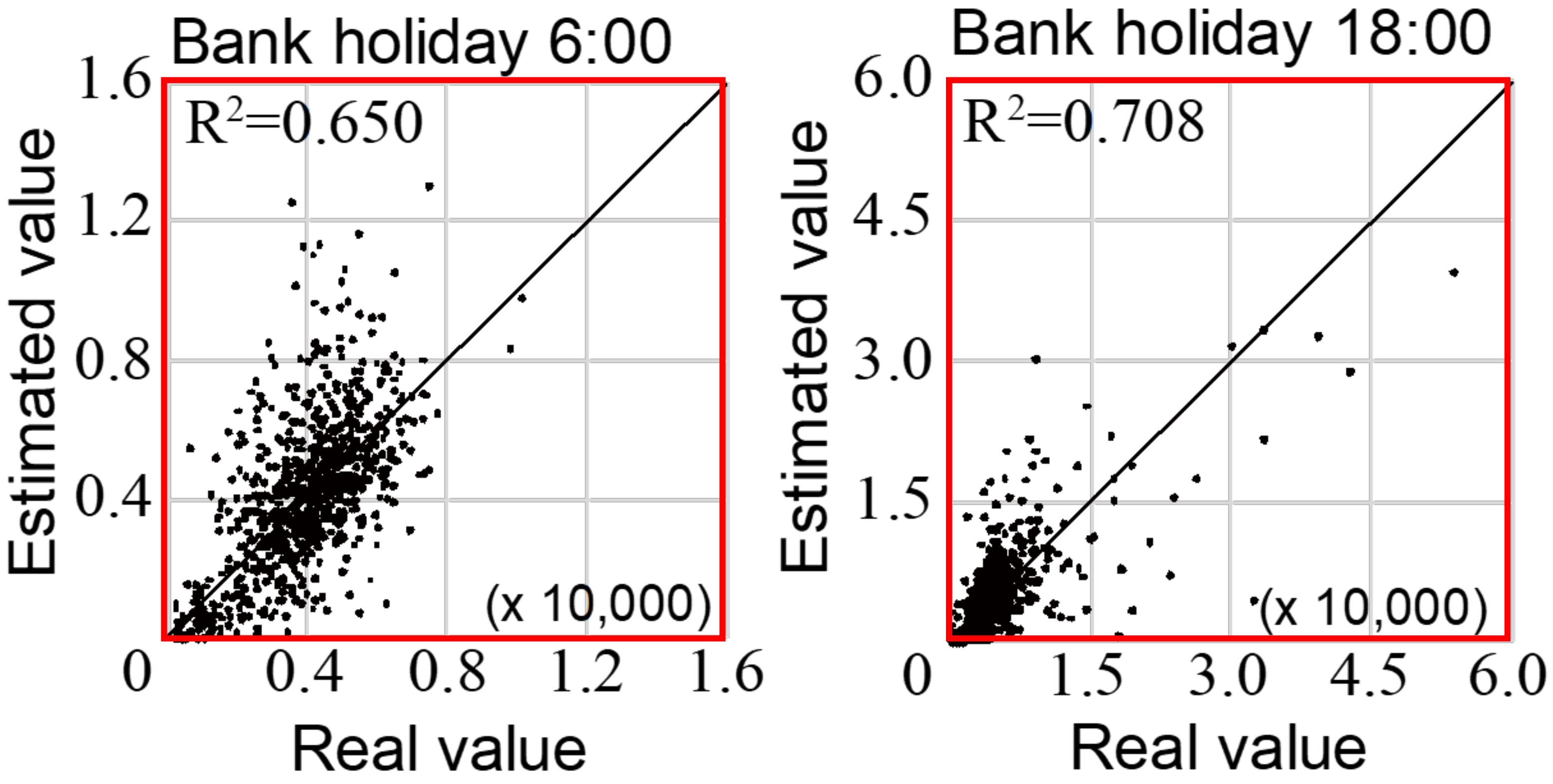




Validation of Predictive Model

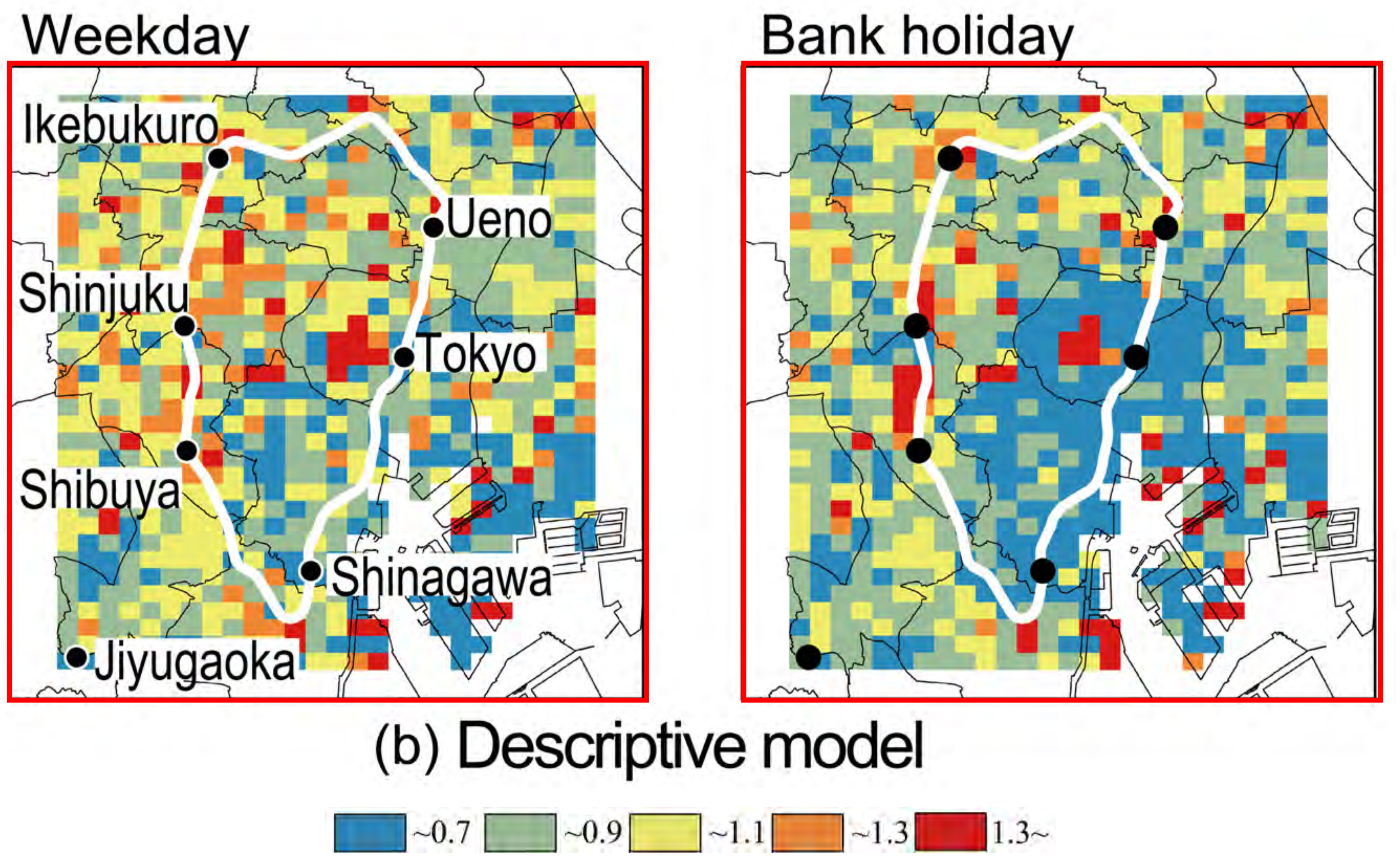


Validation of Predictive Model



More adequate explanatory variables to describe the location characteristics are needed

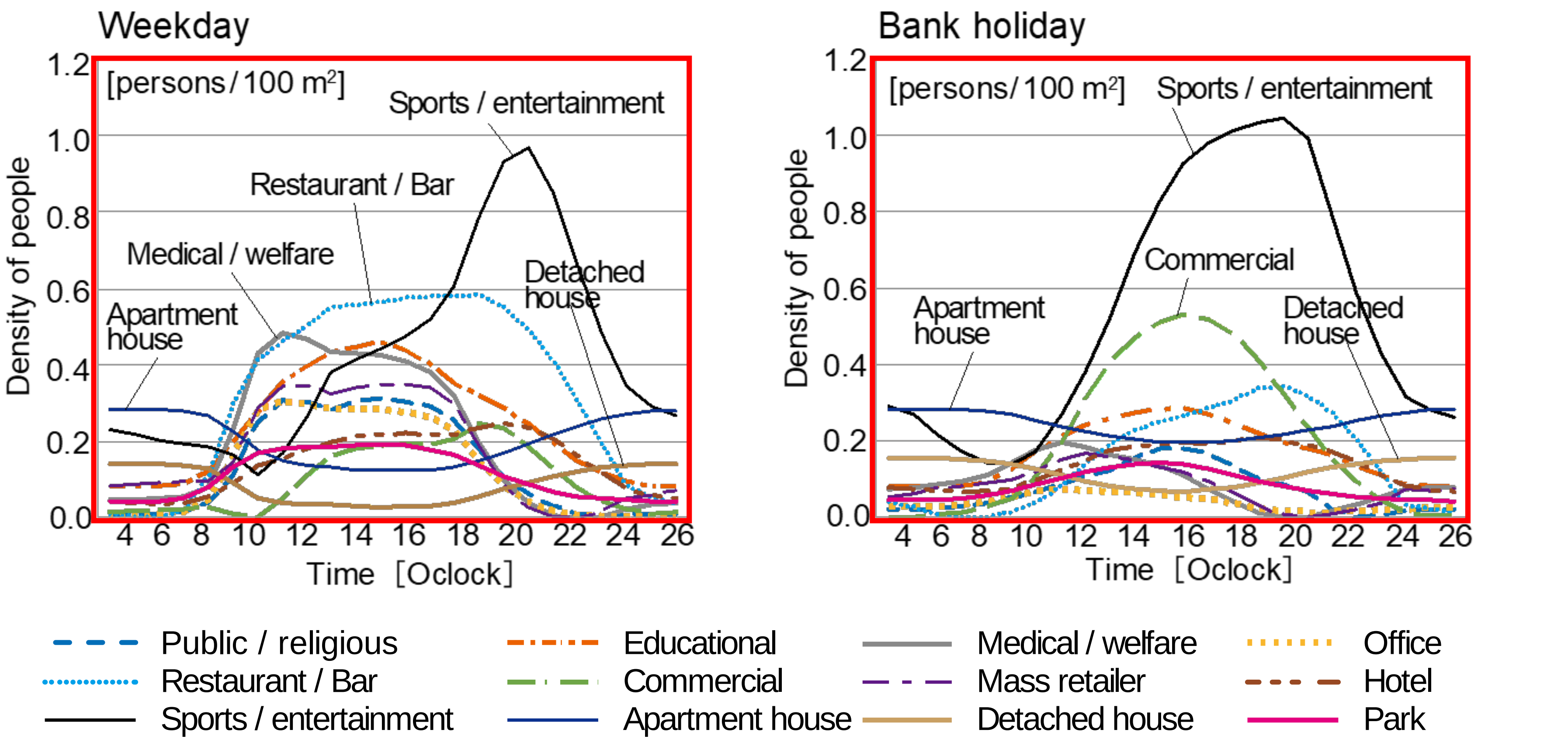
Location Characteristic Factor β_i



Spatial distribution of the estimated values of location characteristic factor β_i

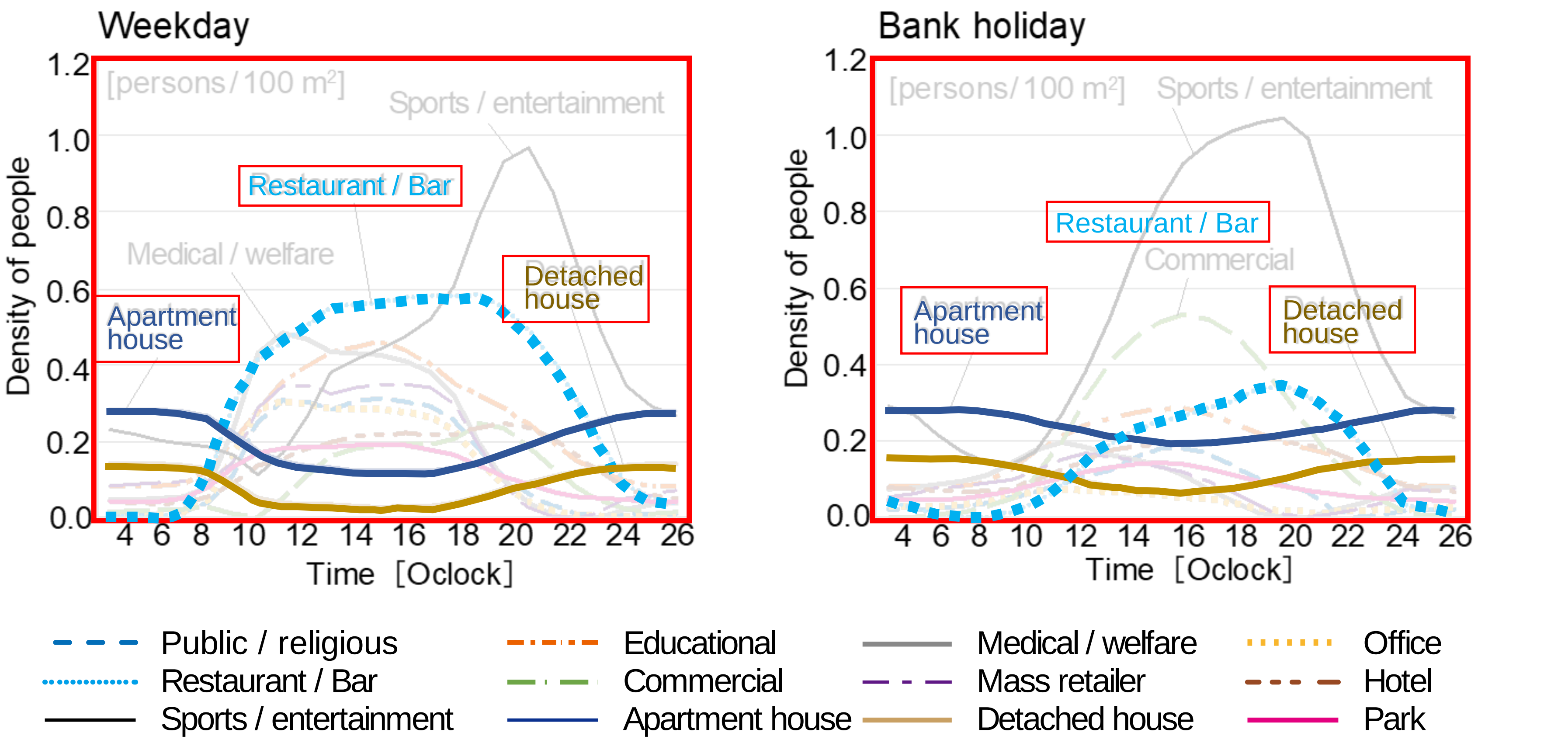
Temporal Change of Density α_i by Building Use

Density of number of people by building use per 100 m^2, for the descriptive model



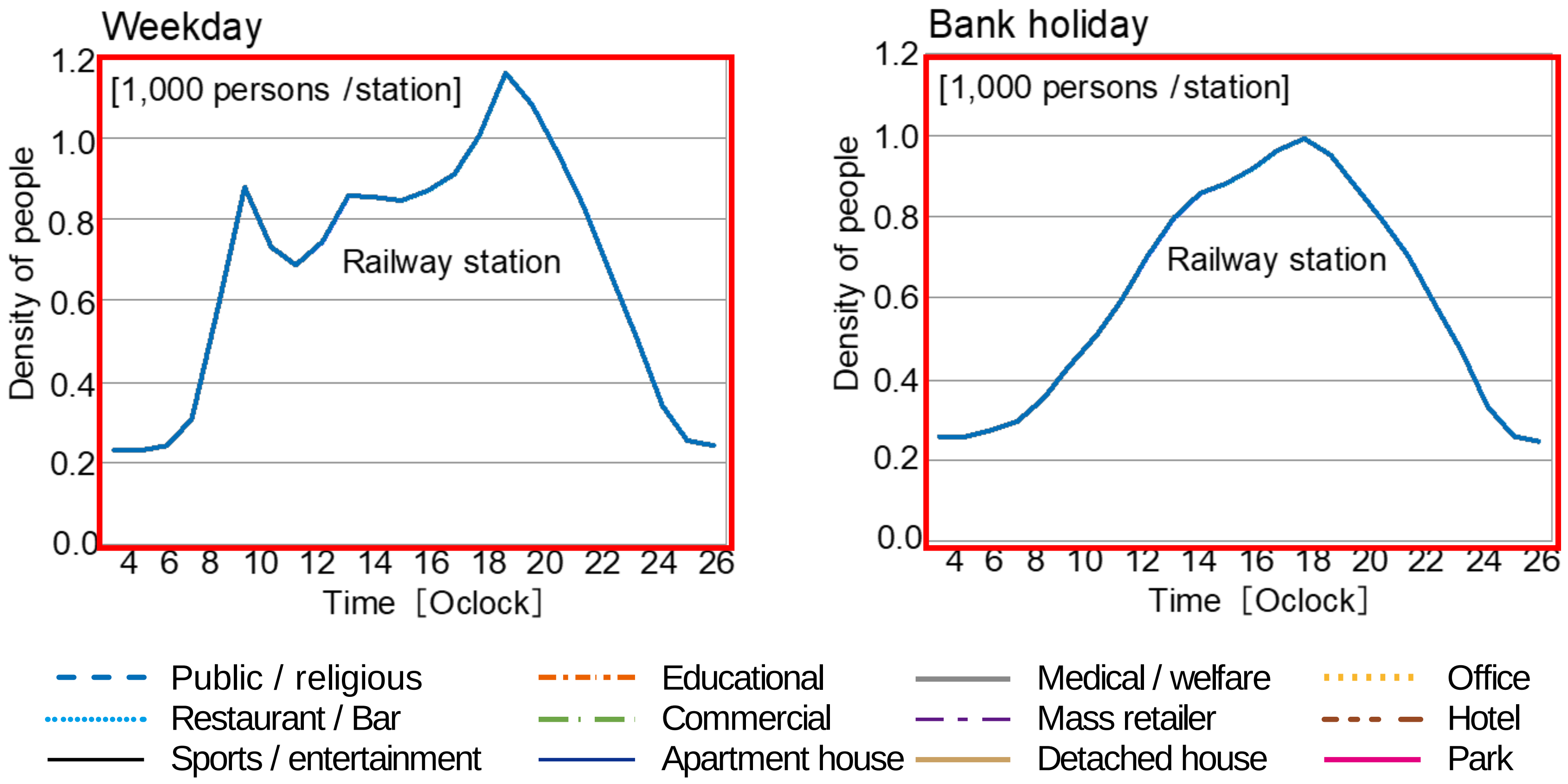
Temporal Change of Density α_i by Building Use

Density of number of people by building use per 100 m^2, for the descriptive model



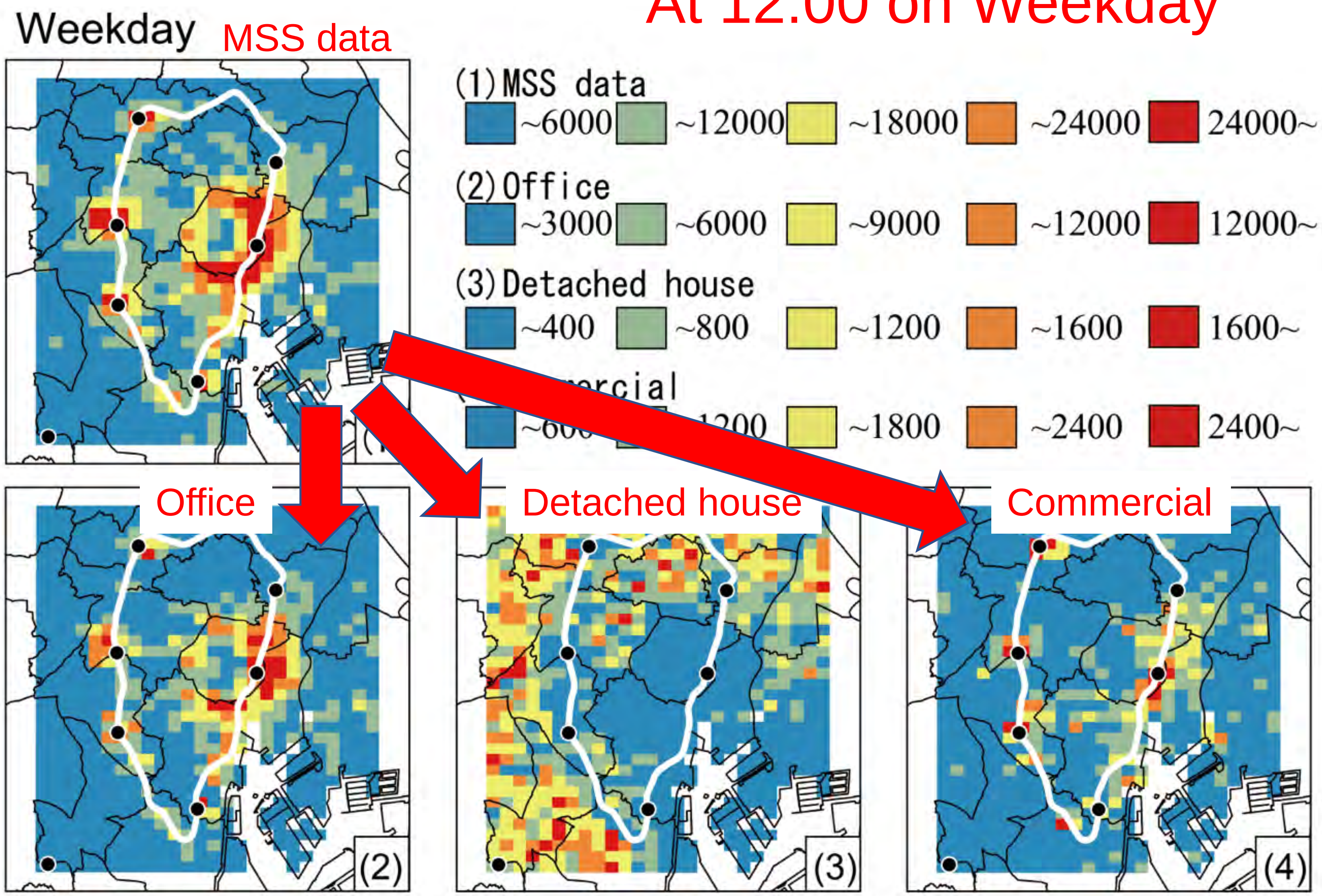
Temporal Change of Density α_i by Building Use

Density of number of people by building use per 100 m^2, for the descriptive model

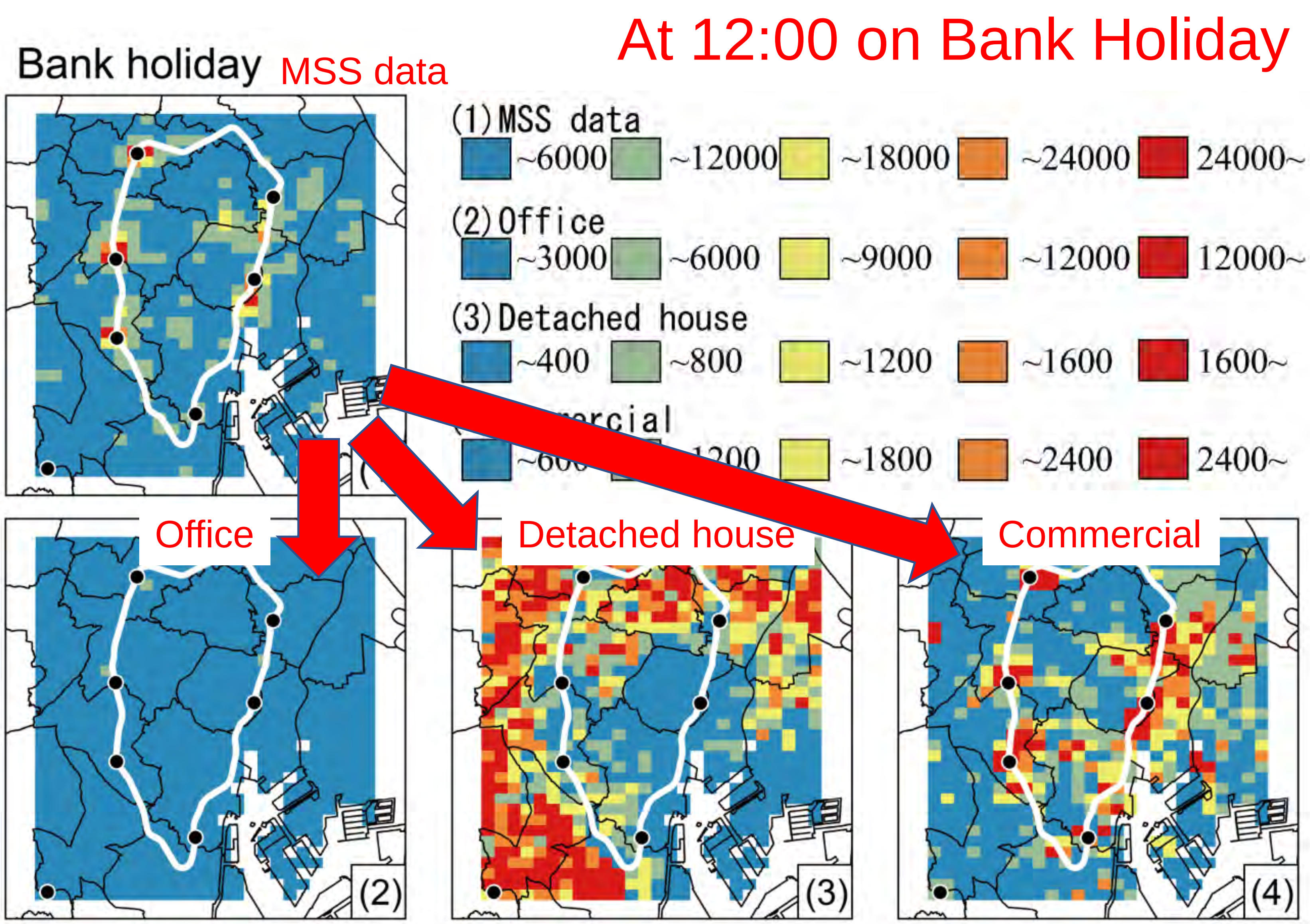


Number of People by Building Use

At 12:00 on Weekday



Number of People by Building Use



Key Concept for Linking Population Statistics

PT data

Purposes of stays
Attributes of stayers

Composition ratios

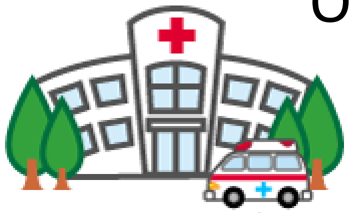
Building use
Day of week
Time of day
Location

School

Office

Restaurant

Shop



Hospital

Amusement

Bar

Estimating the Number of People by Purpose

$$Y_{ijl}{}^{t} = m_{ijl}{}^{t}\, y_{ij}{}^{t} \qquad where \quad m_{ijl}{}^{t} = \frac{n_{ijl}{}^{t}}{\sum_{l} n_{ijl}{}^{t}}$$

Estimated number of people
for each building use *j* at time *t*

PT data

$$y_{ij}{}^{t} = \alpha_{j}{}^{t} \beta_{i}\, x_{ij}$$

model's assumption

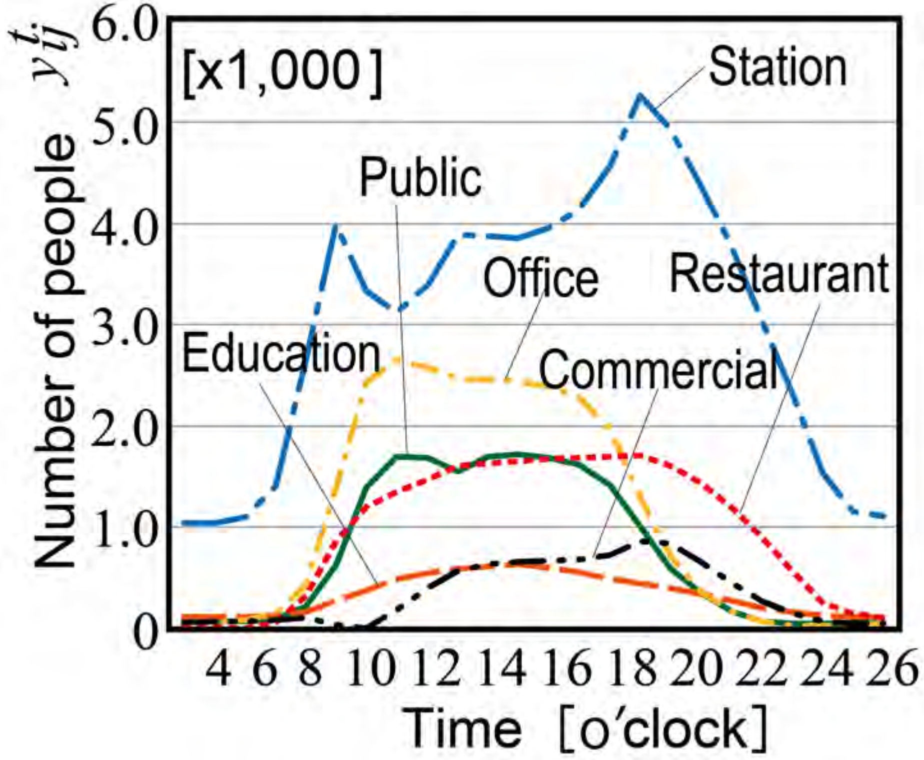
i : cell (location)
j : building use
t : time

⇨ ***l*** **: purpose**

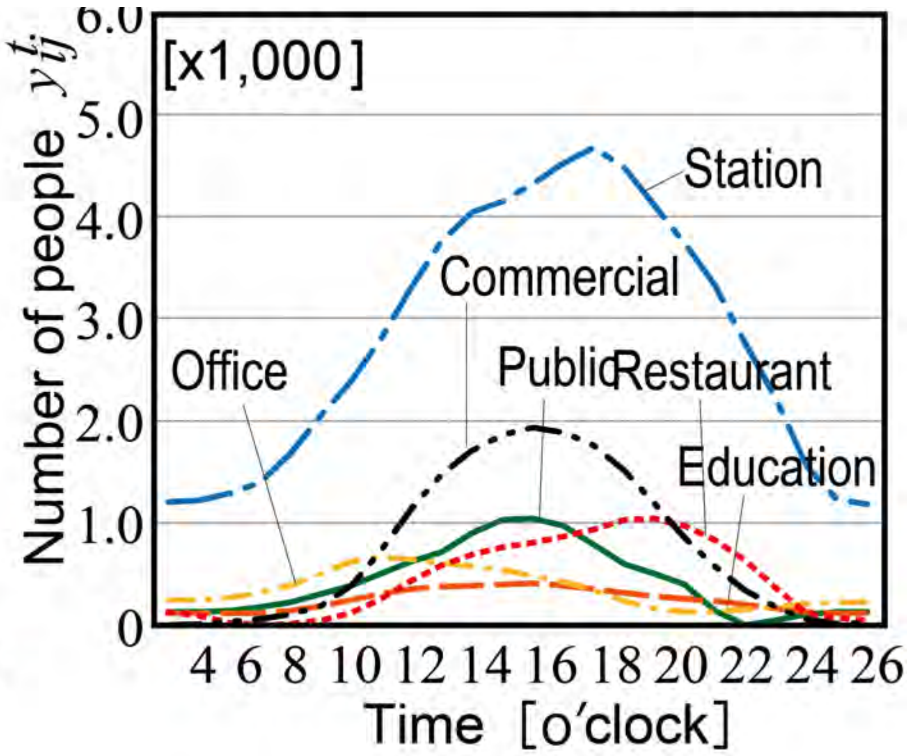
Number of People by Building Use in Specific Cell

Ueno Railway station

Weekday

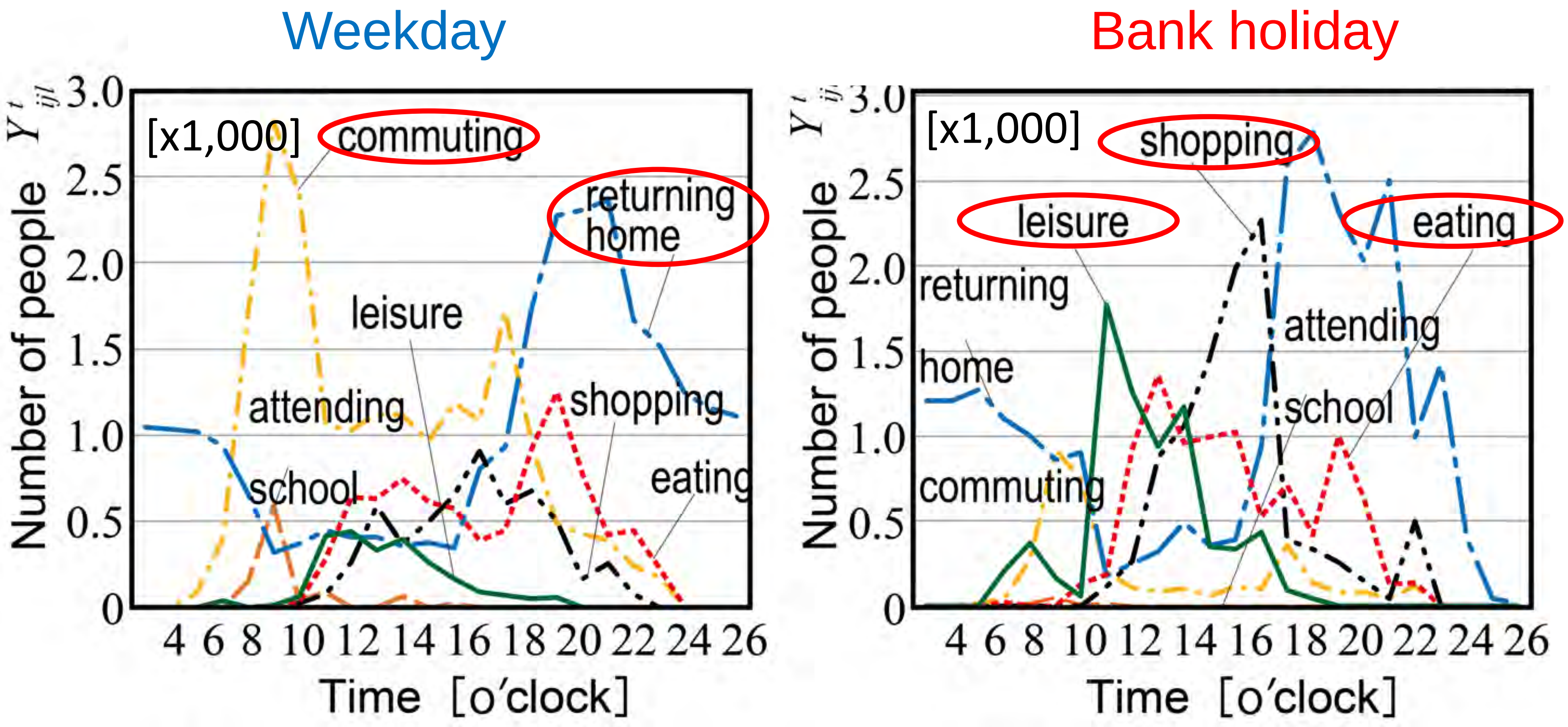


Bank holiday



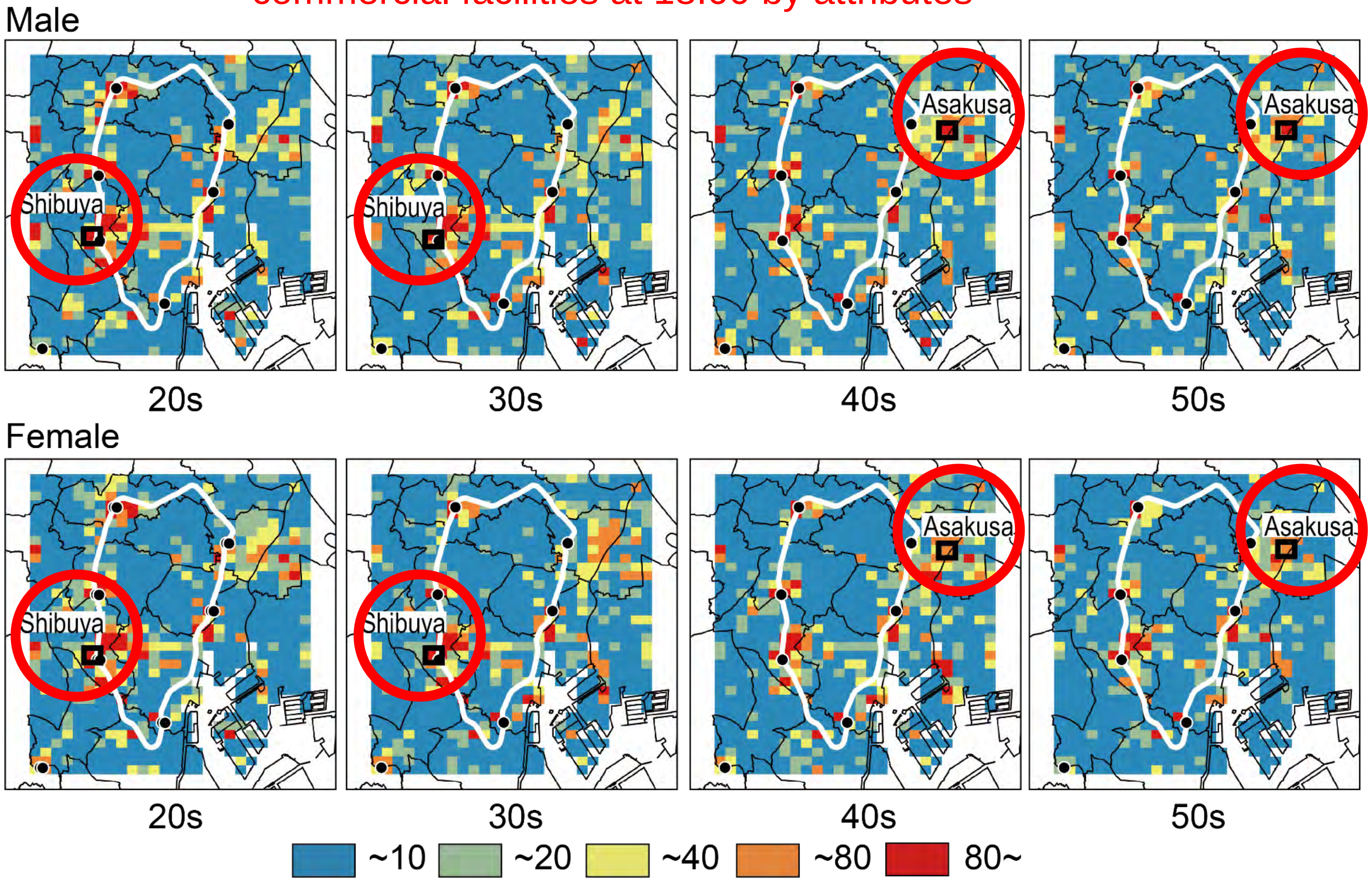
Number of People by Purpose in Specific Cell

Ueno Railway station

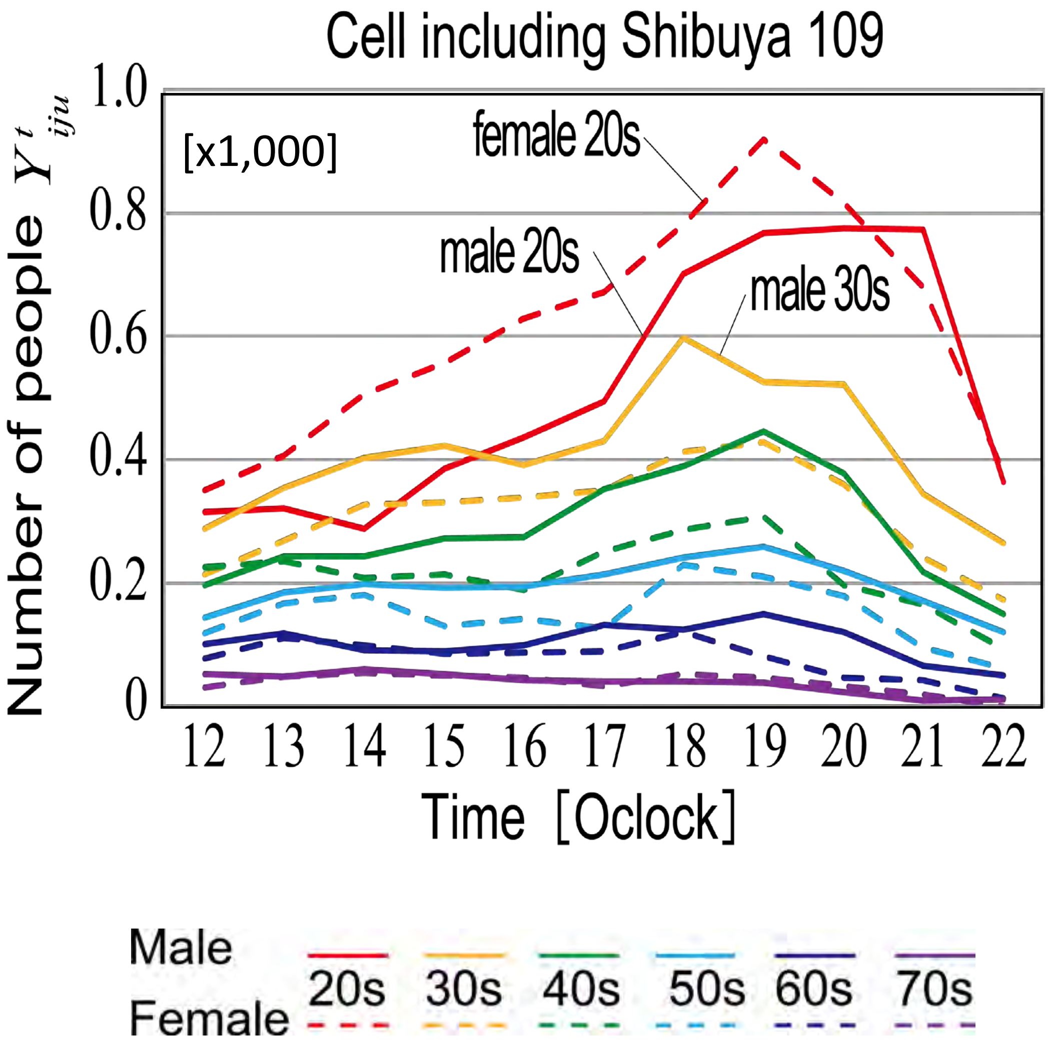


Number of People in Commercial Facilities

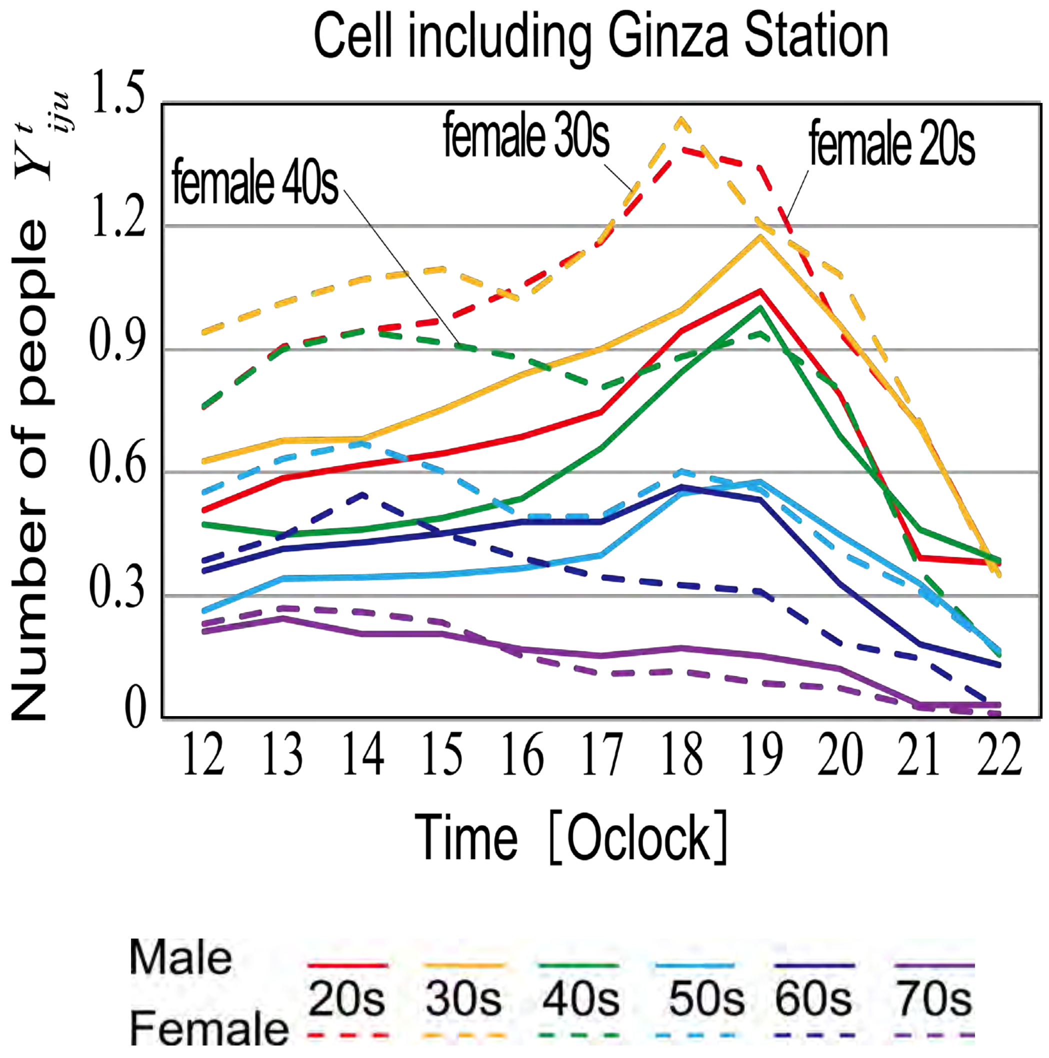
Spatial distribution of the number of people in
commercial facilities at 18:00 by attributes



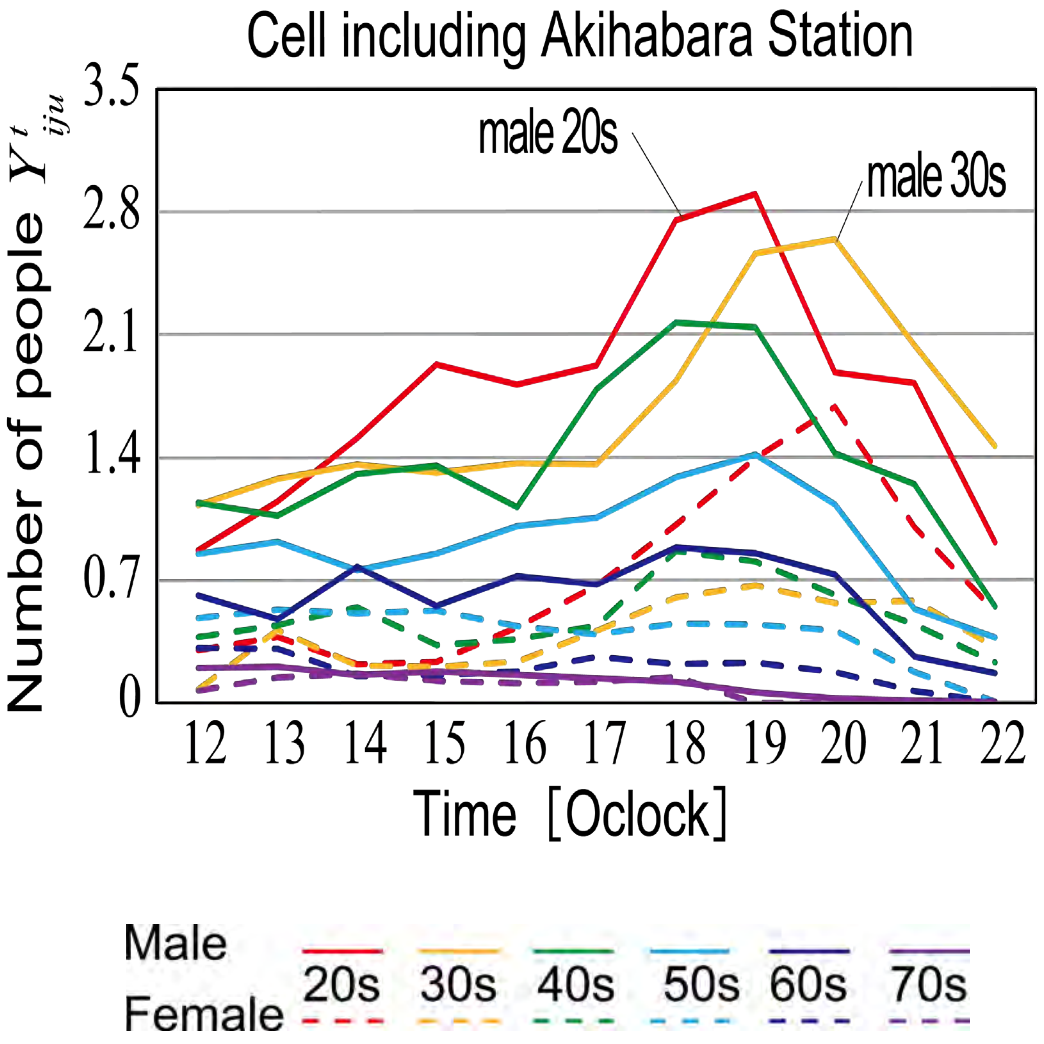
Personal Attributes in Shibuya



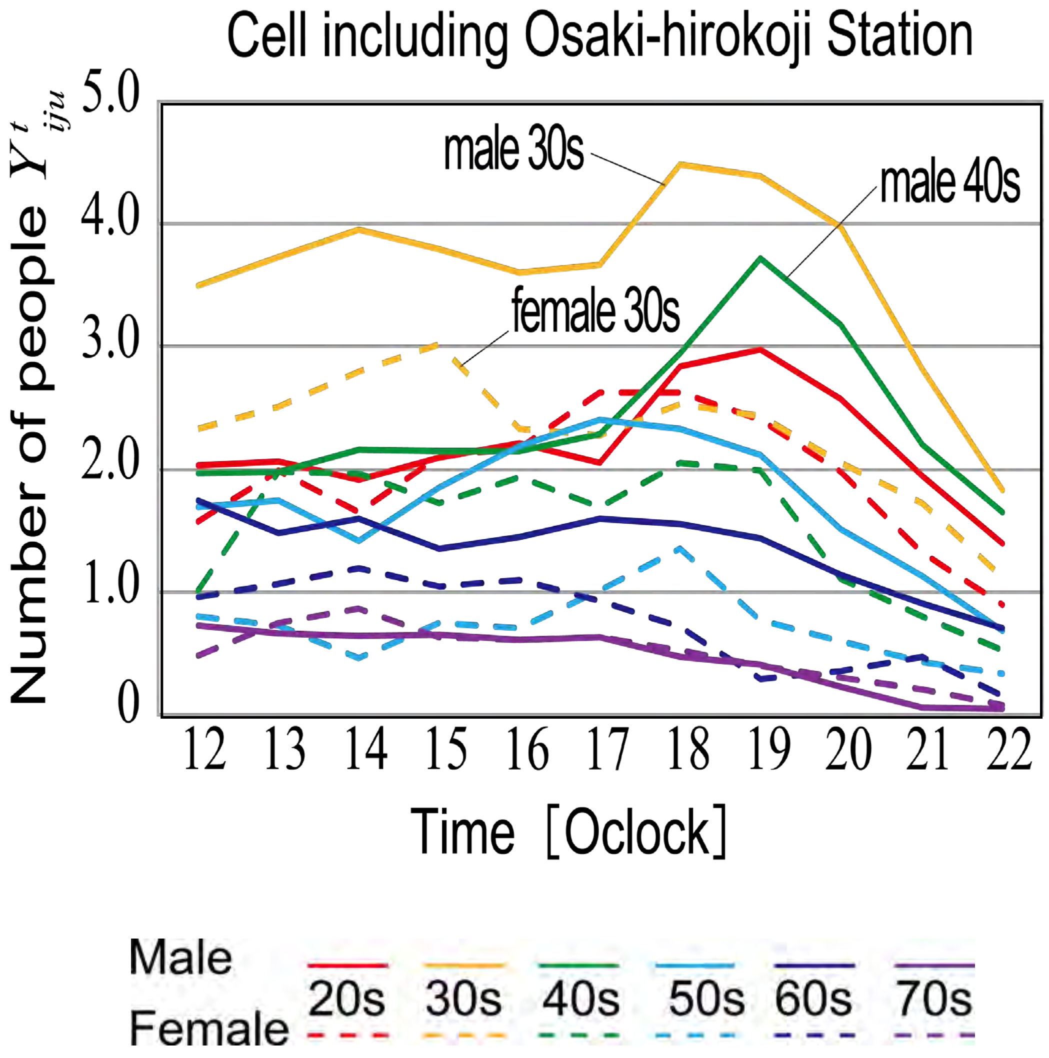
Personal Attributes in Ginza



Personal Attributes in Akihabara



Personal Attributes in Osaki-hirokoji



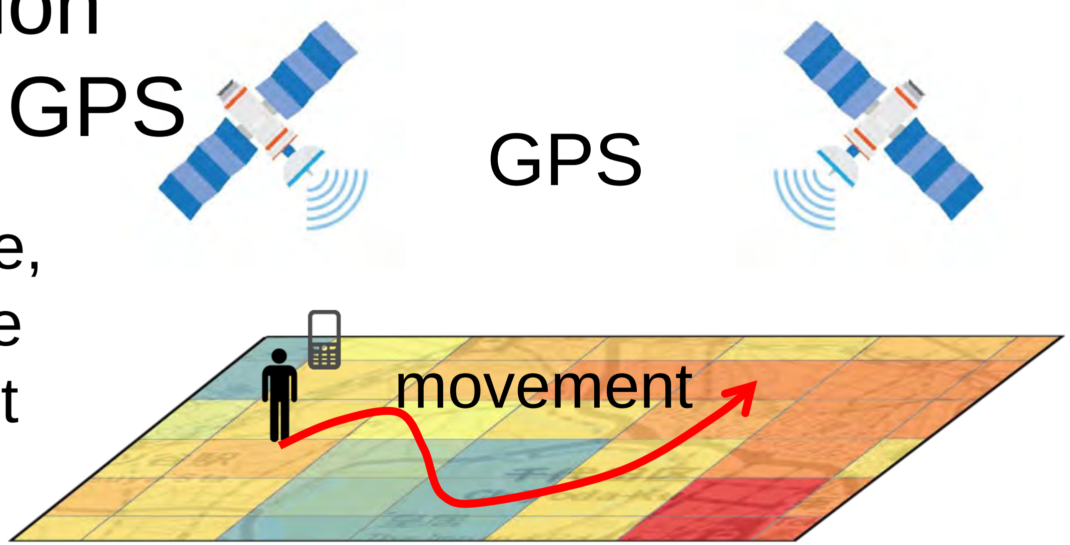
Outline

- ✓ Background & Motivation
- ✓ Spatiotemporal Demographic Data
  (its potential and limitation)
- ✓ Integration Method (1) for Demographic data
  (building use / purpose / attribute)
- ✓ Integration Method (2) for Demographic data
  (inflow / outflow / static)
- ✓ Applications for Disaster Mitigation Planning
- ✓ Summary and Conclusions

Konzatsu Tokei® (KT) data

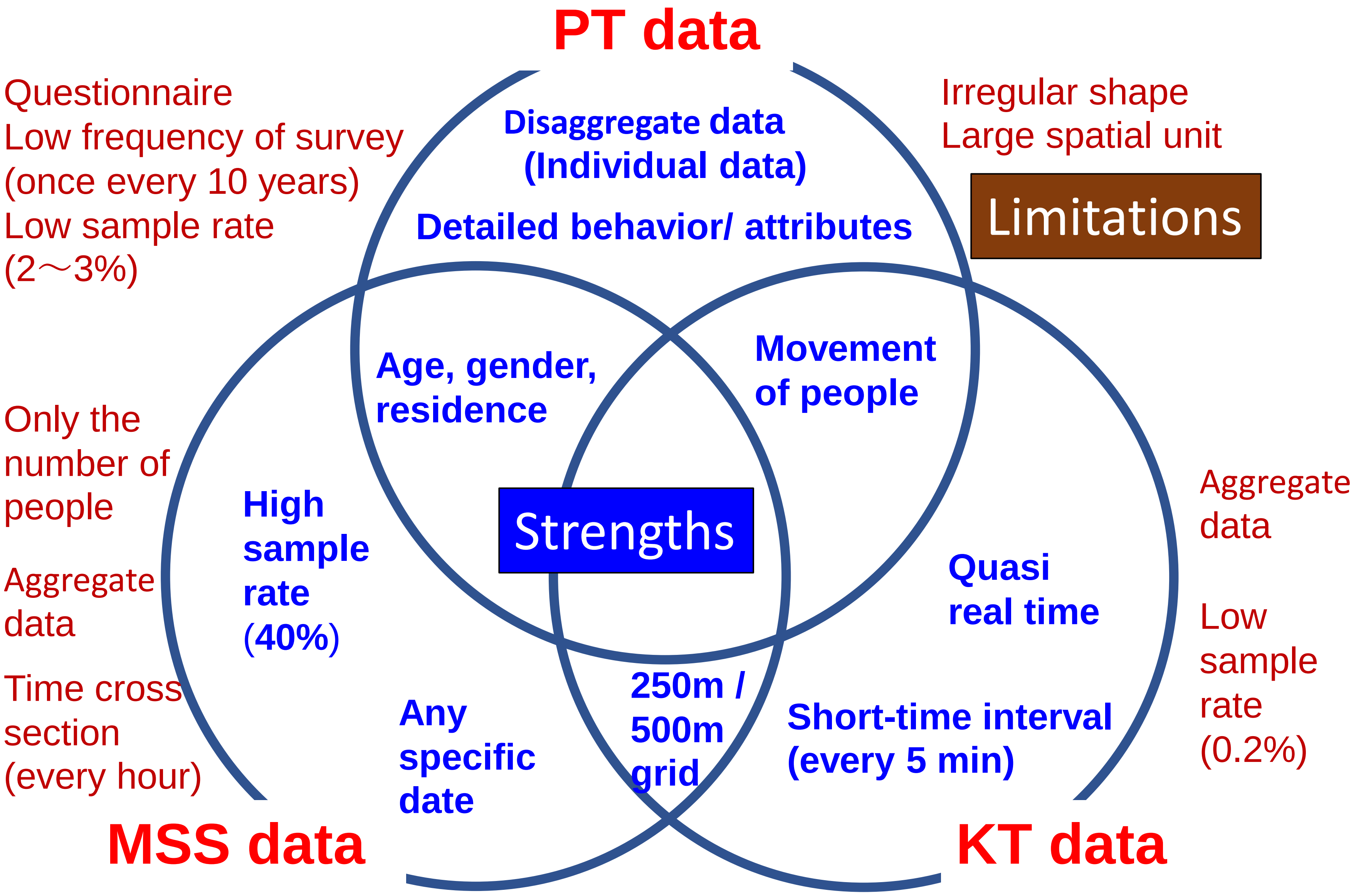
Mobile phone location data acquired from GPS

Data on the flow of people, showing where they came from and where they went

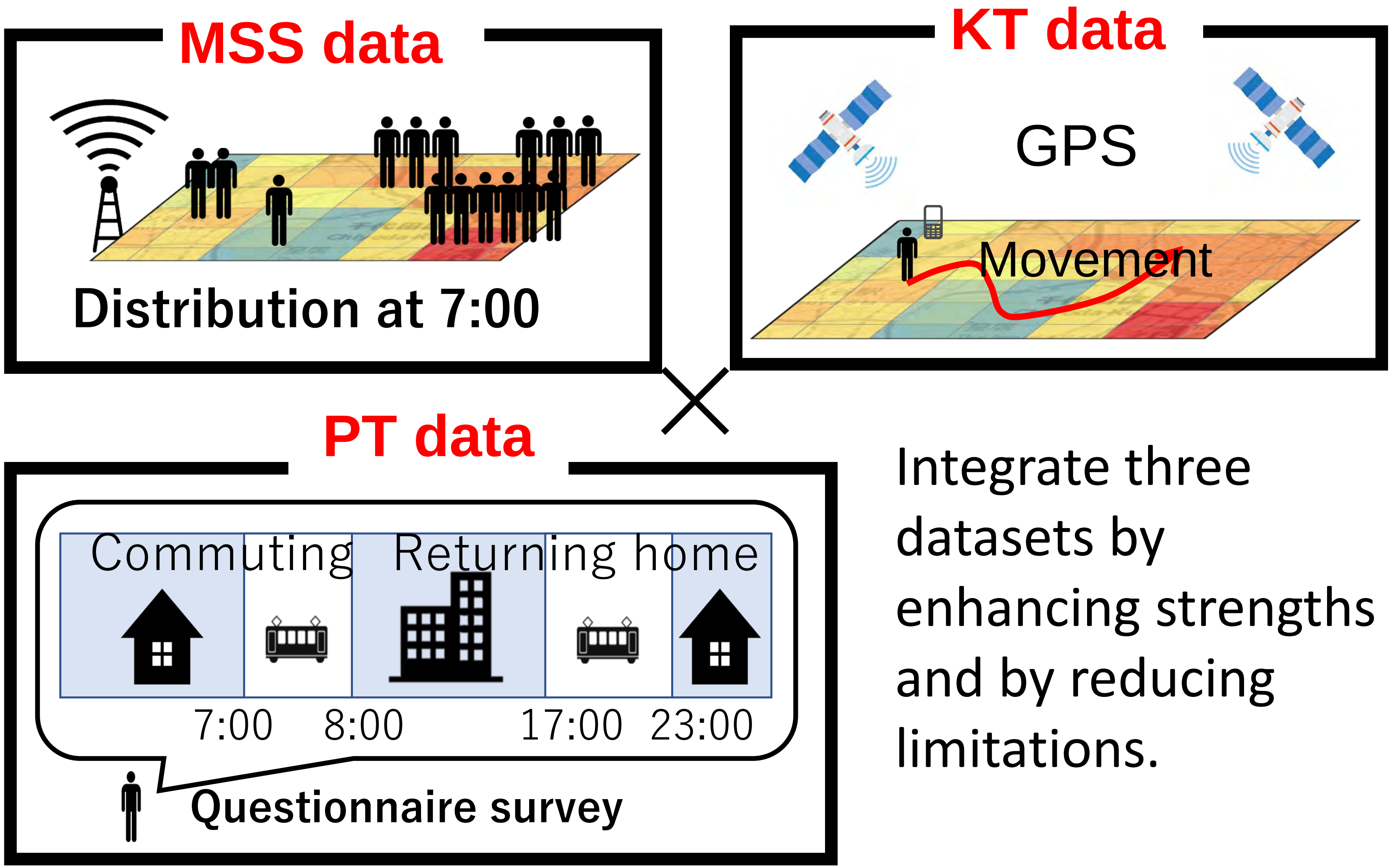


Strengths	Able to grasp **movement of people**
	Able to get data in **quasi real time data**
Limitations	**Low sample rate** (**0.2～0.3%**)
	Few kinds of attributes (age, gender)

Advantages/ Disadvantages

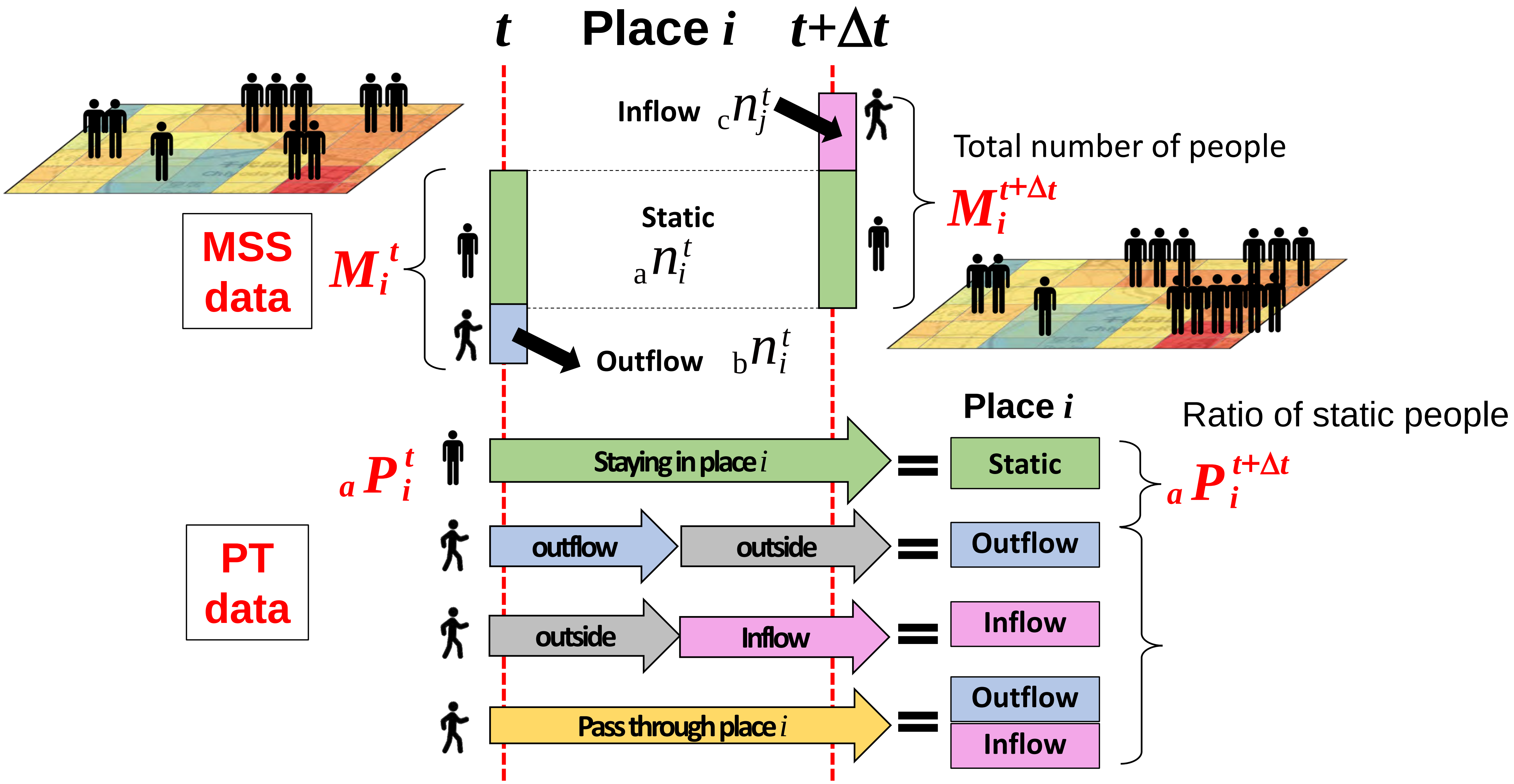


Integration of Demographic Data



Integrate three datasets by enhancing strengths and by reducing limitations.

Data Used for Integration



Data Used for Integration

KT data

Matrix of
Spatial Movement

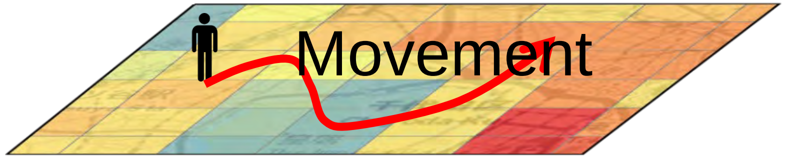
	to $j\ (t+\Delta t)$	
from	$\vdots$	
$i(t)$	$\cdots\ \ d_{ij}^{t}\ \ \cdots$ $(t \rightarrow t+\Delta t)$	
	$\vdots$	

Probability Matrix of
Spatial Movement

	to $j\ (t+\Delta t)$	*total*
from	$\vdots$	
$i(t)$	$\cdots\ \ p_{ij}^{t}\ \ \cdots$ $(t \rightarrow t+\Delta t)$	1
	$\vdots$	

average value for one year

Weekday
Weekend
Special day



Outline of Integration Method

Matrix of Spatial Movement

	to $j\ (t+\Delta t)$	*total*
from $i(t)$	$\vdots$ $\cdots\ T_{ij}^{t}\ \cdots$ $(t \rightarrow t+\Delta t)$ $\vdots$	M_i^{t}
total	$M_j^{t+\Delta t}$	

MSS data (constrain)

Number of people for each grid

$$M_i^{t} \quad M_j^{t+\Delta t}$$

KT data (probability of movement)

Probability of movement among grids $d_{ij}^{t} \rightarrow p_{ij}^{t}$

PT data (ratio of static people)

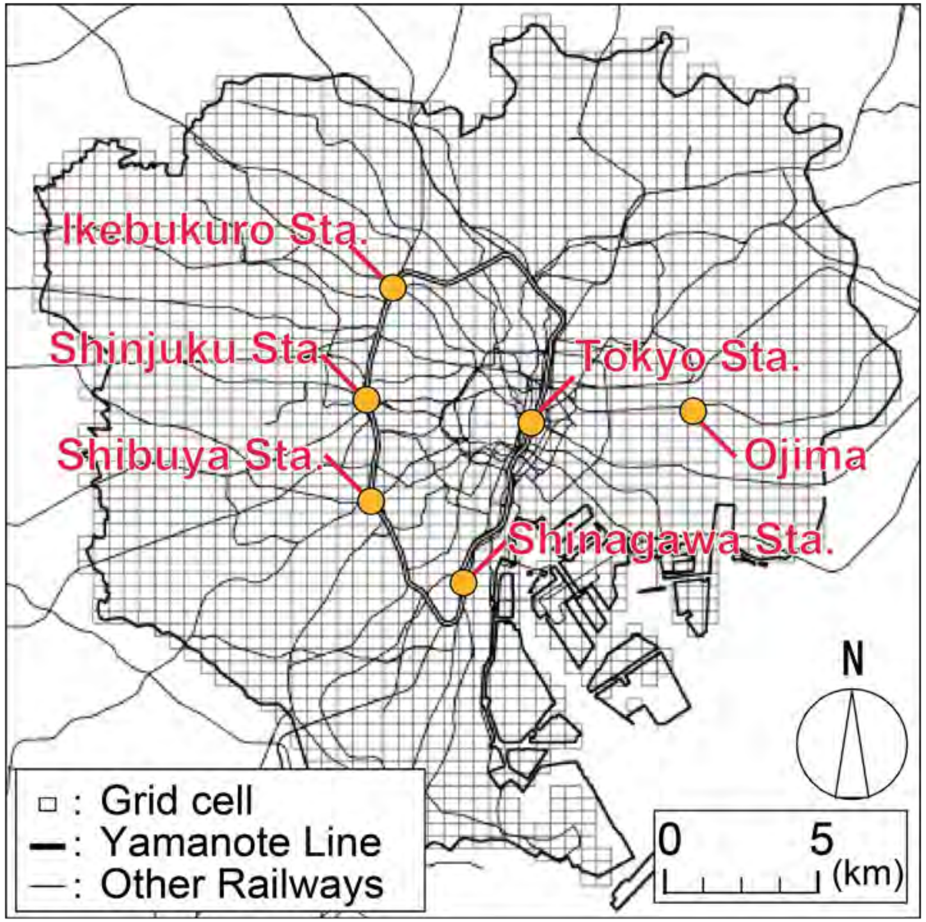
Ratio of Static people

$${}_{a}P_i^{t} \rightarrow T_{ii}^{t} / \Sigma_j T_{ij}^{t}$$

$\Downarrow$

Maximum likelihood estimation

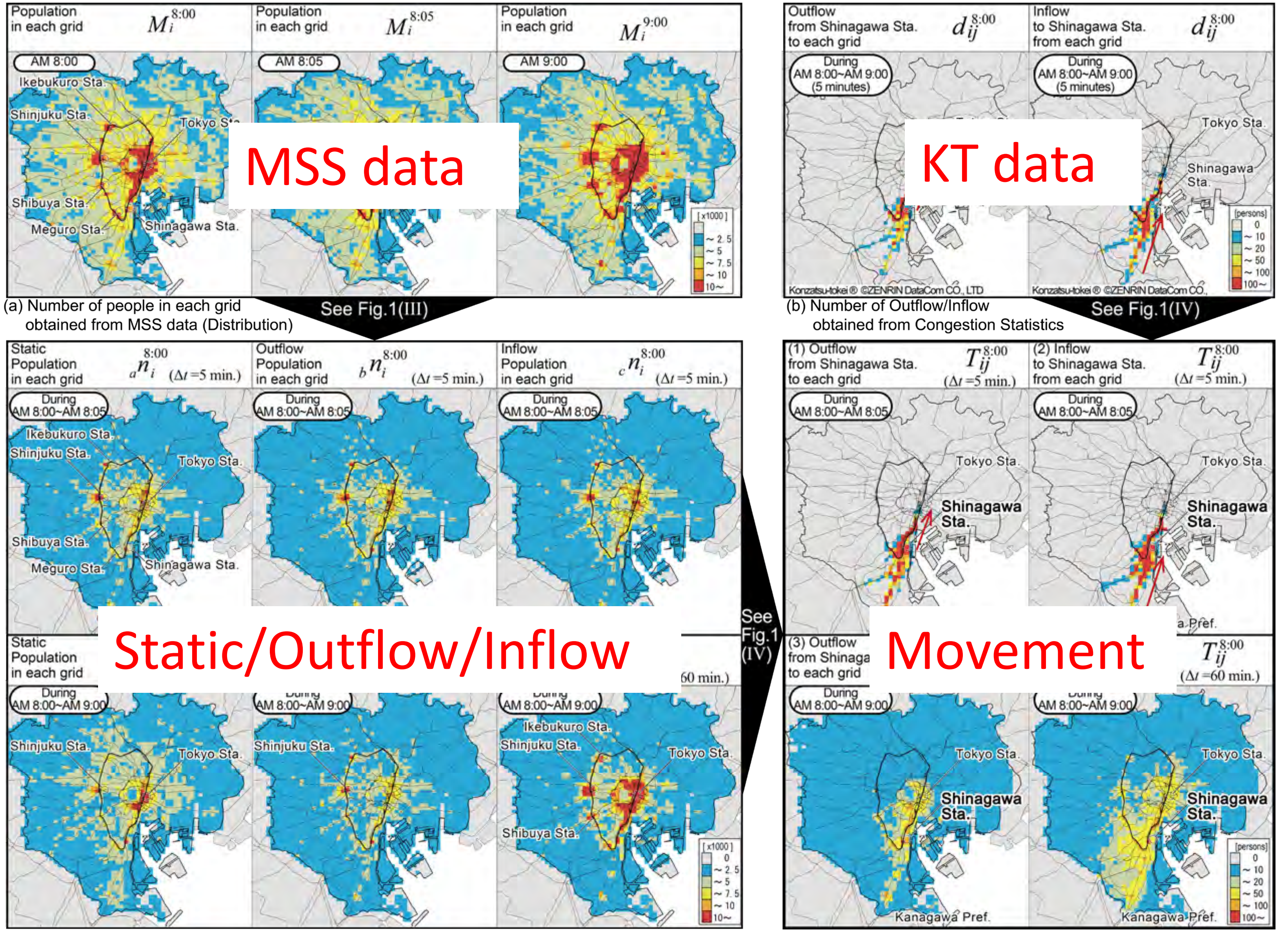
Study Area and Demographic Data



Dataset	Date (weekday)	Date (weekend)
MSS (Distribution)	Tuesday, Oct. 20, 2015	Sunday, Oct. 18, 2015
PT data	A weekday in Oct. of 2008 (Excluding Mon. and Fri.)	A weekend in Oct. of 2008 (Estimated by Osaragi, 2016)
Konzatsu-tokei ®	223 weekdays from Apr. 1, 2015 to Mar. 31, 2016	87 weekends from Apr. 1, 2015 to Mar. 31, 2016
MSS (Flow) (for validation)	Tuesday, Oct 20, 2015	

Area: 2500 grids (about 500 m by 500 m) in Tokyo ward
Time: 3:00~26:00

Static/Outflow/Inflow population



(a) Number of people in each grid obtained from MSS data (Distribution)

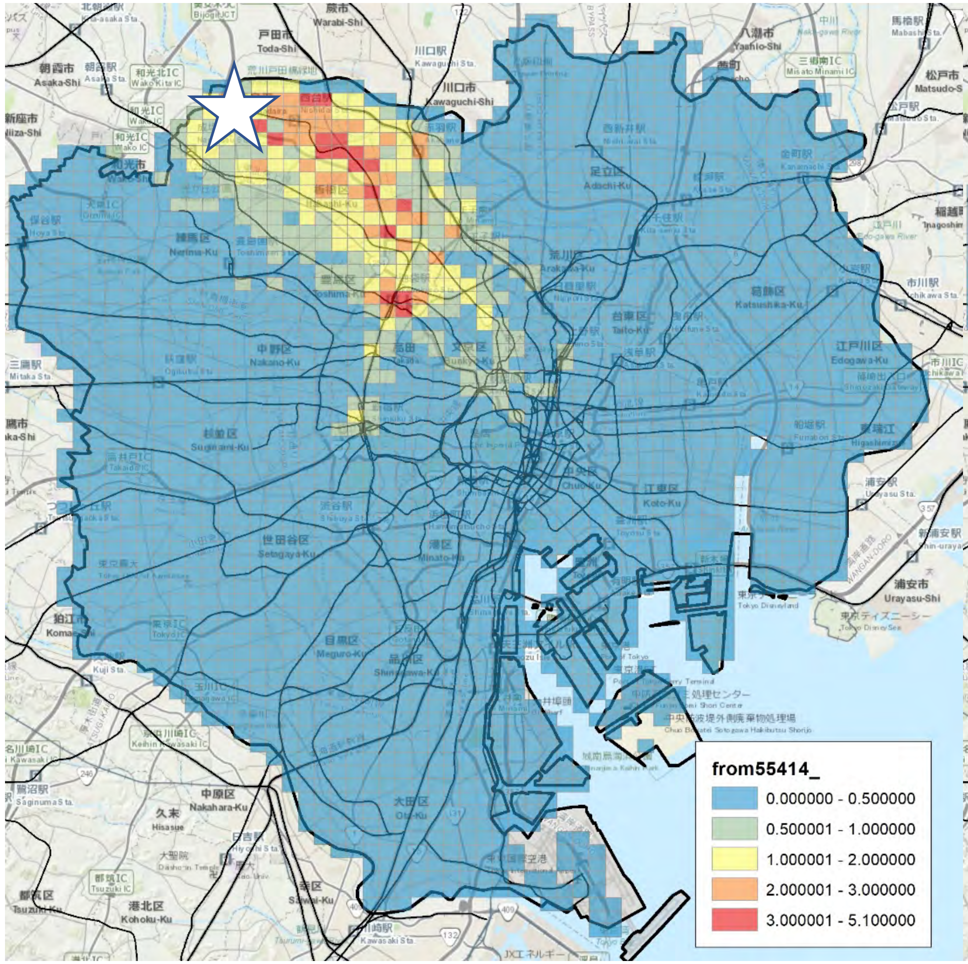
(b) Number of Outflow/Inflow obtained from Congestion Statistics

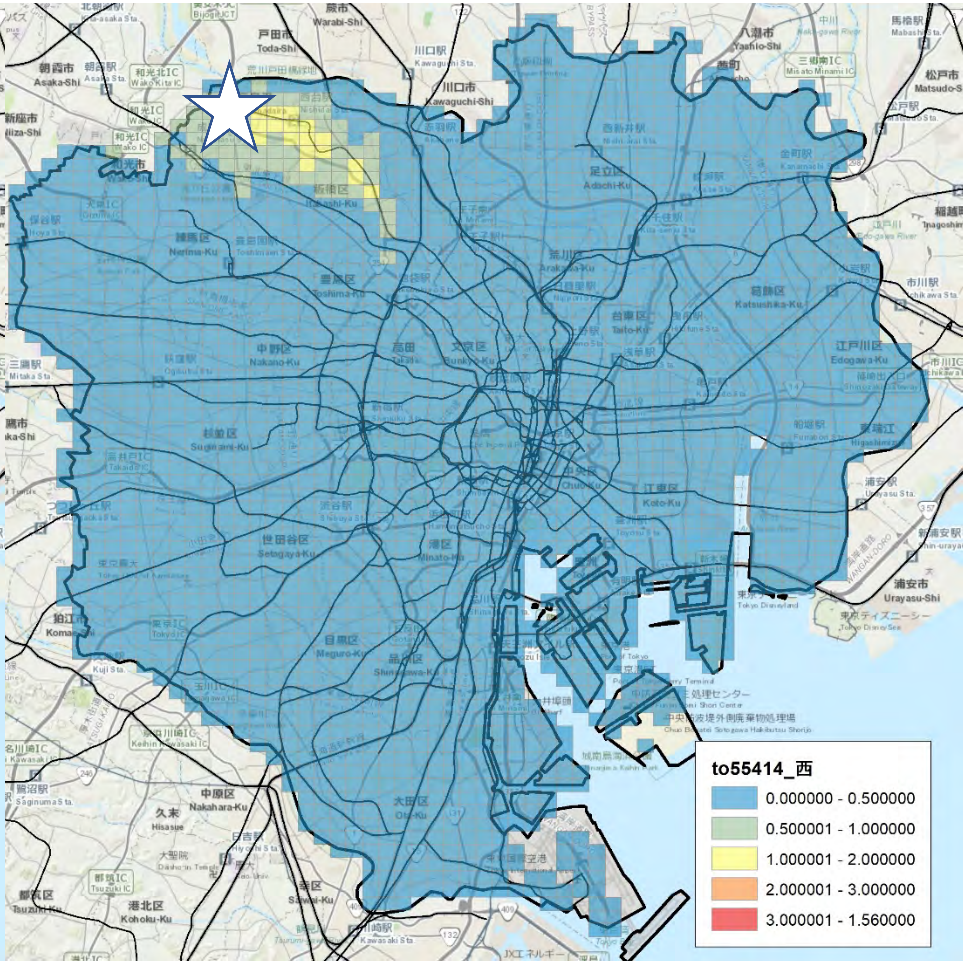
(c) Number of Stay/Outflow/Inflow in each grid estimated by using MSS data and PT data

(d) Number of Outflow/Inflow estimated by maximum likelihood method

Outflow/Inflow Population at Specific Cell

Outflow (8:00 – 9:00) Inflow

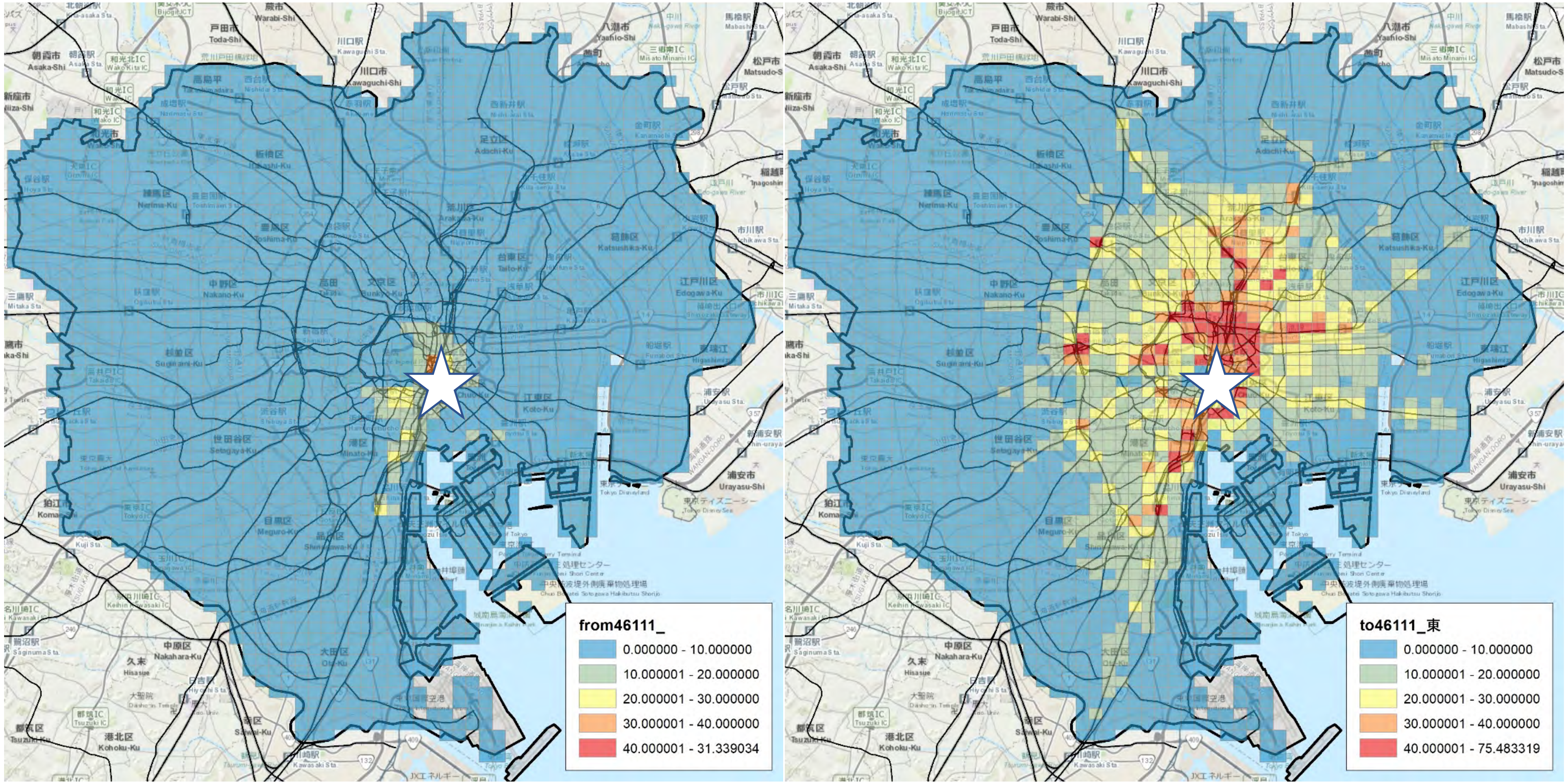




Takashimadaira Housing estate

Outflow/Inflow Population at Specific Cell

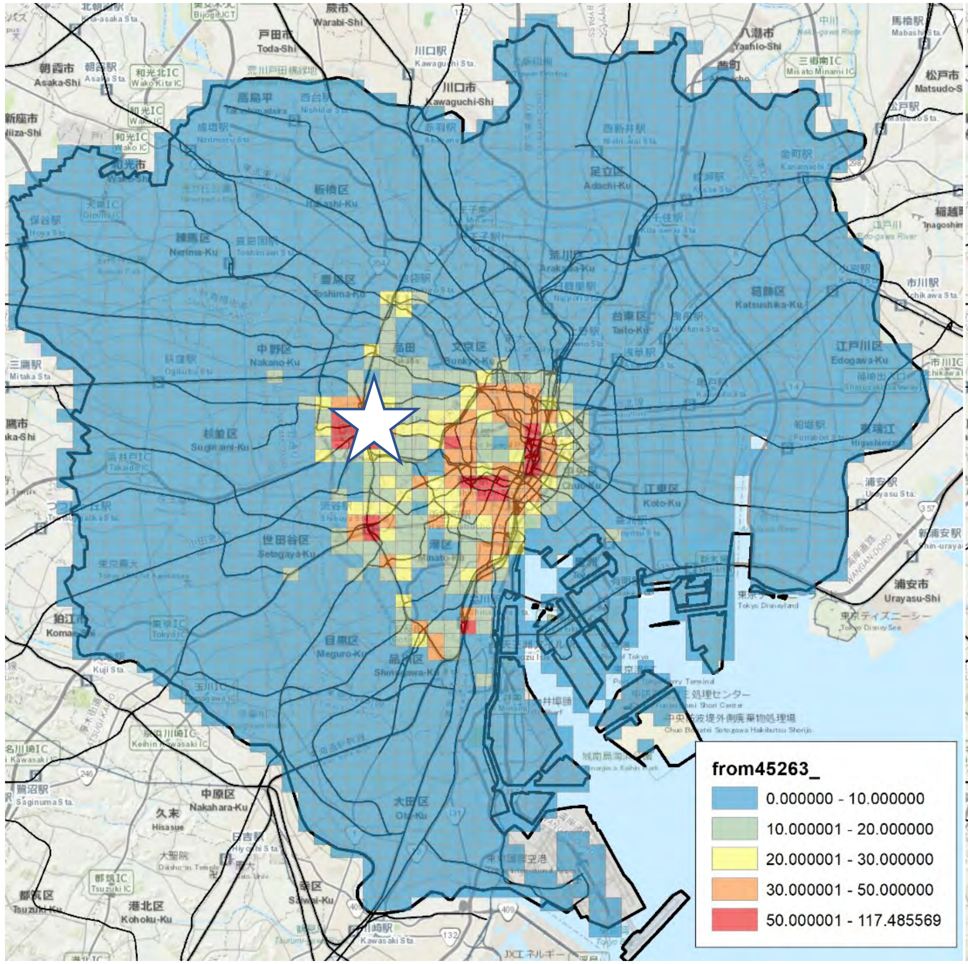
Outflow (8:00 – 9:00) Inflow

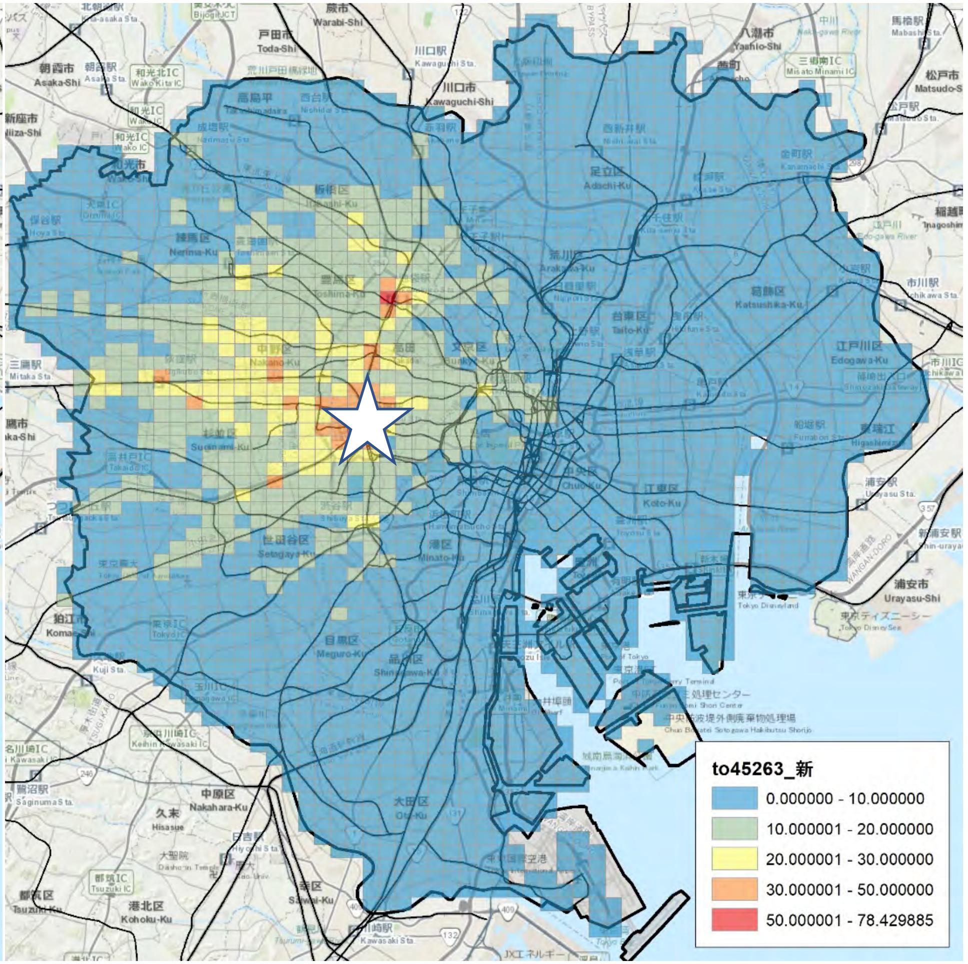


Tokyo Business center

Outflow/Inflow Population at Specific Cell

Outflow (8:00 – 9:00) Inflow

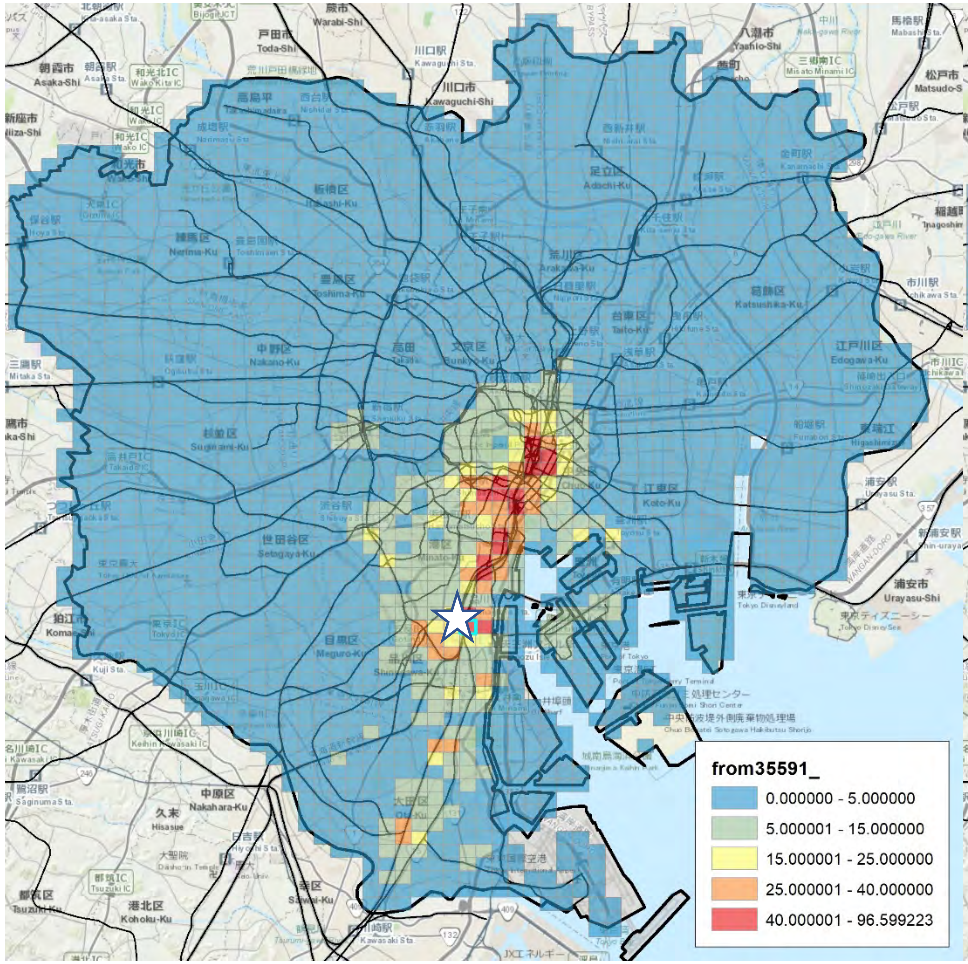


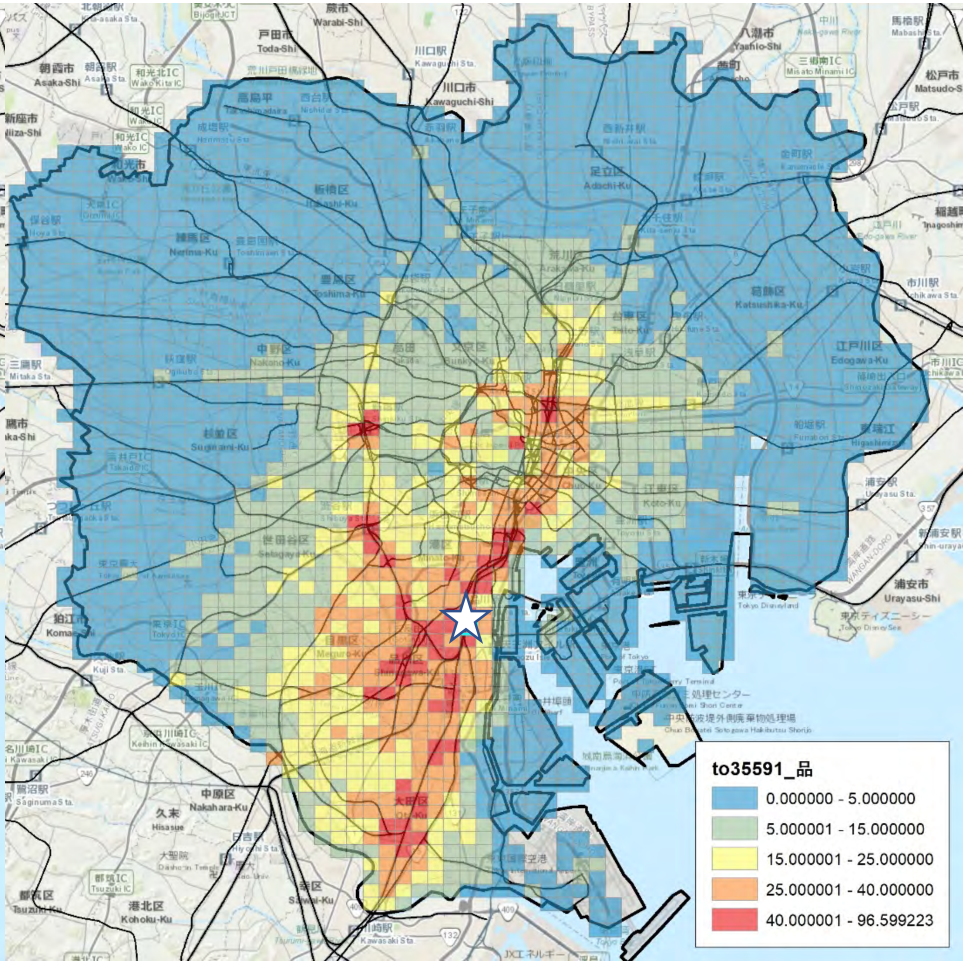


Shinjuku Commercial & business

Outflow/Inflow Population at Specific Cell

Outflow (8:00 – 9:00) Inflow





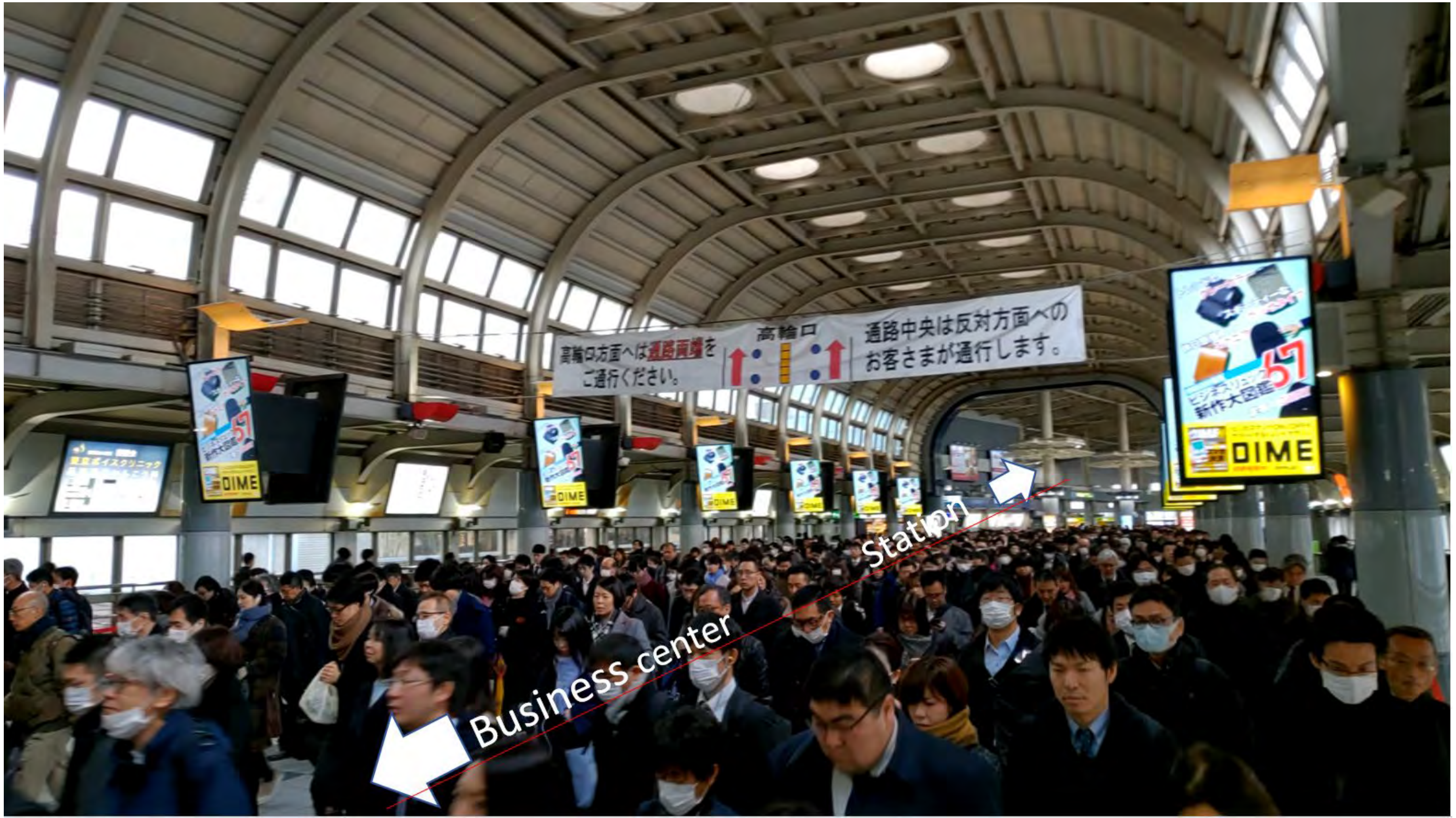
Shinagawa Business center

Pedestrian Flow at Shinagawa Station

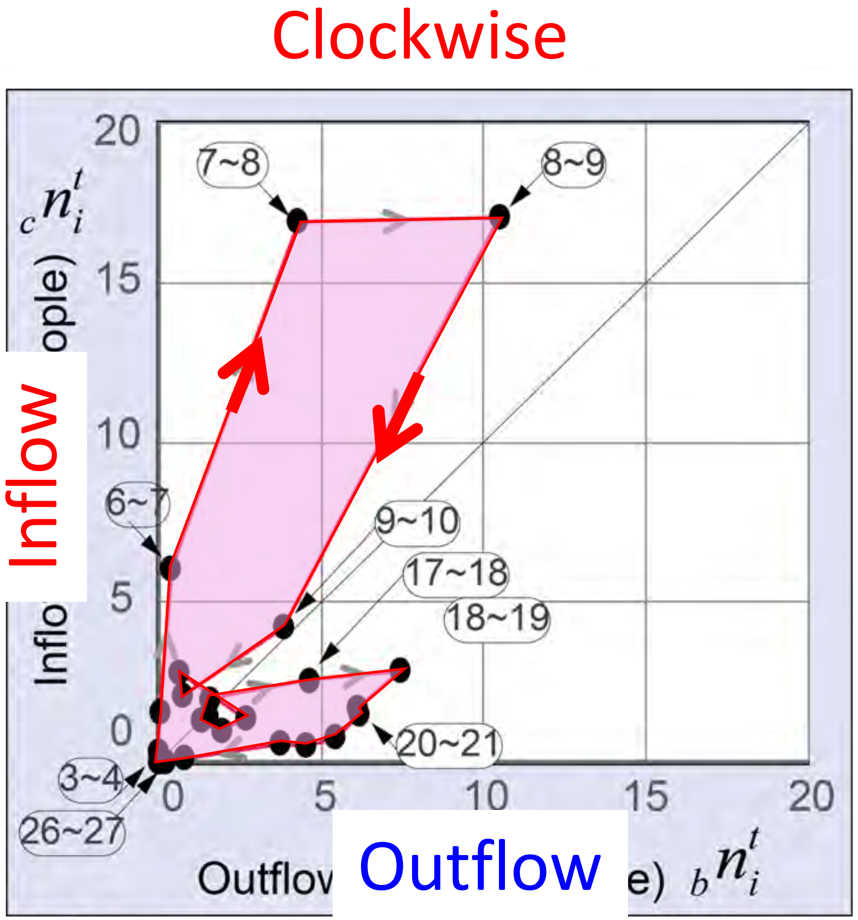
(8:00 – 9:00)

Pedestrian Flow at Shinagawa Station

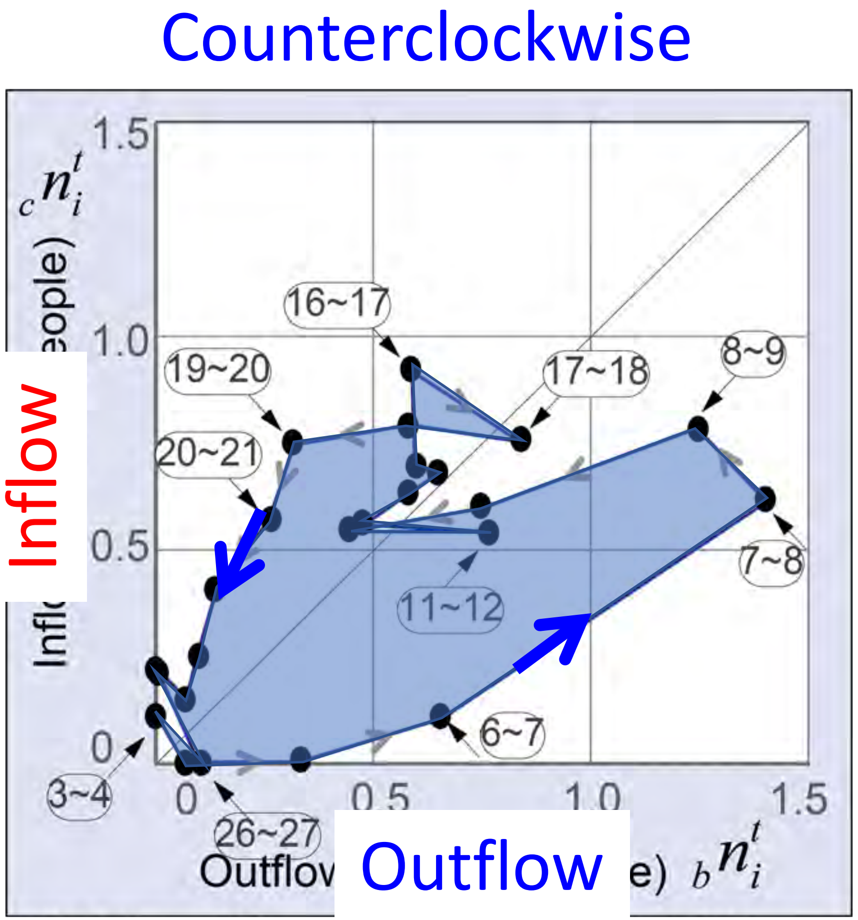
(8:00 – 9:00)



Temporal Change of Outflow/Inflow Population



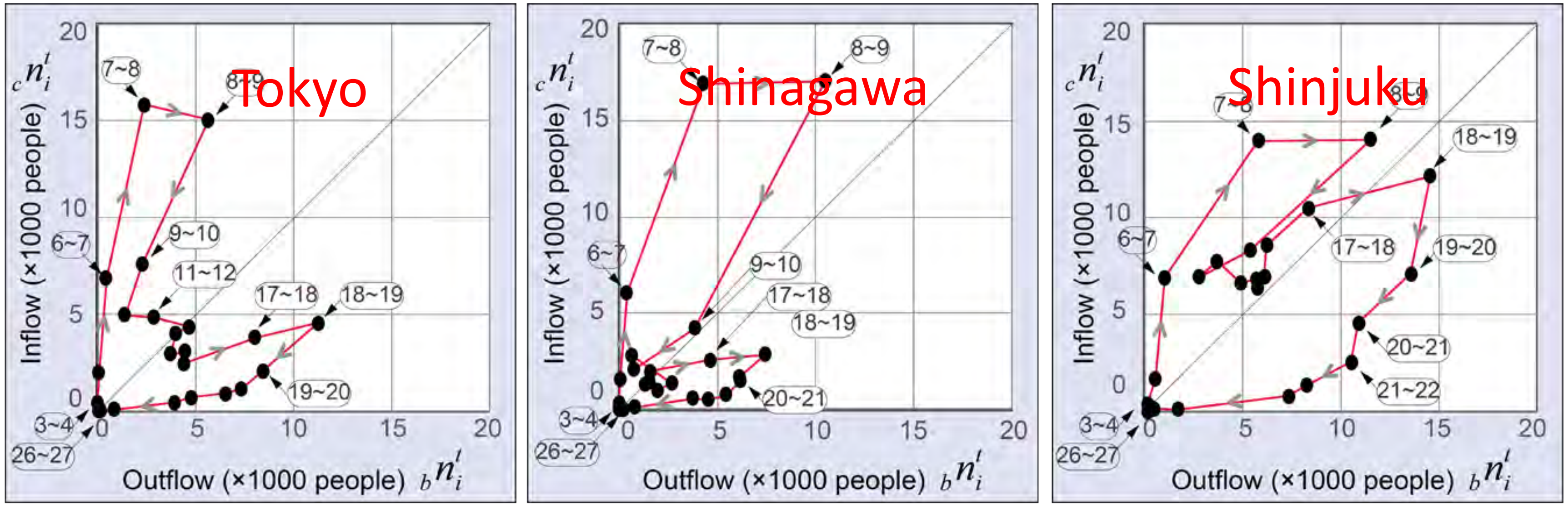
Shinagawa
(Business district)



Ojima
(Large housing complex)

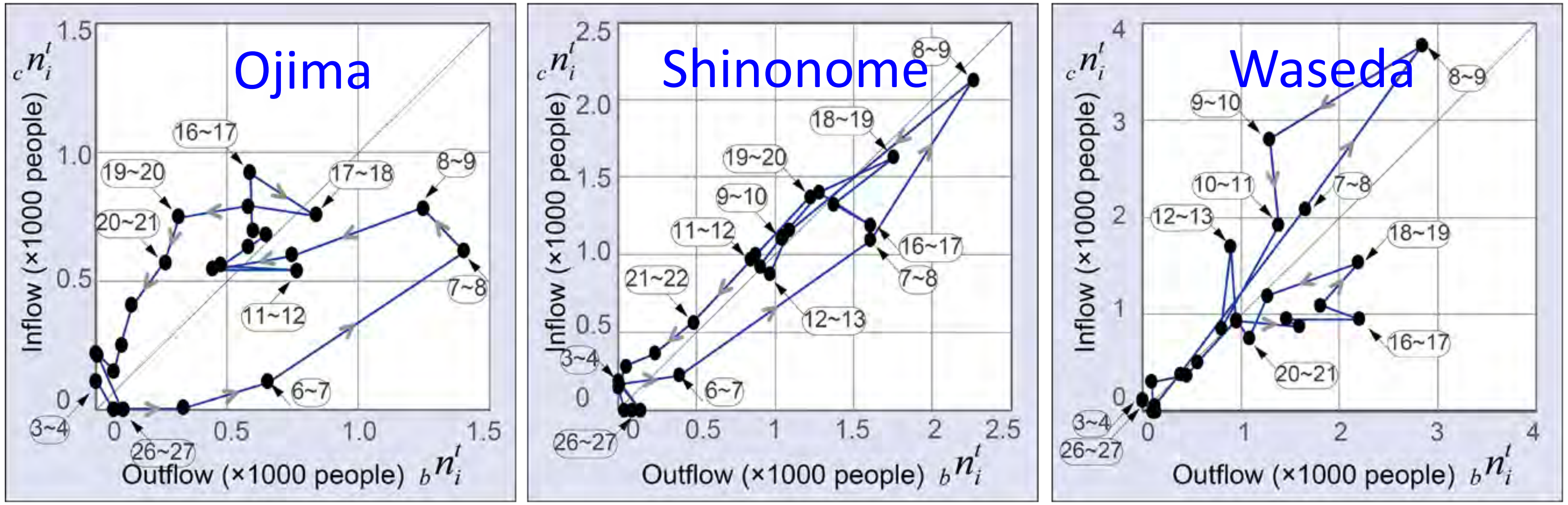
Temporal Change of Outflow/Inflow Population

Clockwise (positive)



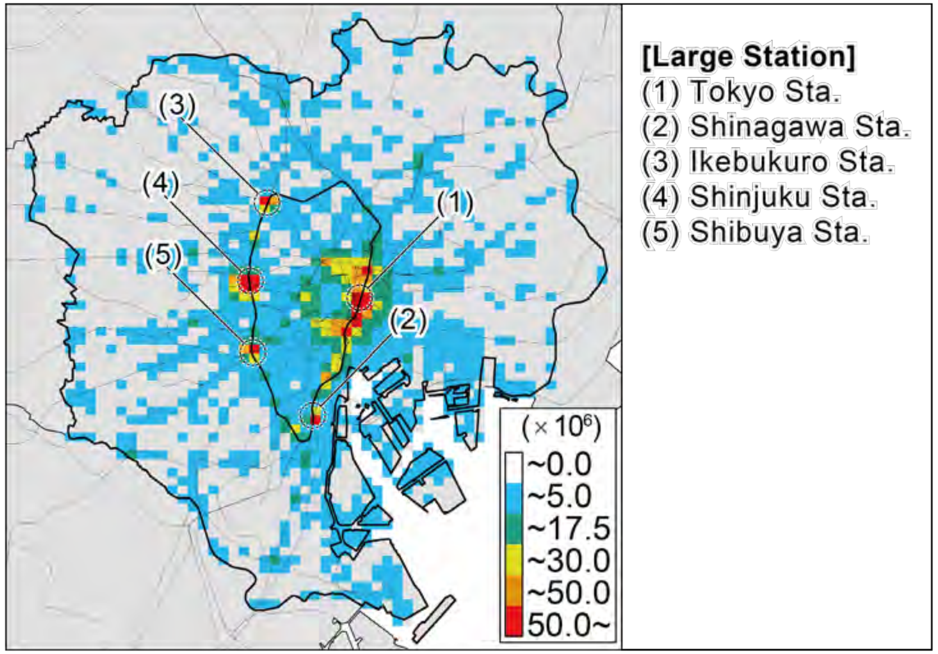
(a)Tokyo (Large Station) [(g)(1)] (b)Shinagawa (Large Station) [(g)(2)] (c)Shinjuku (Large Station) [(g)(4)]

Counter-clockwise (negative)

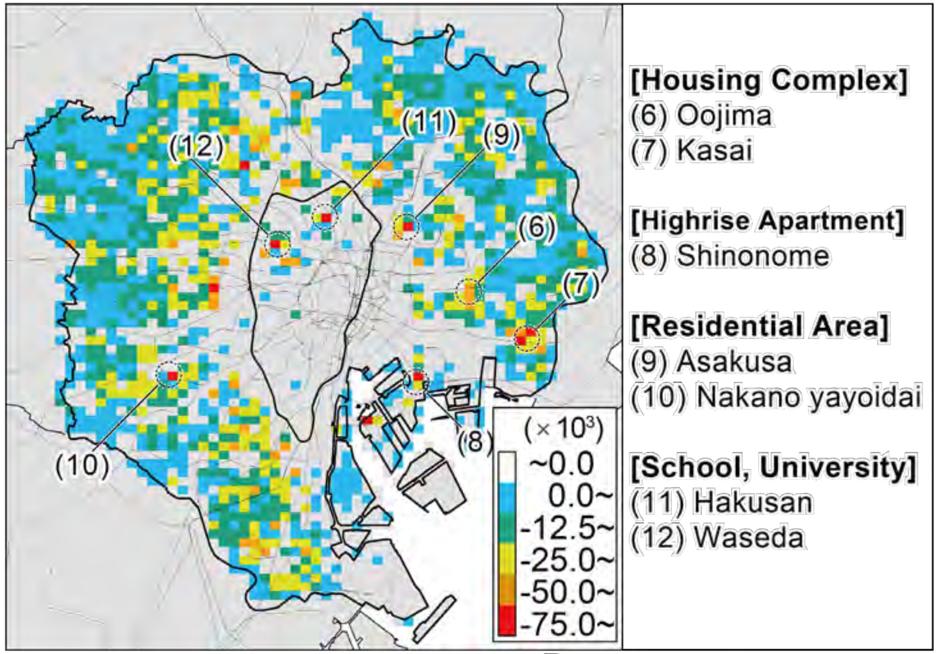


(d)Oojima (Housing Complex) [(g)(6)] (e)Shinonome (Highrise Apartment) [(g)(8)] (f)Waseda (University) [(g)(12)]

Spatial distribution of value of Surface Area



(g) Spatial distribution of value of D_i (0.0 or more)

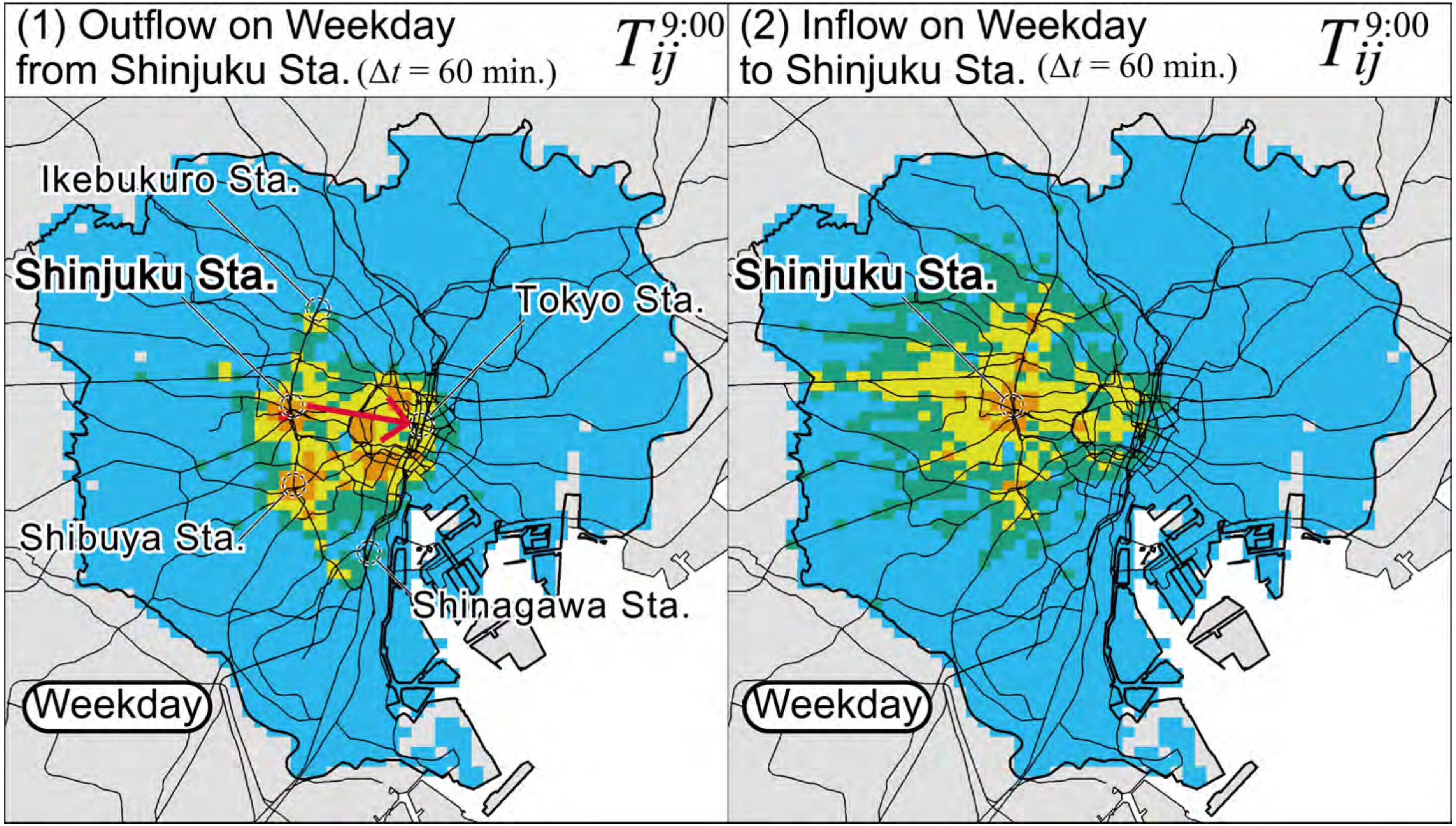


(h) Spatial distribution of value of D_i (less than 0.0)

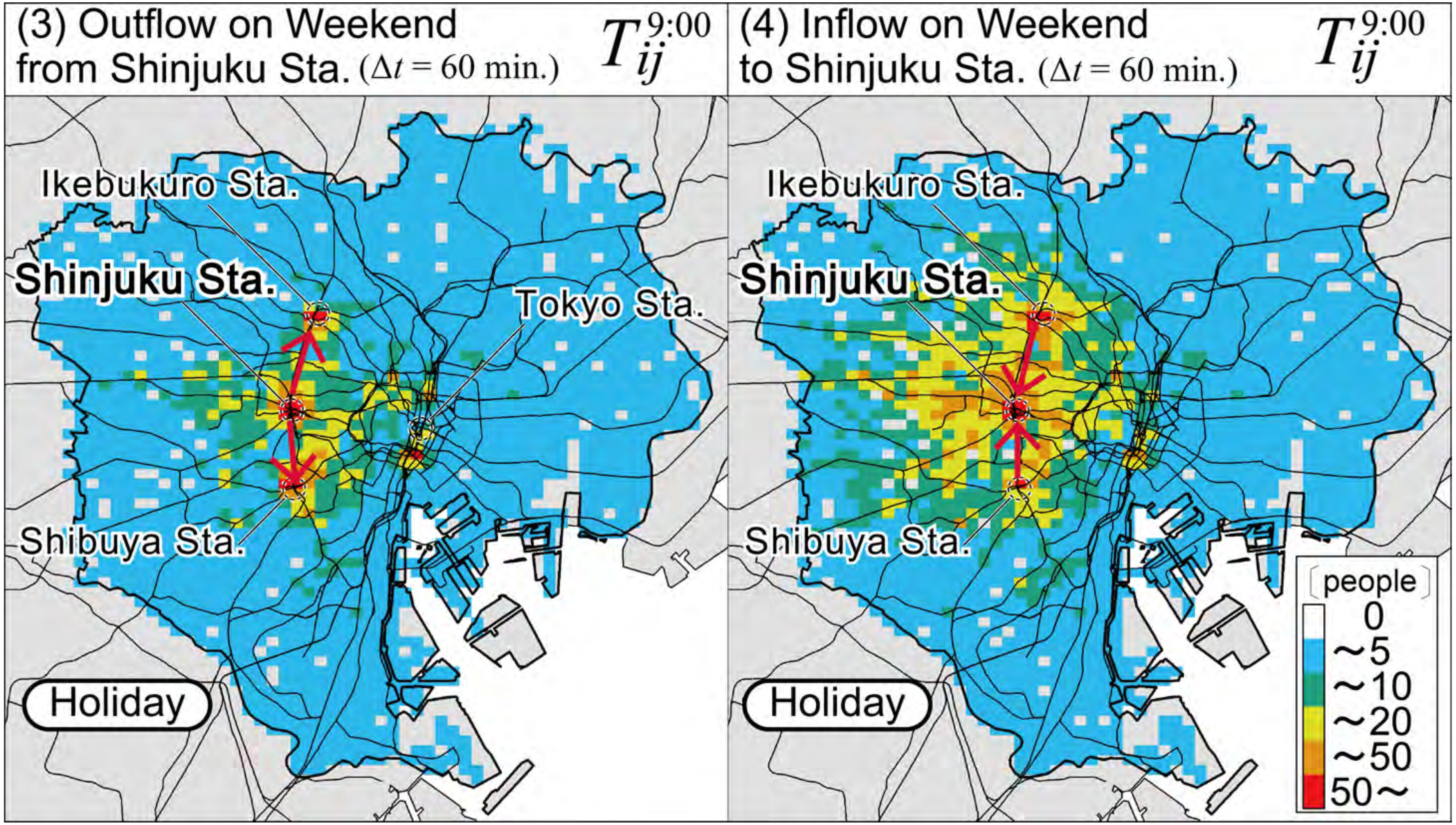
Clockwise
(positive)

Counterclockwise
(negative)

Outflow/Inflow on Weekday at Shinjuku Station



Outflow/Inflow on Weekend at Shinjuku Station



Outline

- ✓ Background & Motivation
- ✓ Spatiotemporal Demographic Data
  (its potential and limitation)
- ✓ Integration Method (1) for Demographic data
  (building use / purpose / attribute)
- ✓ Integration Method (2) for Demographic data
  (inflow / outflow / static)
- ✓ Applications for Disaster Mitigation Planning
- ✓ Summary and Conclusions

Hanshin-Awaji Earthquake 1995/1/17 **Tue 5:46**

Many people lost their lives by **collapsed houses**.
At the same time, however, 70% of rescued people were rescued by the **neighbors** including younger people.

http://www.bo-sai.co.jp/sub6.html

Haiti Earthquake 2010/1/12 **Mon 16:53**

They had difficulty in rescue activities
without electric power during the night.

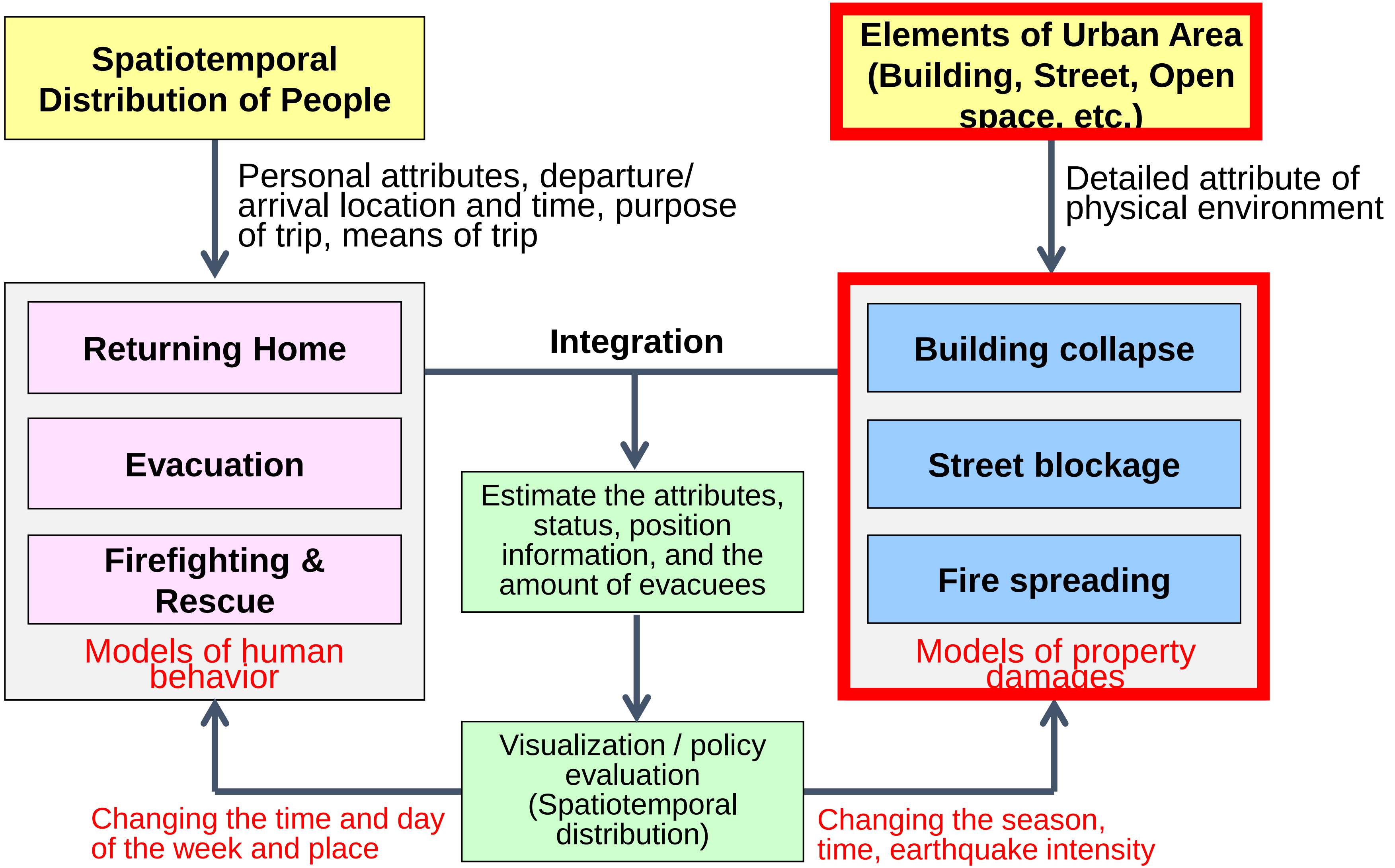
East Japan Earthquake 2011/3/11 **Fri 14:46**

Many people who **temporarily came back home** were killed by tsunami.

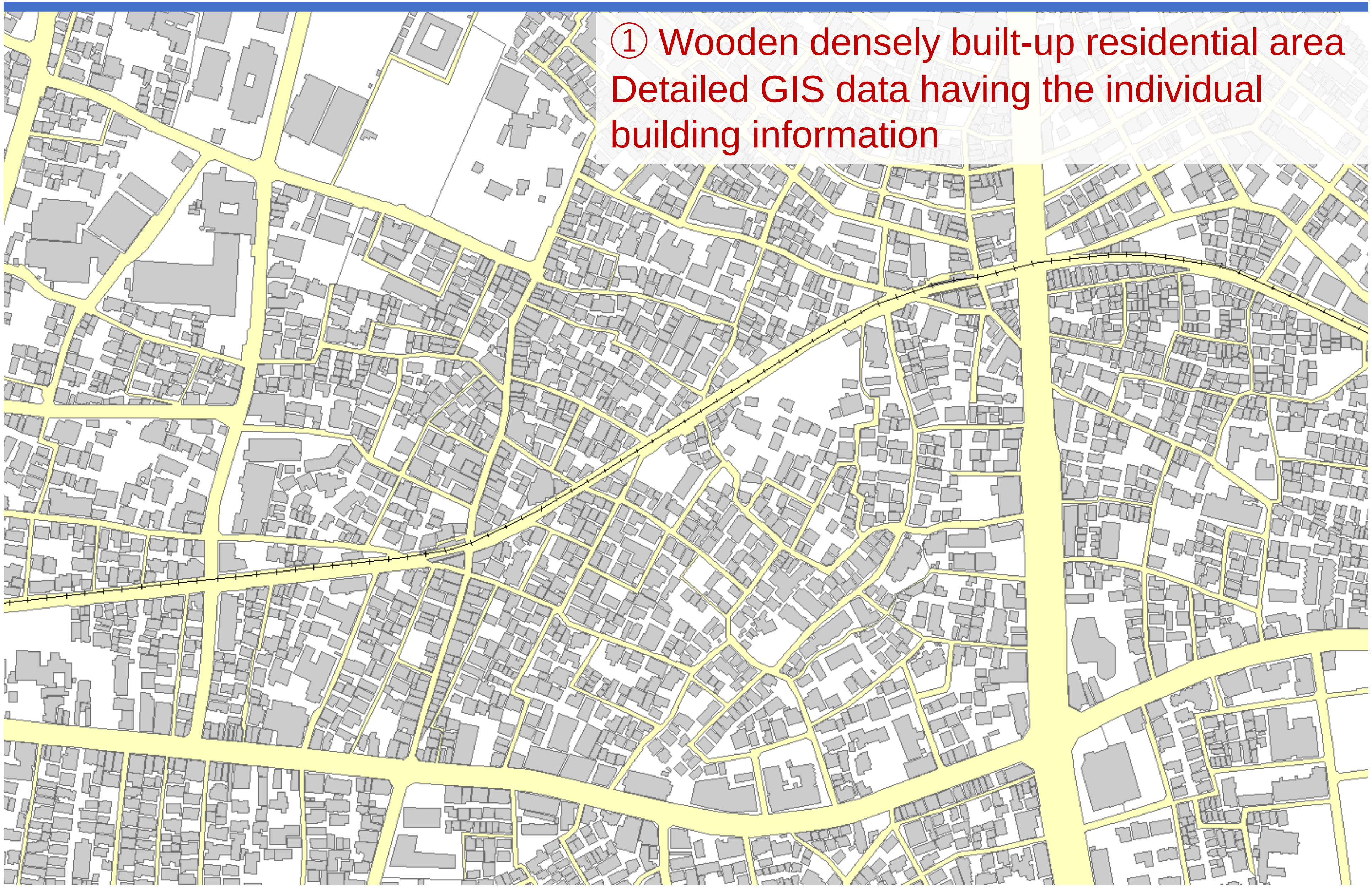
（2011年3月12日午前 読売新聞）

（2011年3月13日20時16分 読売新聞）

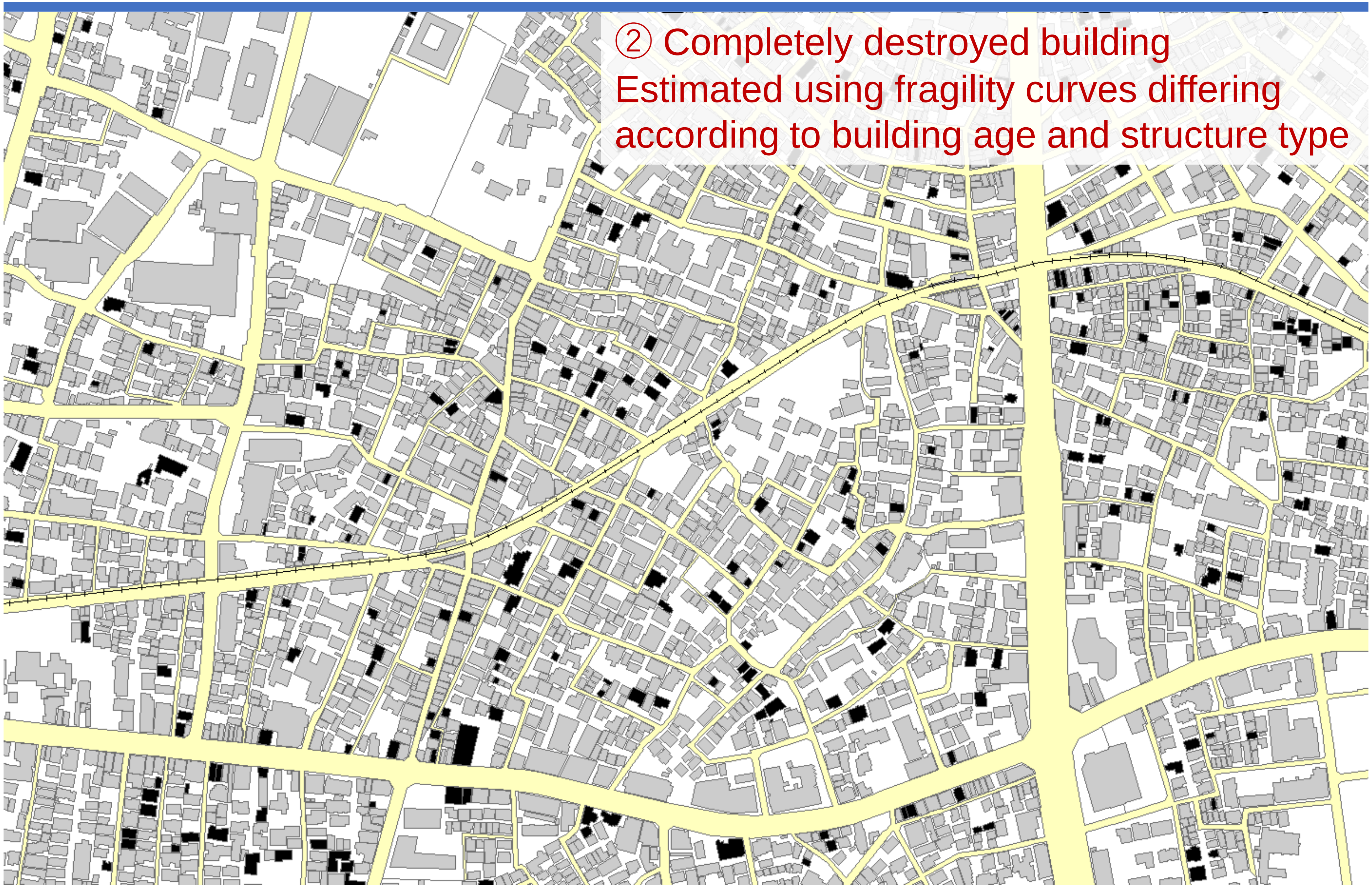
Framework of Simulation System



Wooden Densely Built-up Residential Area



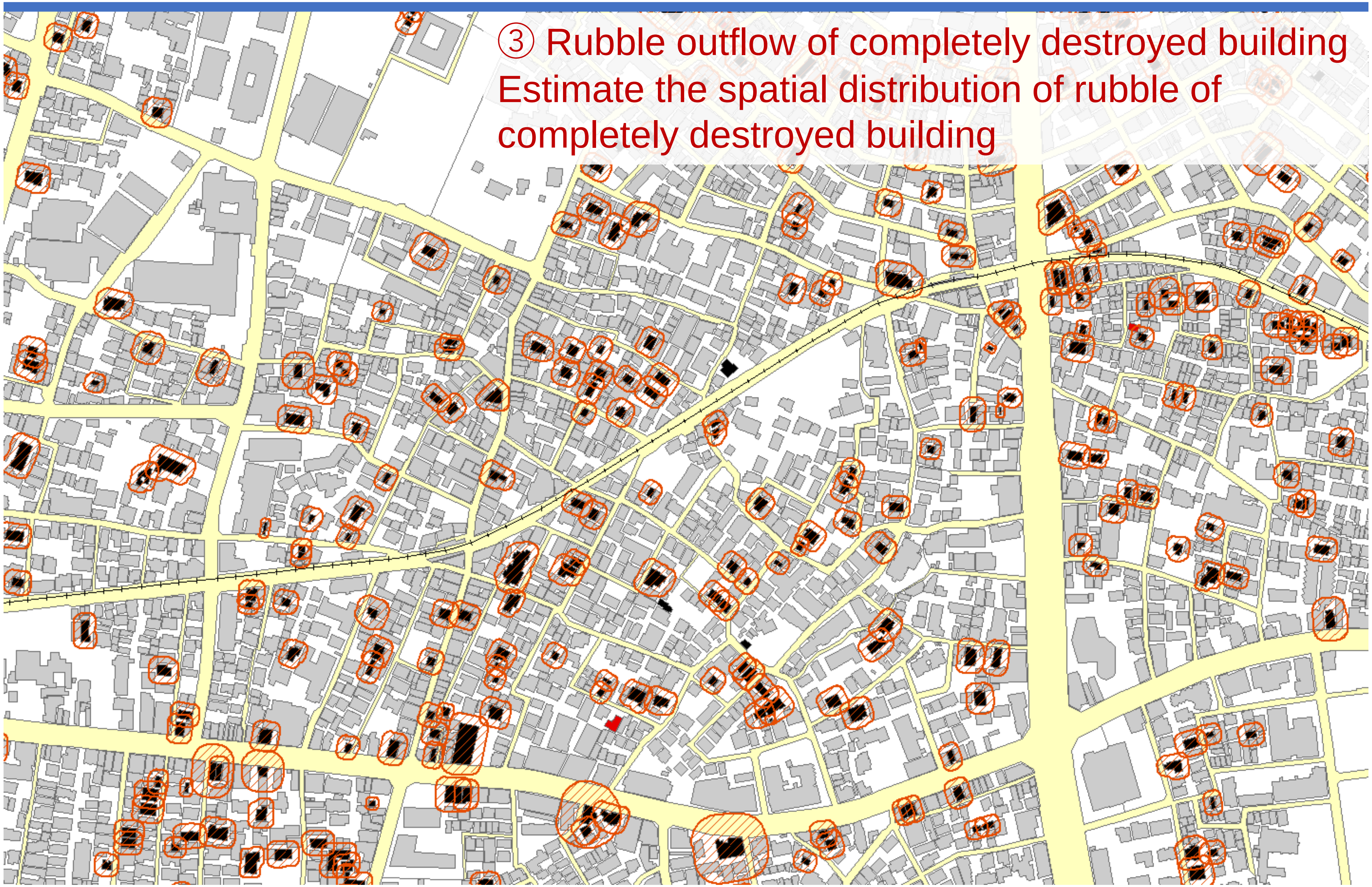
Completely Destroyed Buildings



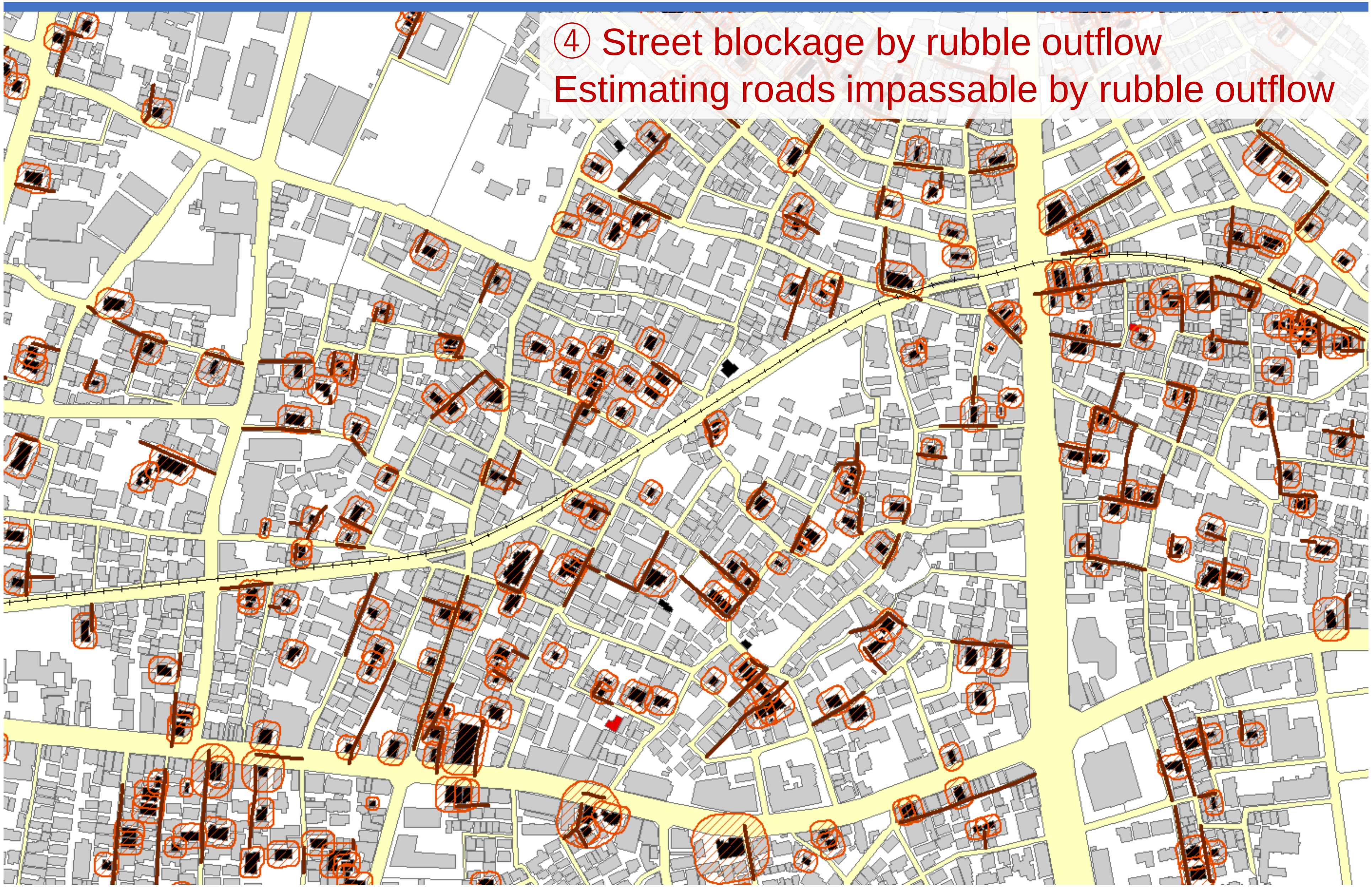
Rubble Outflow of Destroyed Building

③ Rubble outflow of completely destroyed building

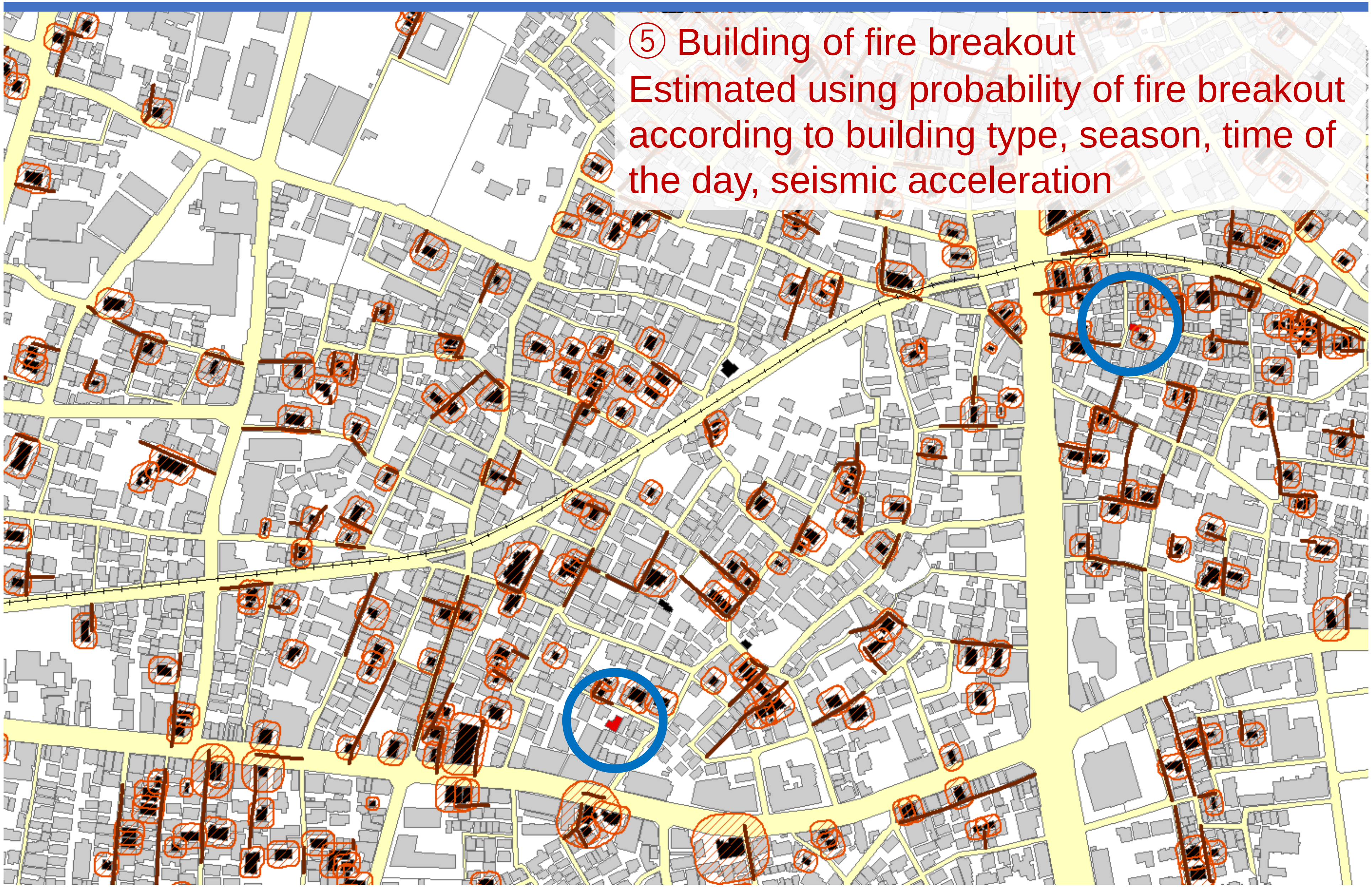
Estimate the spatial distribution of rubble of completely destroyed building



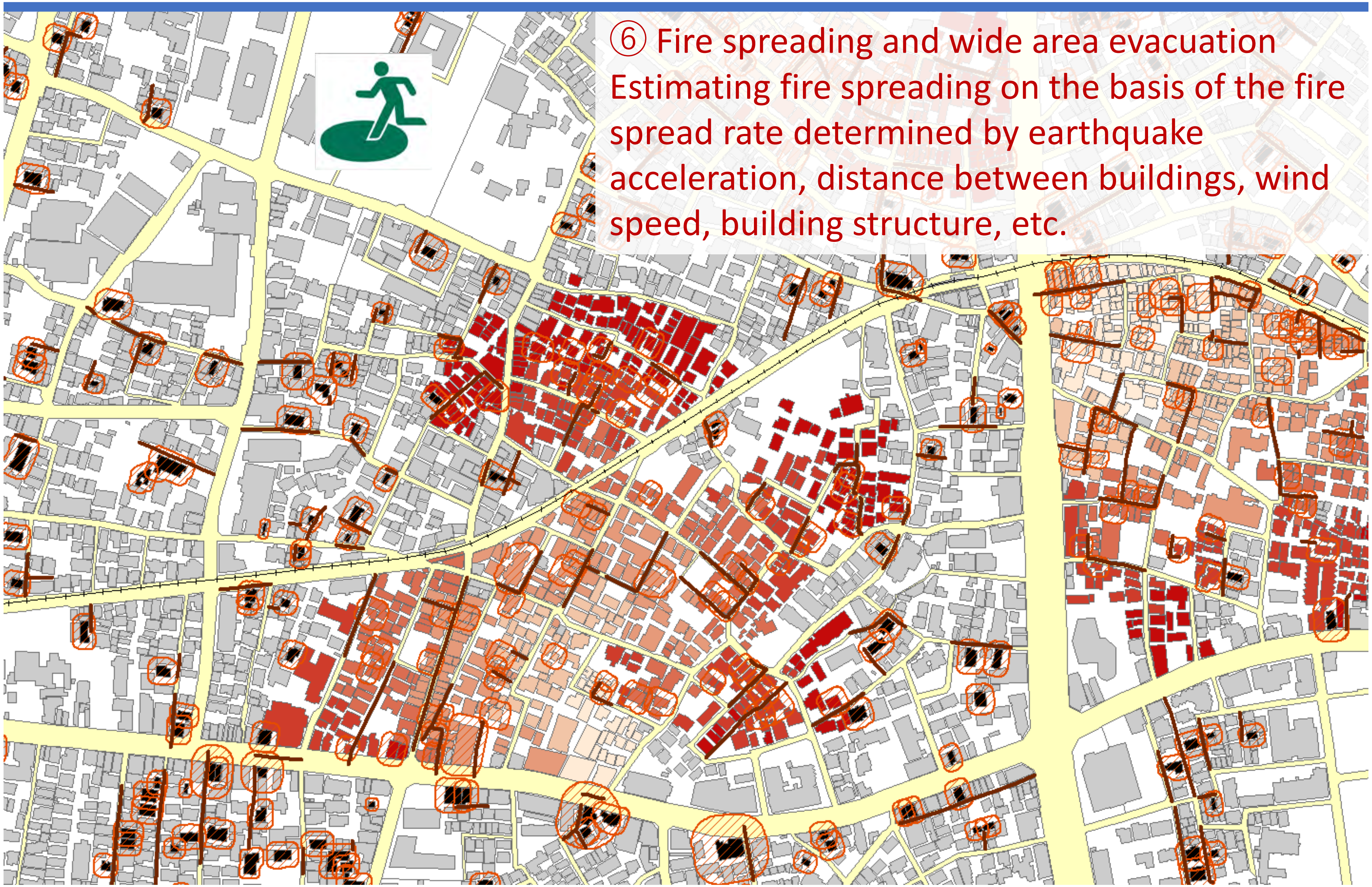
Street Blockage by Rubble Outflow



Buildings of Fire Outbreak

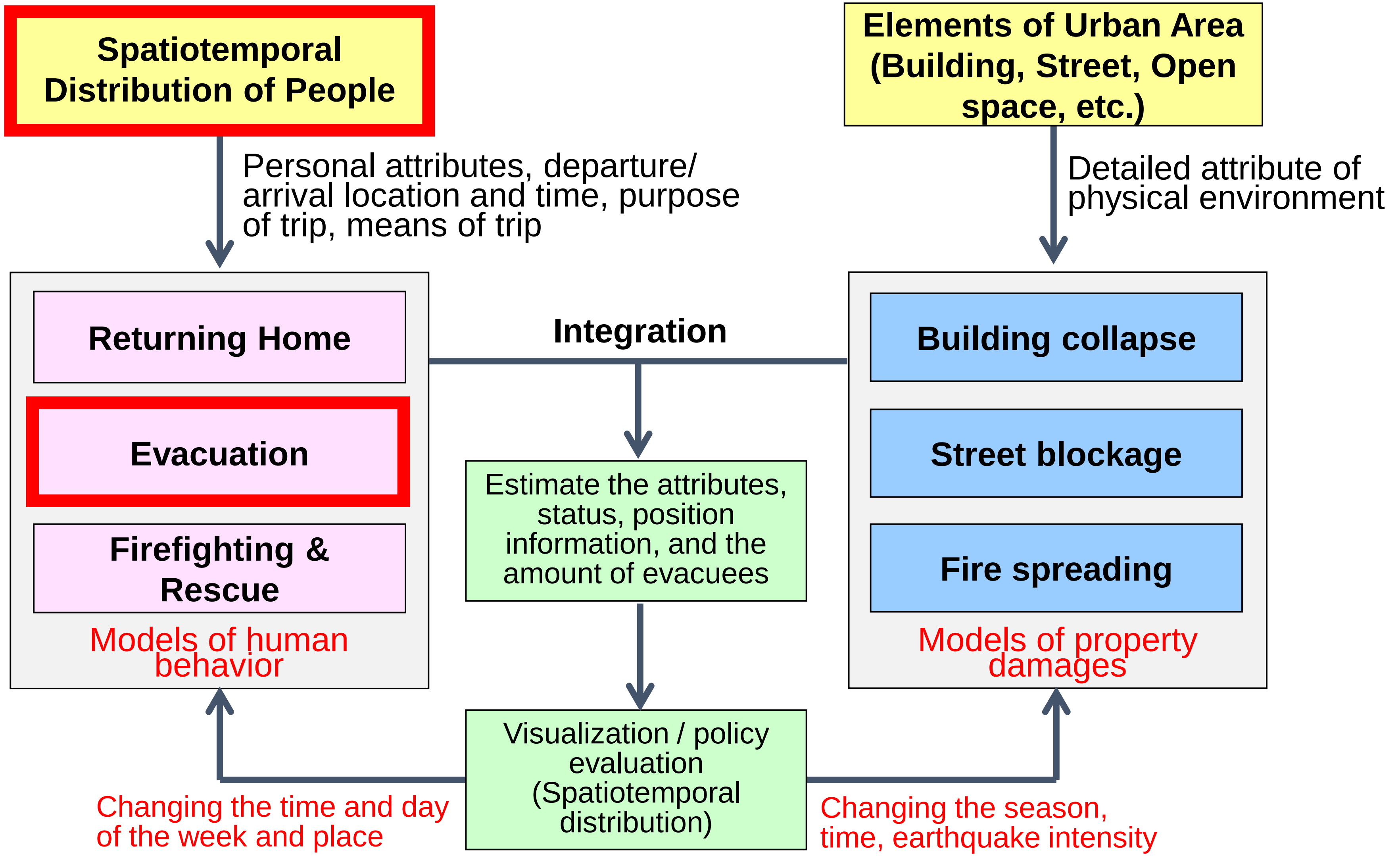


Fire Spreading and Wide Area Evacuation

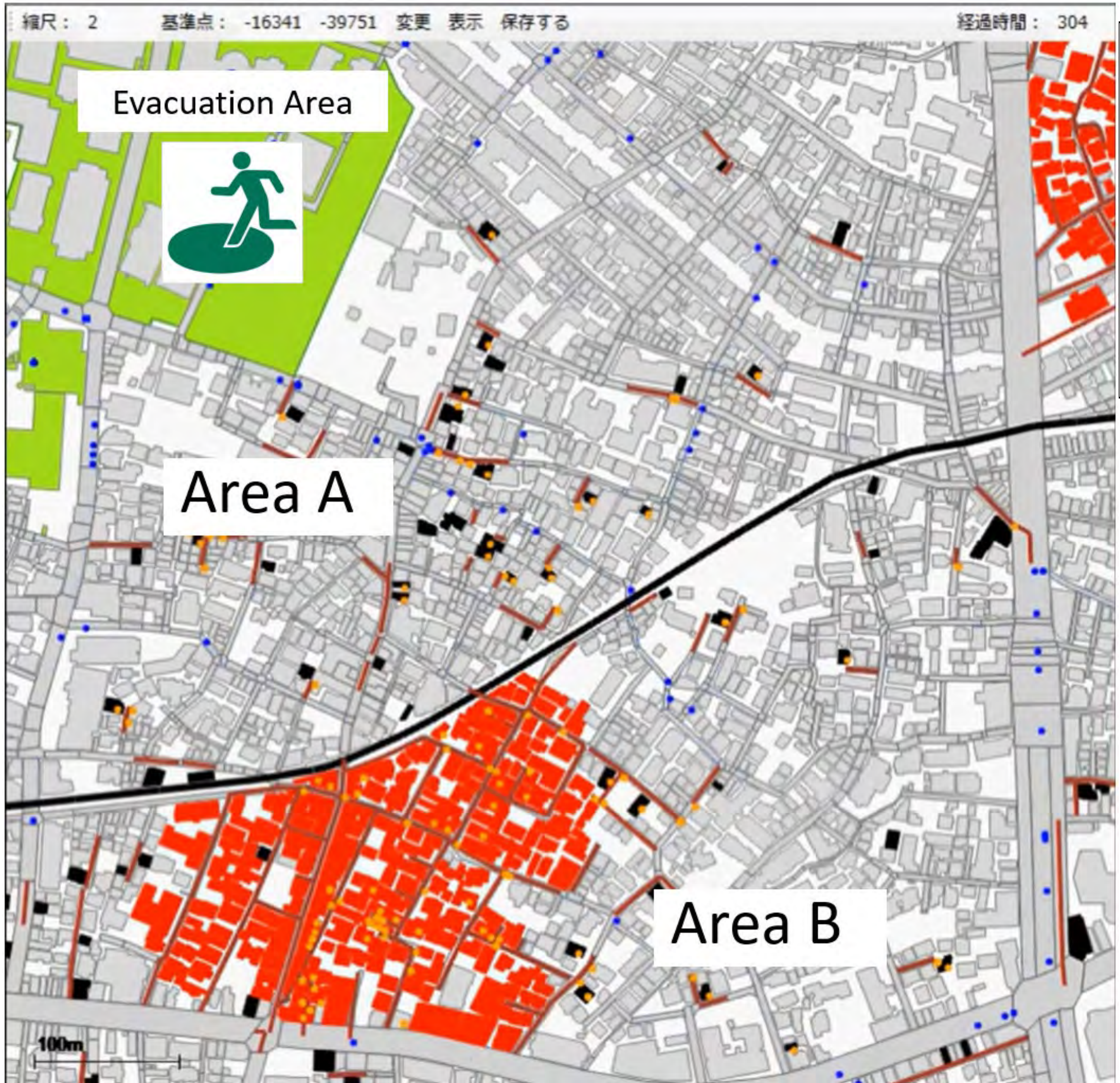


⑥ Fire spreading and wide area evacuation
Estimating fire spreading on the basis of the fire spread rate determined by earthquake acceleration, distance between buildings, wind speed, building structure, etc.

Framework of Simulation System



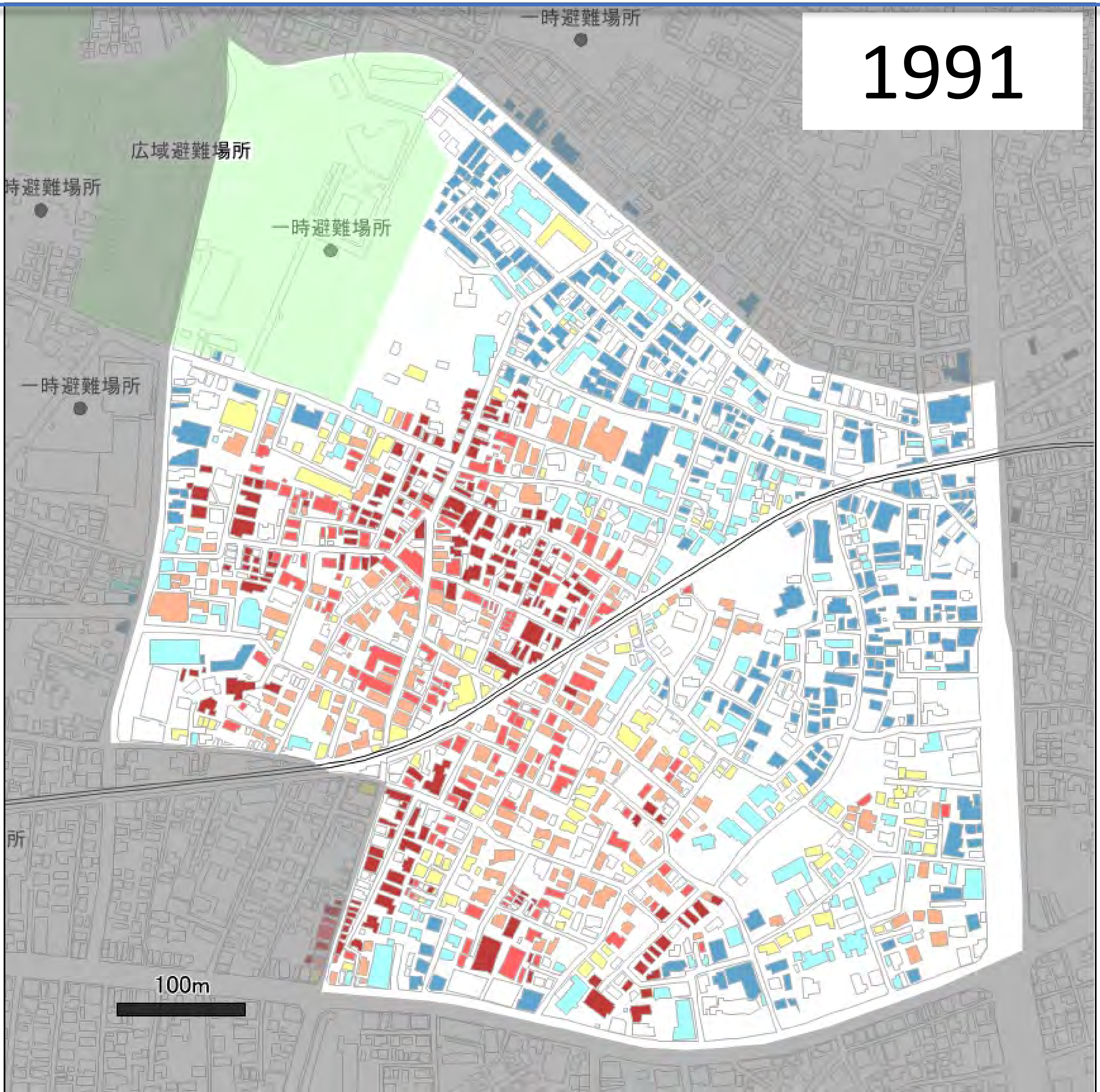
Fire Spreading and Wide Area Evacuation



[Legend]

- Evacuation area
- Collapsed building
- Fire building
- Street blockage
- People in evacuation
- People with difficulty in evacuation

People with Difficulty in Evacuation

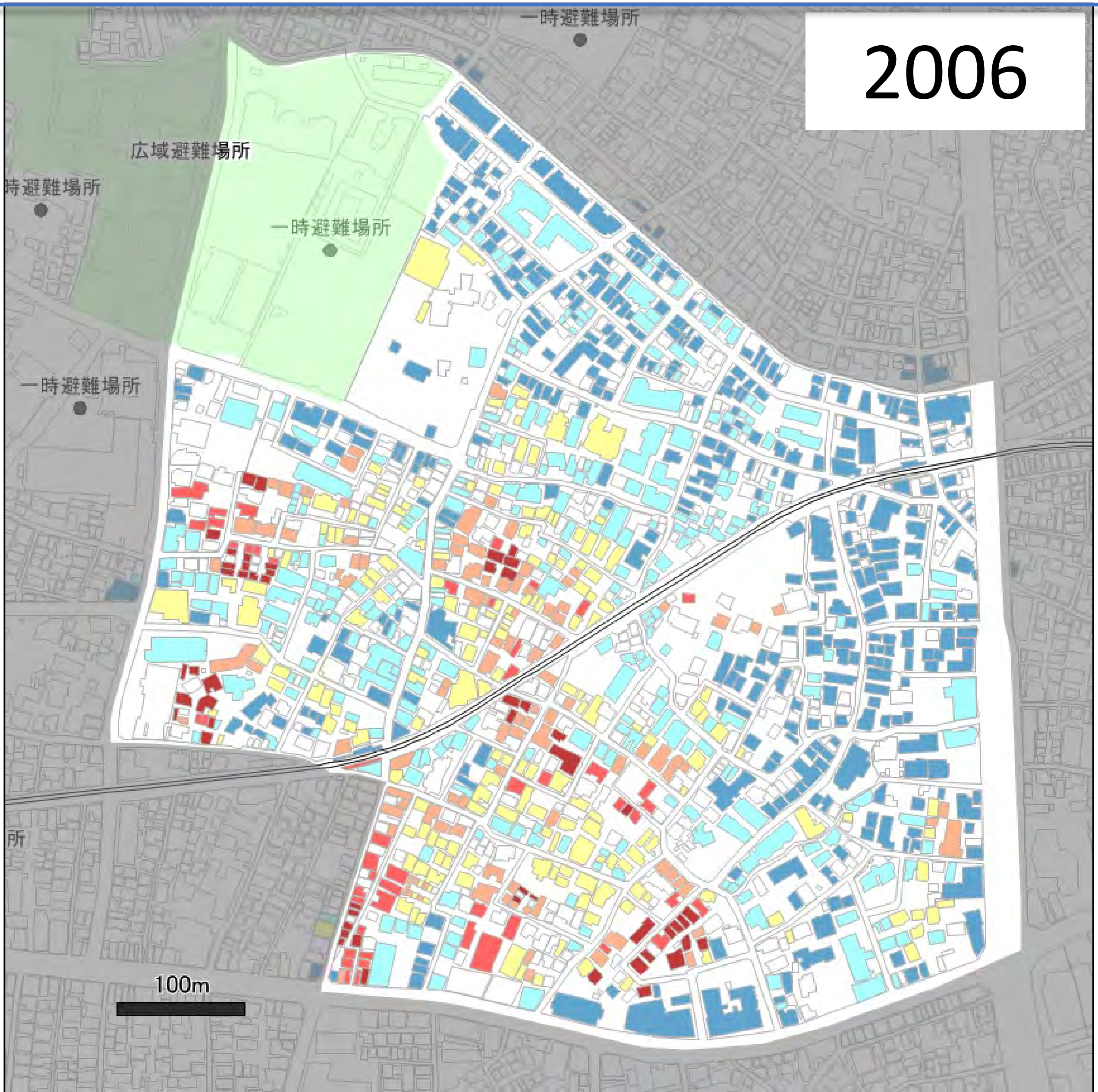


Percentage of people who could not evacuate among people who tried to evacuate.

Ratio of People with Difficulty in Evacuation

0
0 ～ 0.1
0.1 ～ 0.2
0.2 ～ 0.3
0.3 ～ 0.4
0.4 ～ 0.5
> 0.5

People with Difficulty in Evacuation

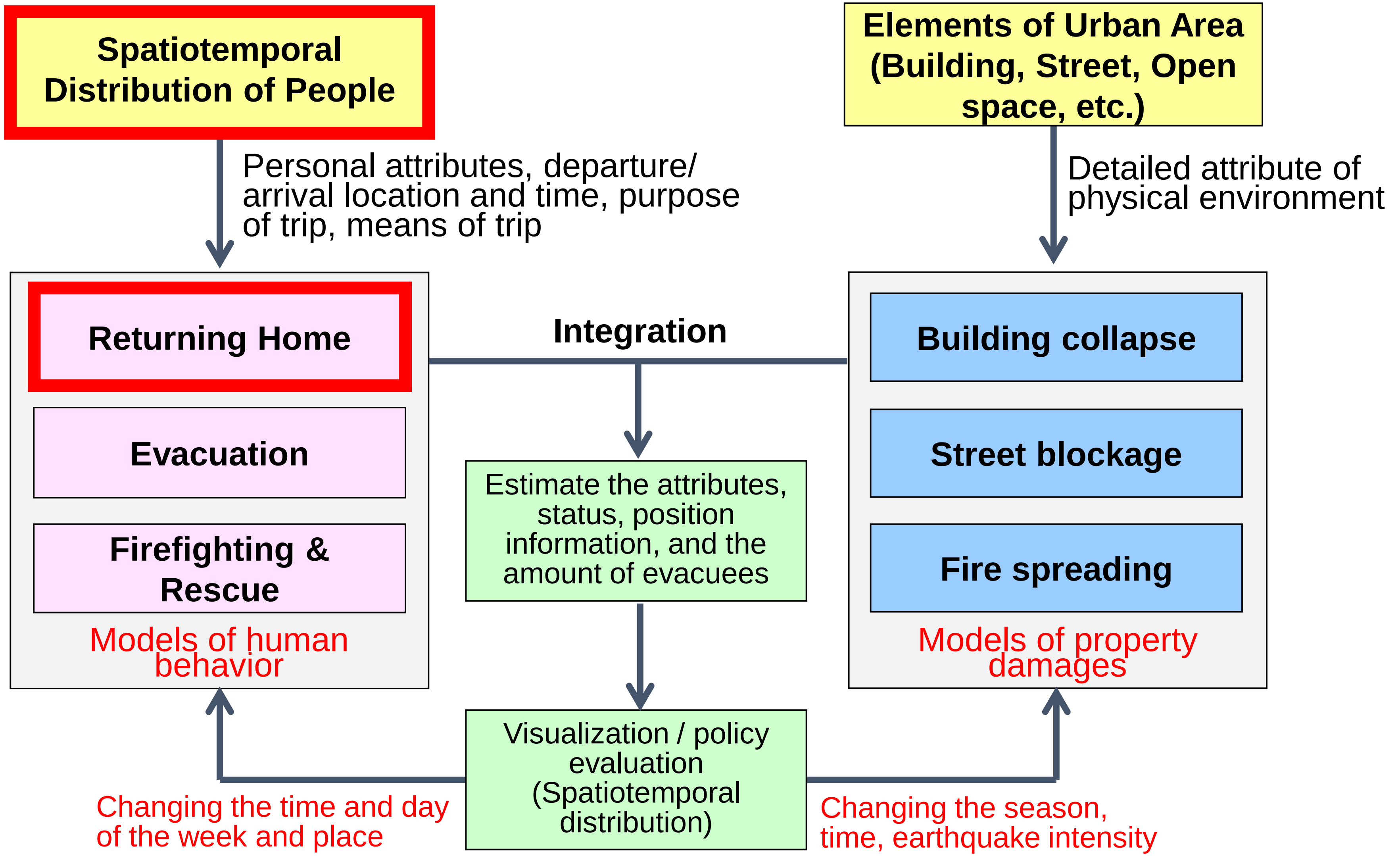


Percentage of people who could not evacuate among people who tried to evacuate.

Ratio of People with Difficulty in Evacuation

0
0 ~ 0.1
0.1 ~ 0.2
0.2 ~ 0.3
0.3 ~ 0.4
0.4 ~ 0.5
> 0.5

Framework of Simulation System



Background

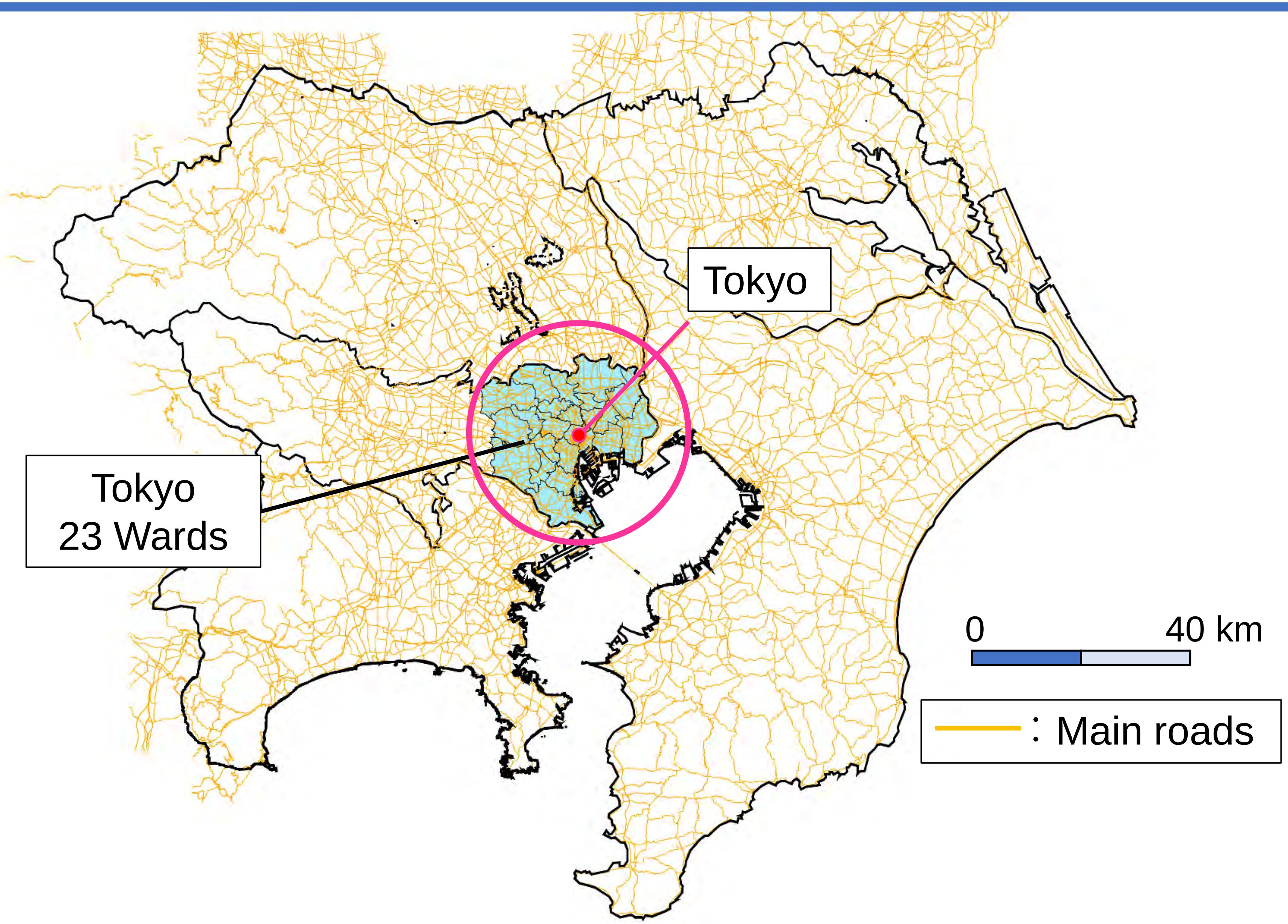
Tokyo Government has enacted the ordinance for people with difficulty in returning home.

(1) Suppression of returning home behavior from secured places (school/ workplace).
(2) Providing information about disaster situation.
(3) Temporary Shelters for people with difficulty in returning.
(4) Support Stations for people returning home on foot.

Questions:
The number of facilities, size, and arrangement is sufficient?
If not, how can we reduce congestion of facilities?

Evaluation by simulation

Main Roads in Simulation



Facilities to be Analyzed in Simulation

Temporary Shelter

ex: City hall, Concert hall, High school (Public facilities)

These facilities are destinations for those who are going to stay

Support Station

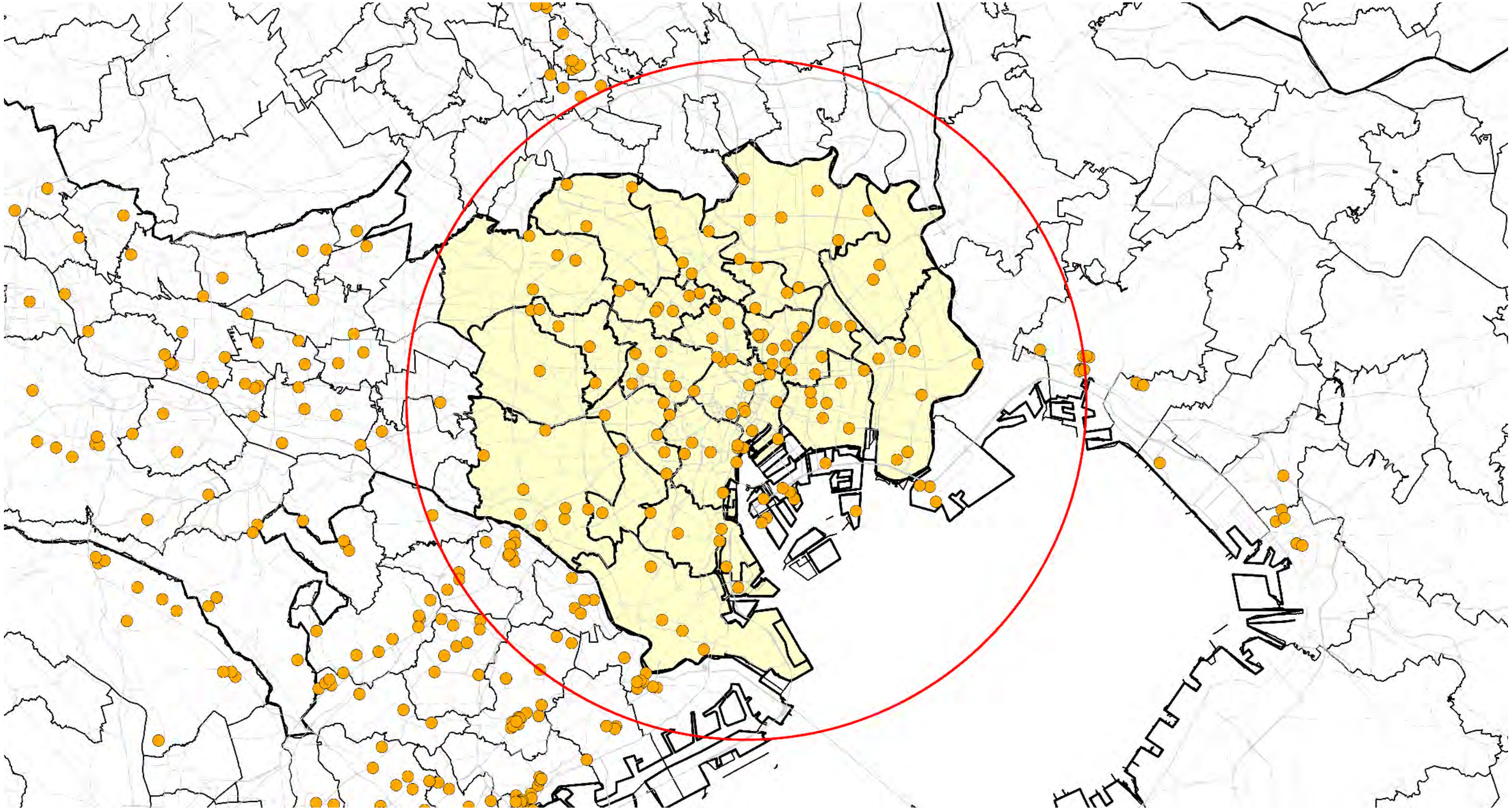
ex: Convenience stores/ Gas stations

Train Station

ex: Large Train stations

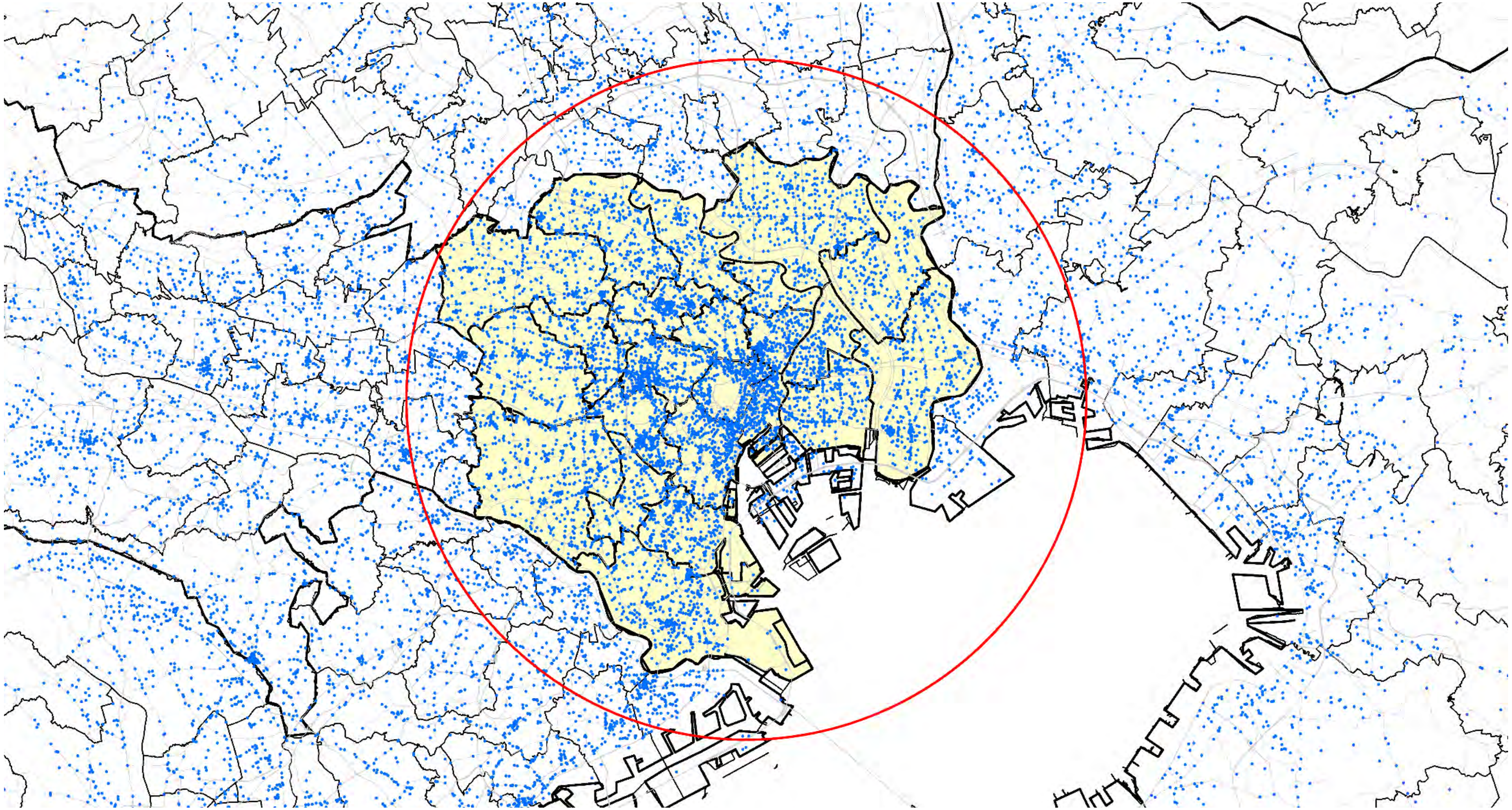
People drop in at these facilities while traveling for toilets and a rest on the way returning home

Temporary Shelters



Ex: City hall, Concert hall, High school
(Mainly public facilities)

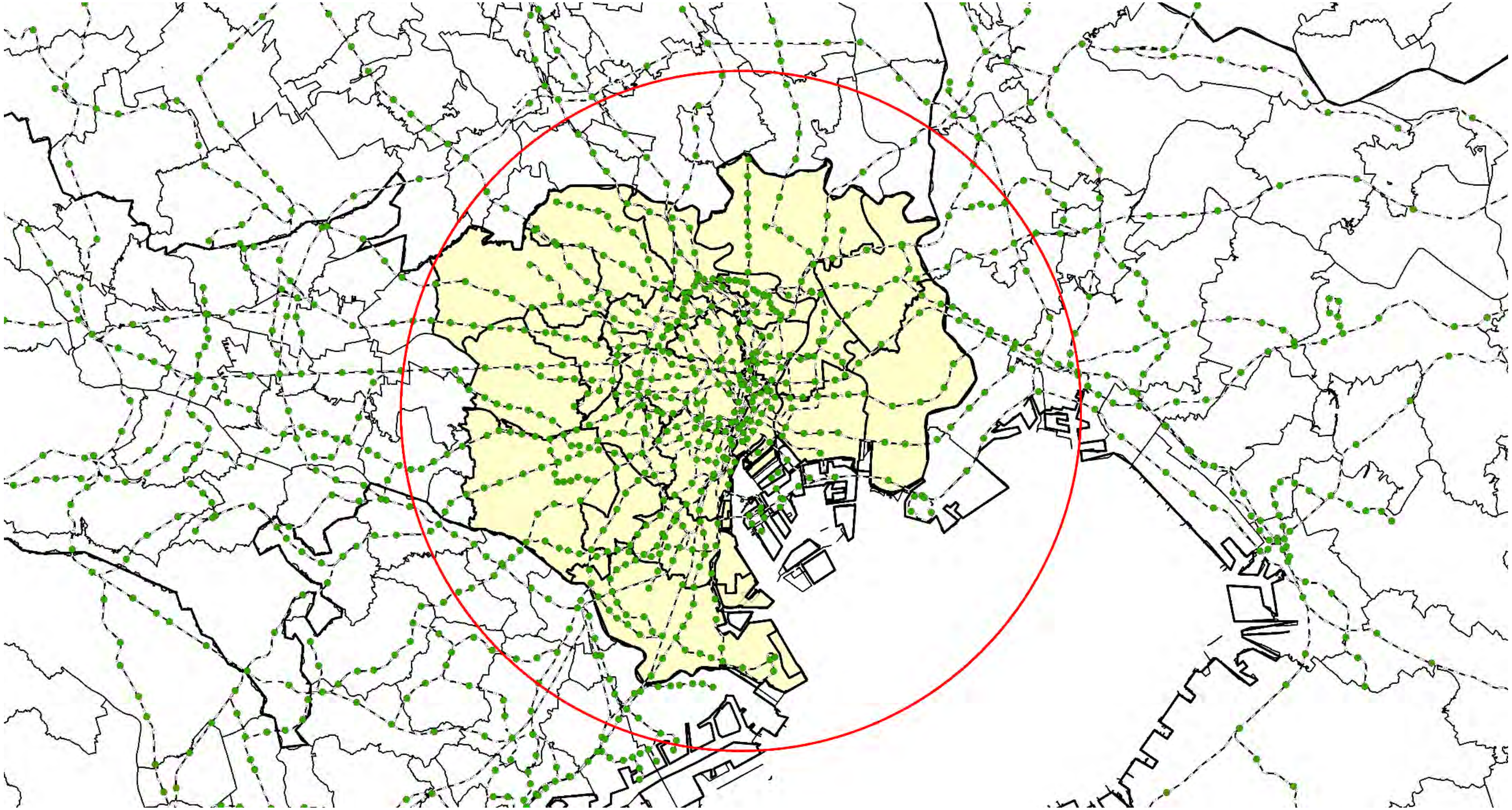
Support Stations



Ex: Convenience stores/ Gas stations

: Main roads

Train Stations



Ex: Train stations

- - - : Trains

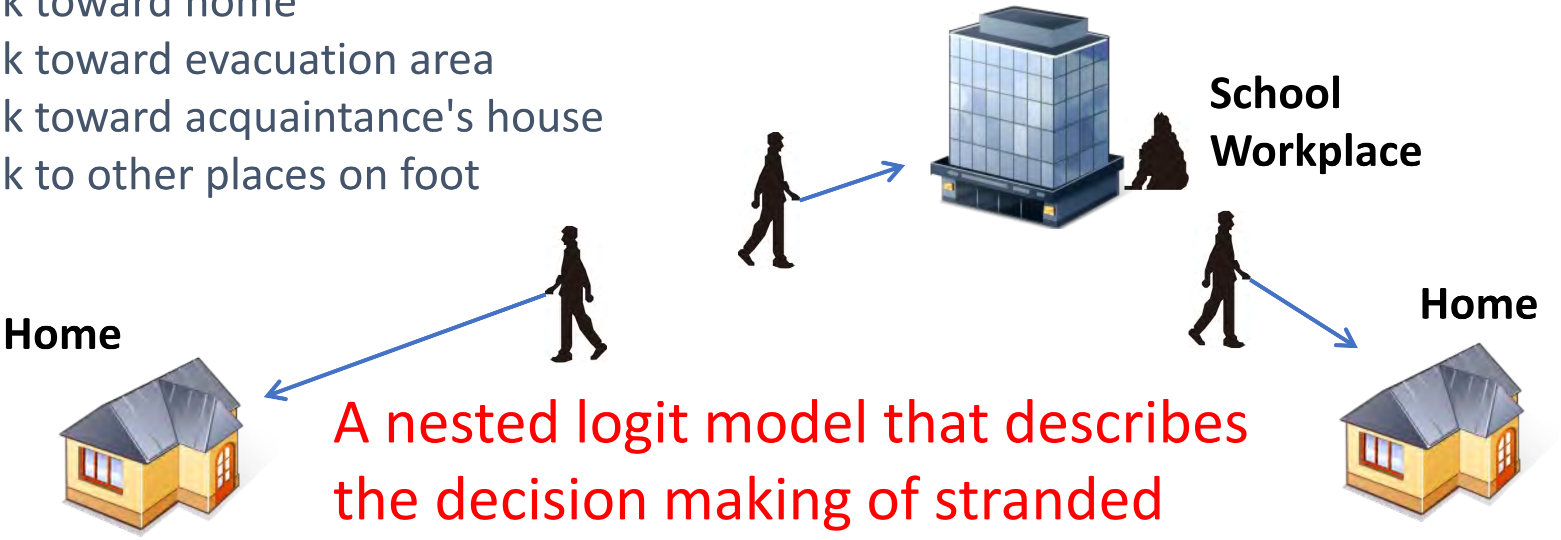
Questionnaire Survey on People's Behavior

Responders

Occupation: Ordinal employee / Student
Location of workplace /school: Inside 23 special districts in Tokyo
Means of transportation: Public transportation (Train or bus)
Attributs: Family type, Sex, Age, Address of workplace/school, Address of house
Number of responders: 2,348 persons

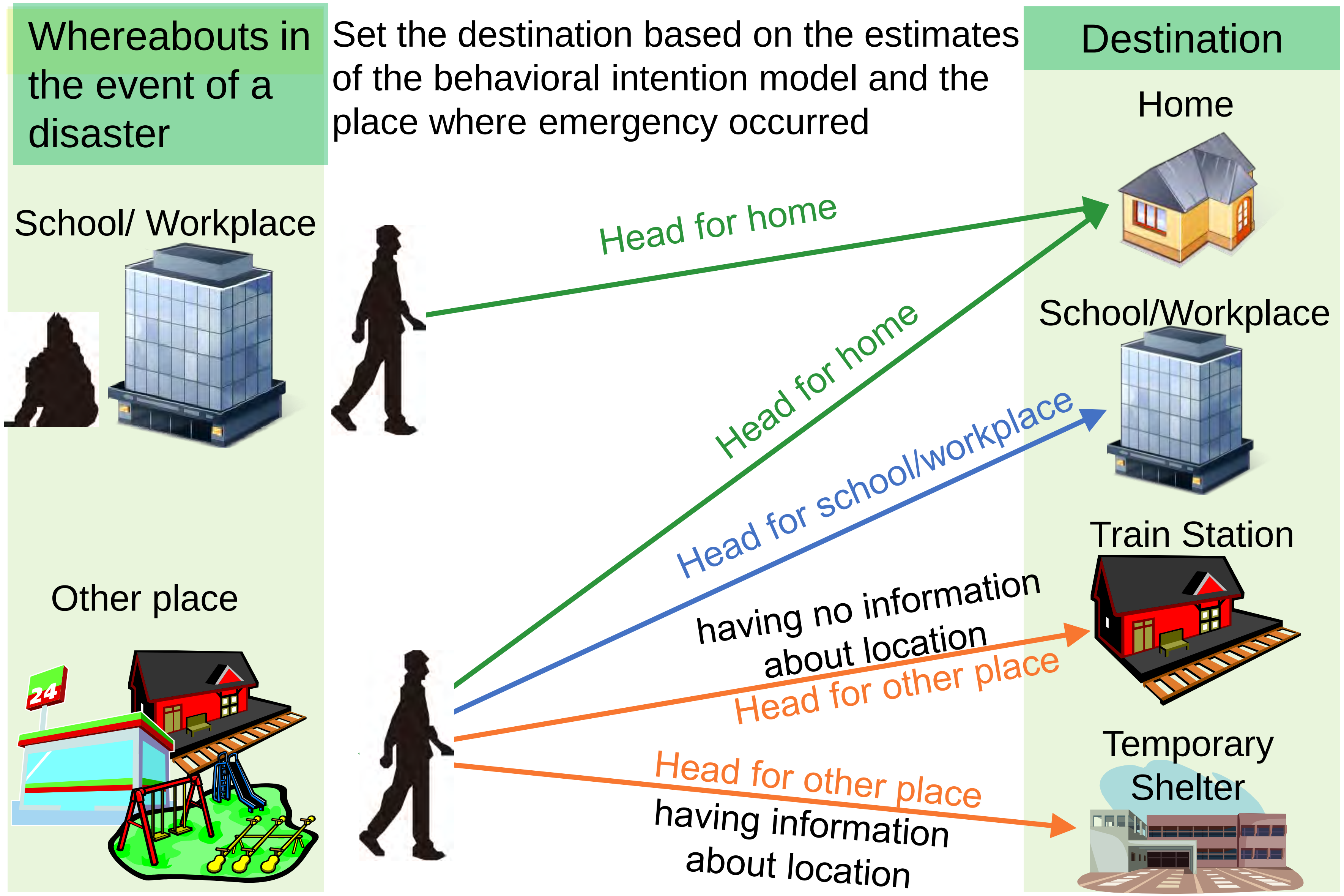
Behavior

1: Stay at school or workplace/ Walk toward school or workplace
2: Walk toward home
3: Walk toward evacuation area
4: Walk toward acquaintance's house
5: Walk to other places on foot

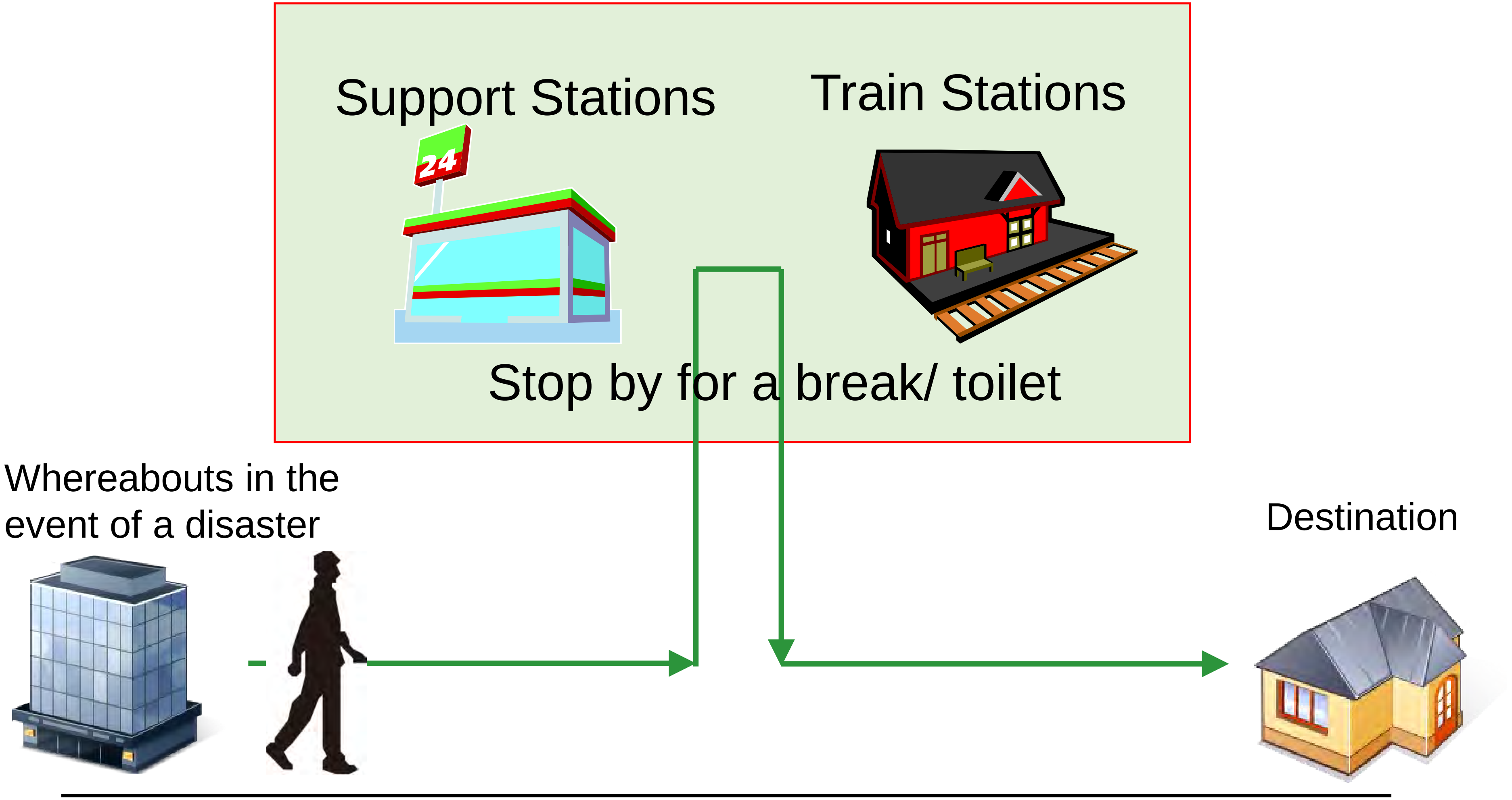


A nested logit model that describes the decision making of stranded people after a large earthquake.

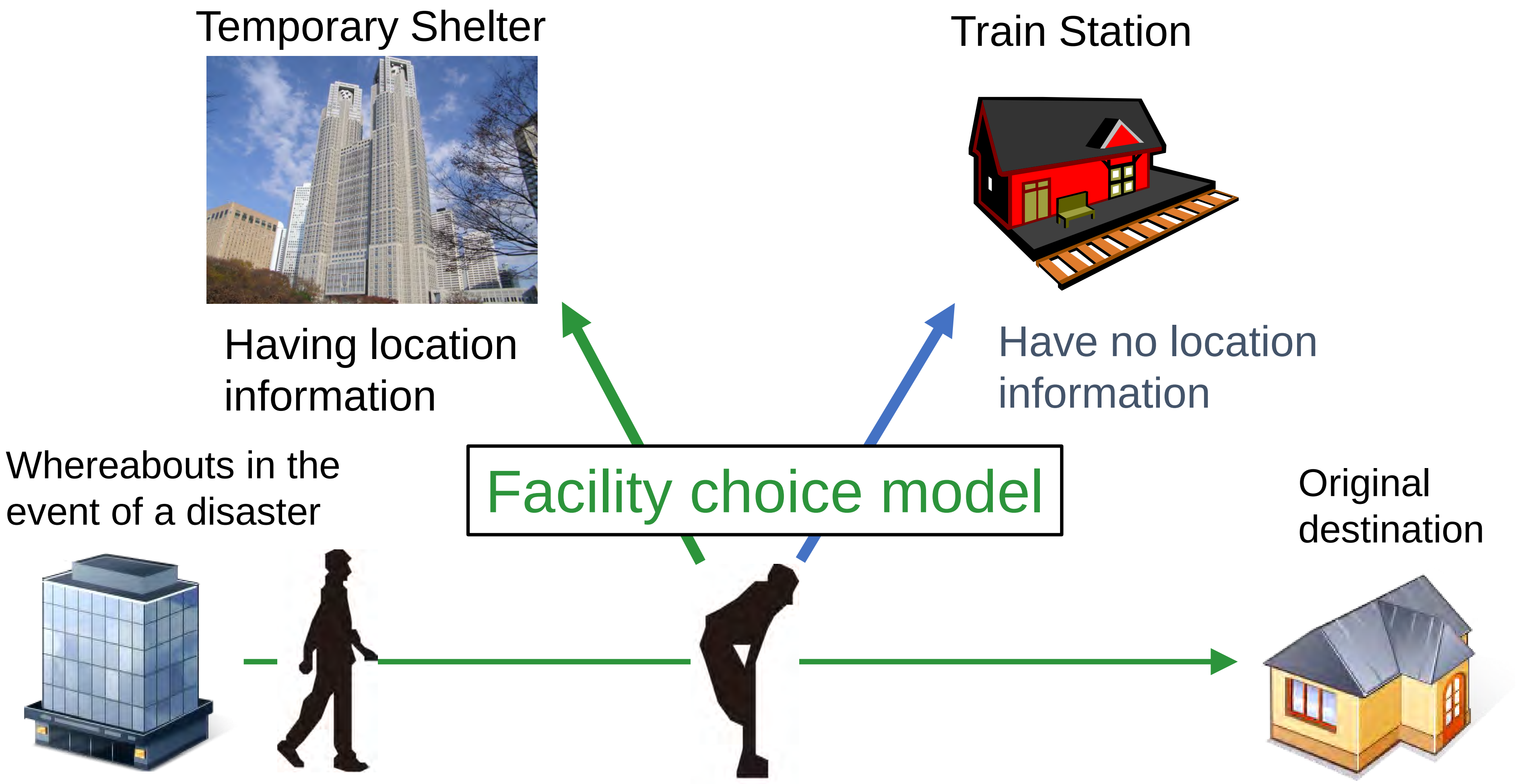
Destinations of Walkers



Movement of Walkers to Destinations

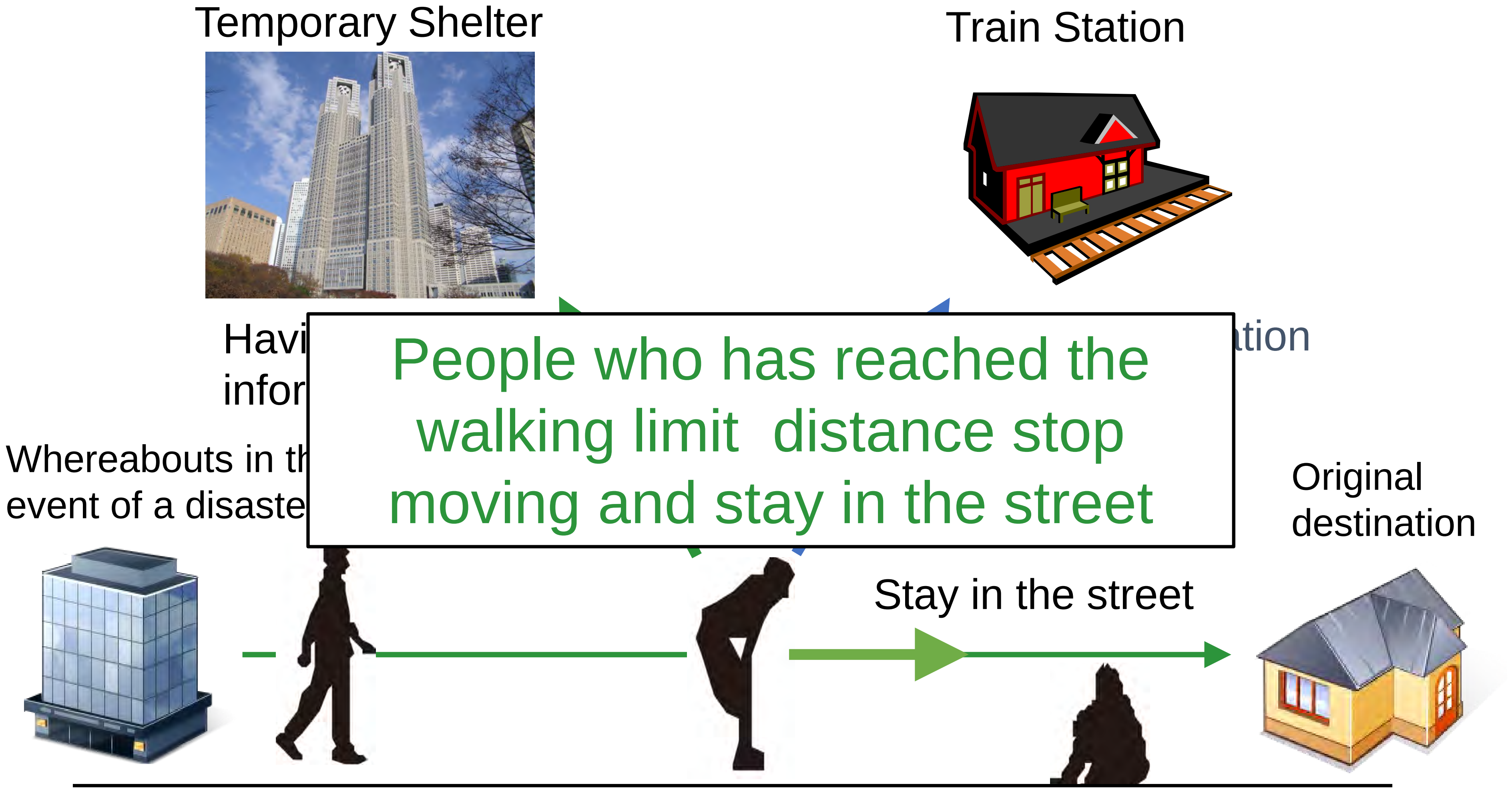


Behavior after Abandon of Movement



When walkers approached a place within 2 km from
the walking limit distance

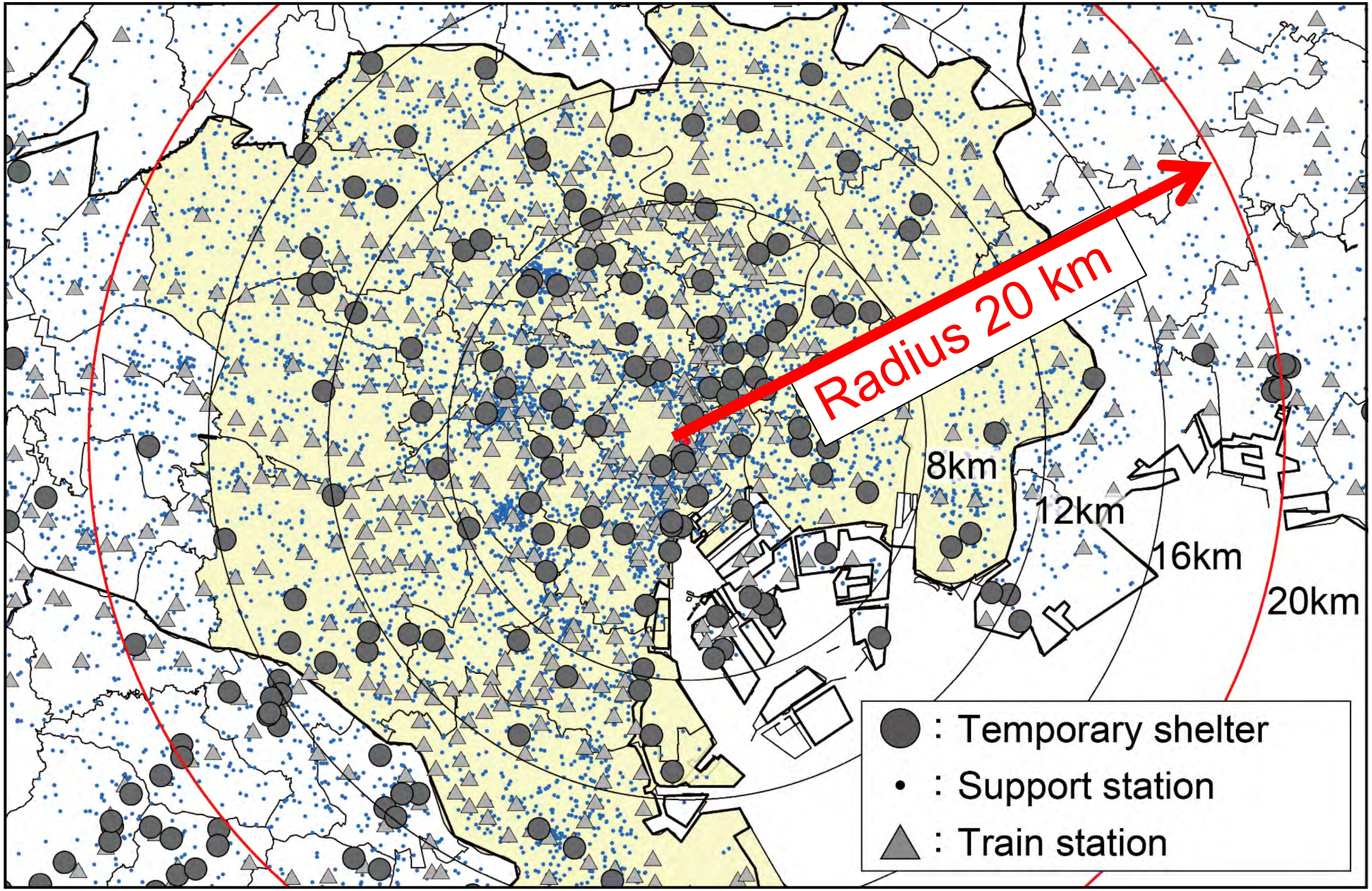
Behavior after Abandon of Movement



When walkers approached a place within 2 km from

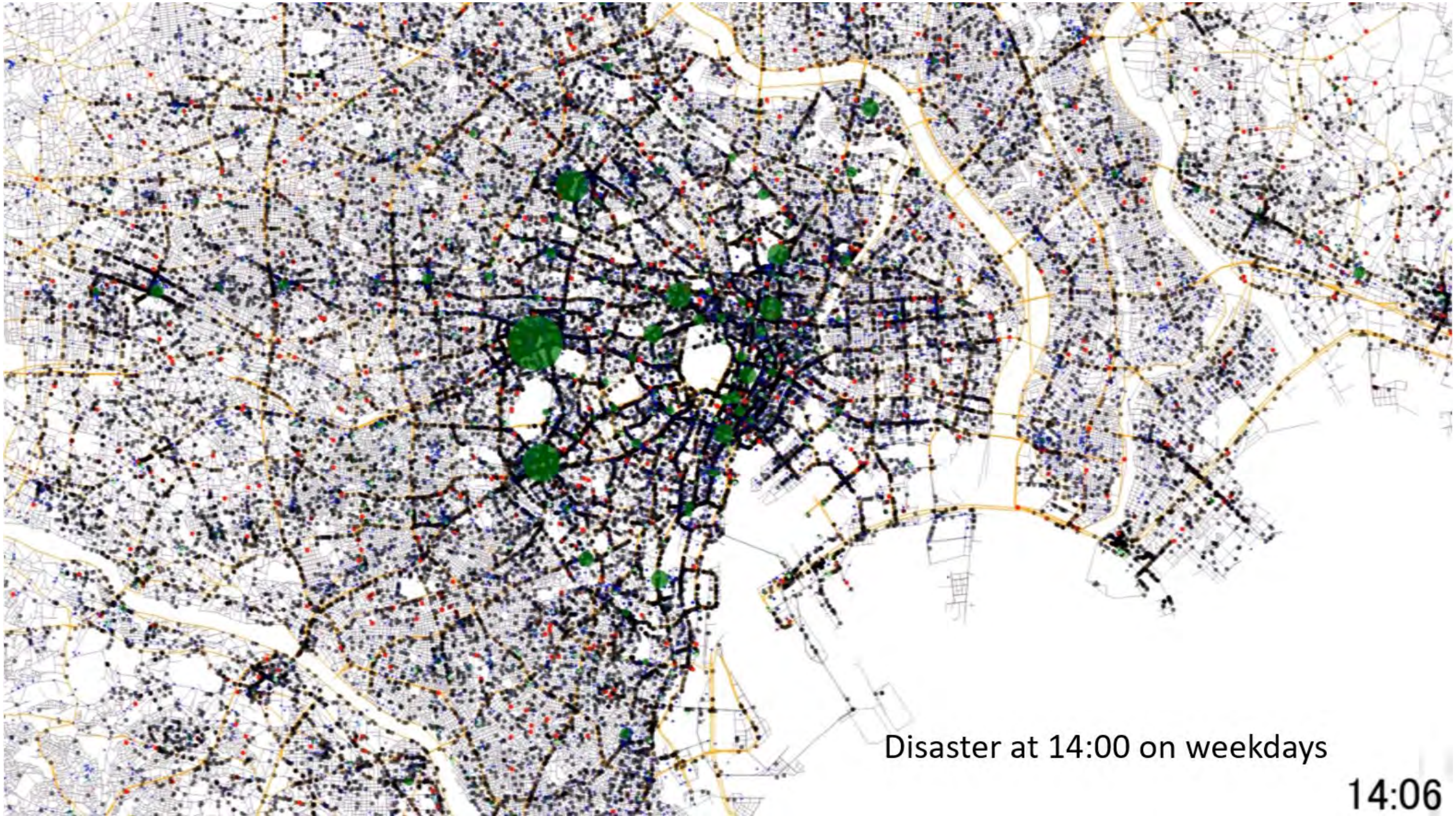
the walking limit distance

Spatial Distribution of Disaster Facilities



Demonstration of Simulation

●: Walkers, ●: Level of Crowding at Temporary Shelter,
●: Level of Crowding at Support Station, ●: Number of stayers at Train Station



Example of Specific Person

Sex: Female

Age: 40 years old

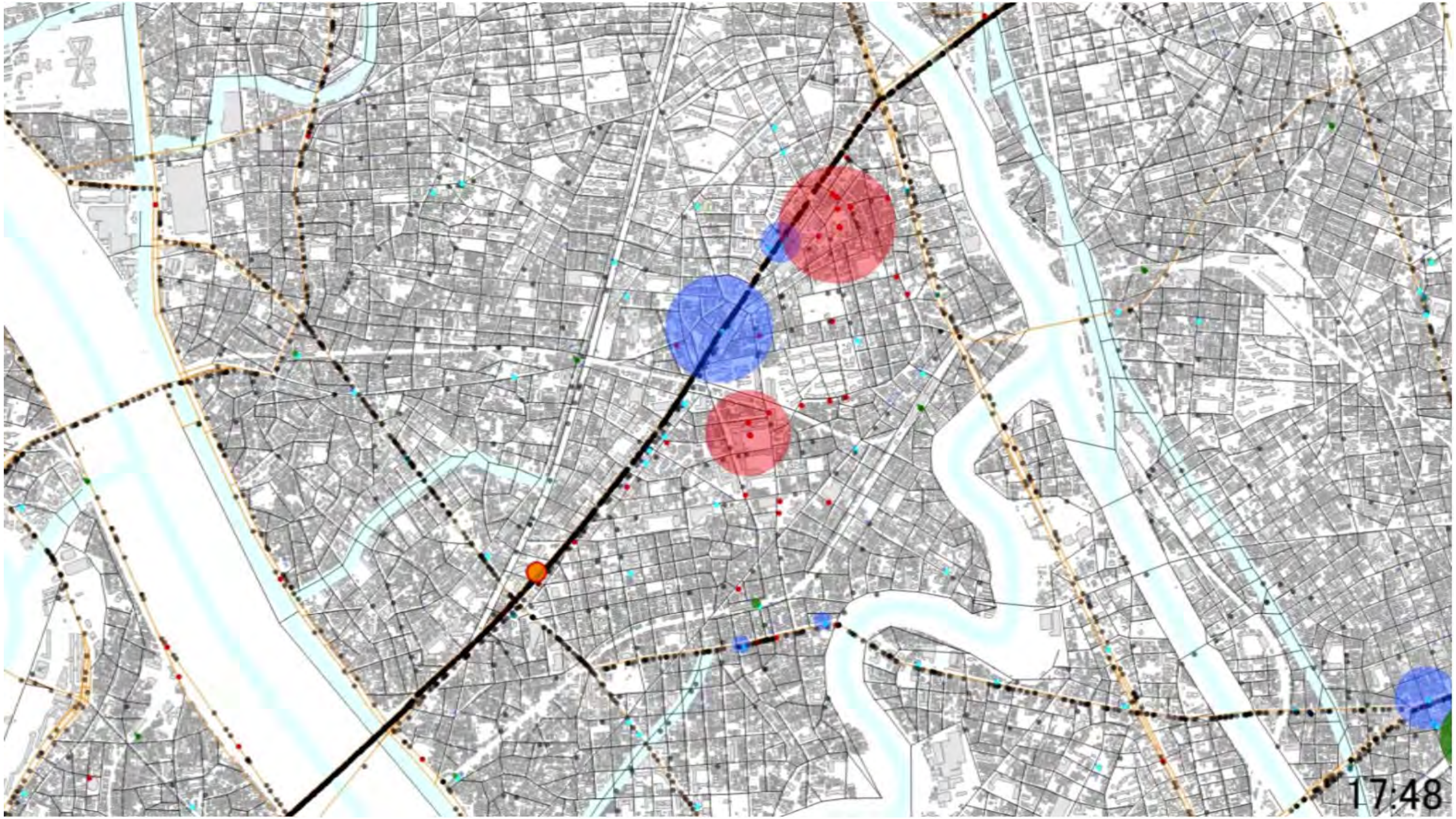
Family: Husband + Two Kids

Employment status: Full-time

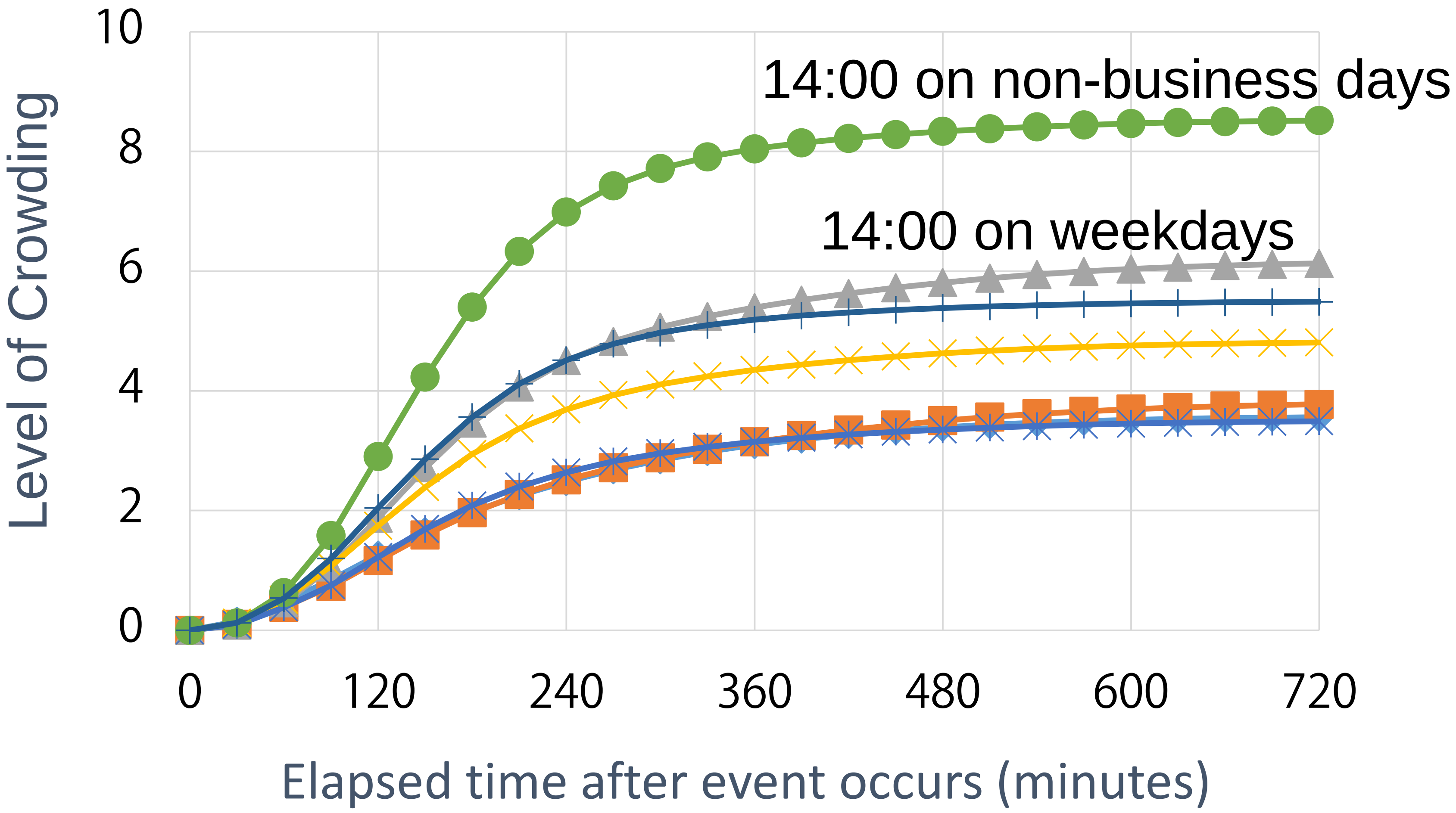
Workplace: Vicinity of Tokyo station

Location of home: 25 km from workplace

Returning Home Behavior in Simulation

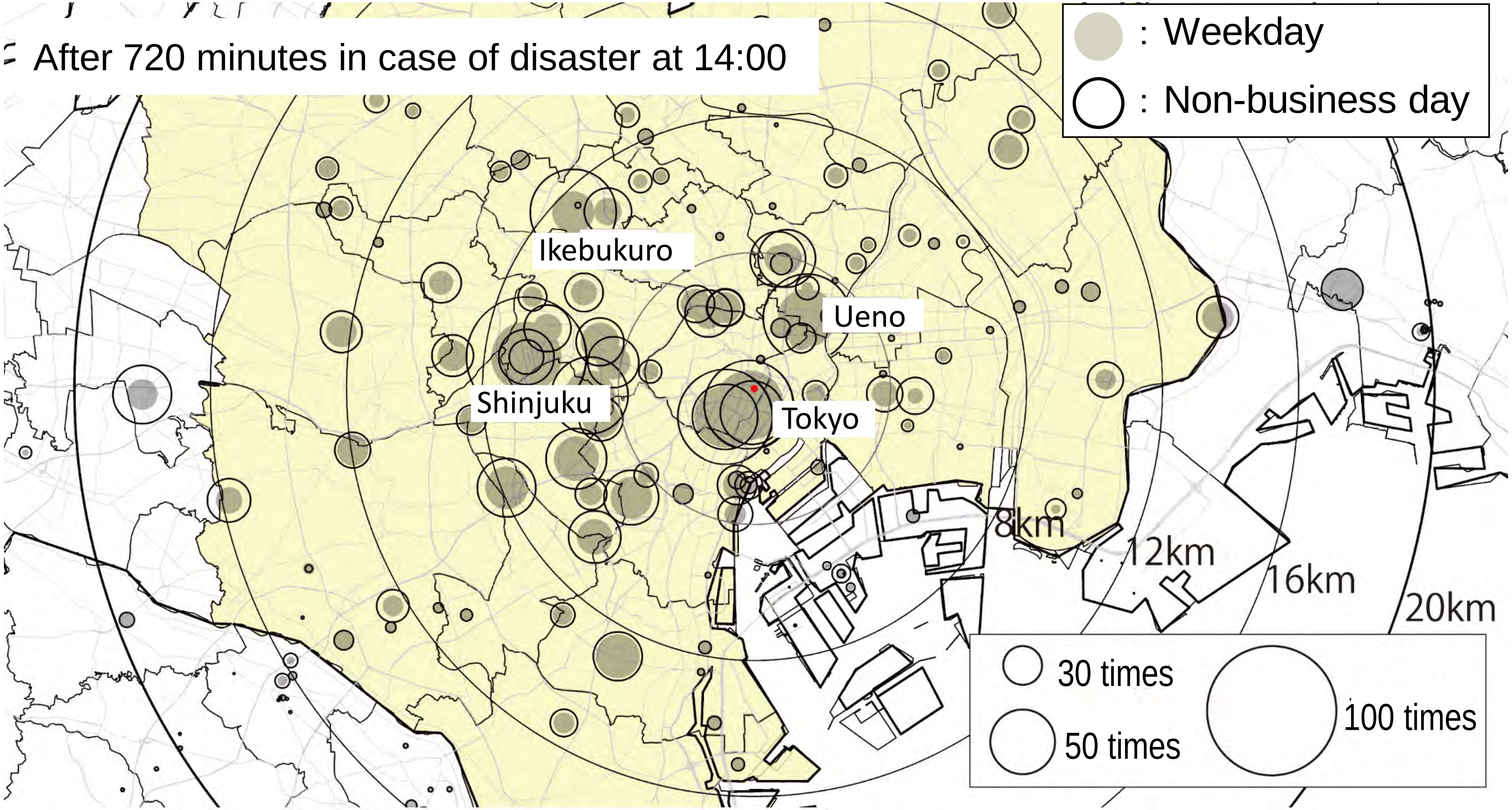


Level of Crowding of Temporary Shelters

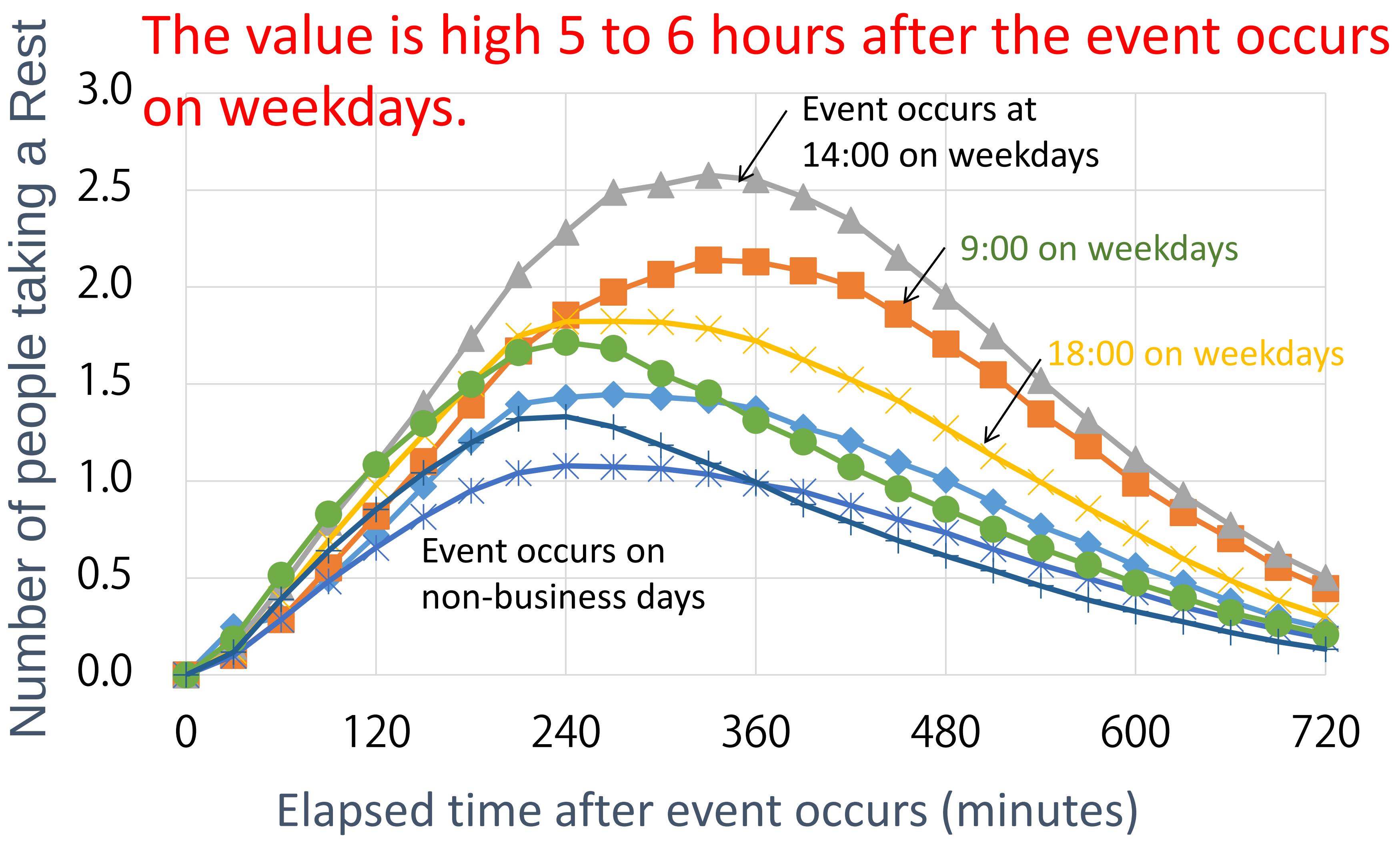


Spatial Distribution of Level of Crowding

Level of Crowding of Temporary Shelters is particularly high around large train stations on non-business days



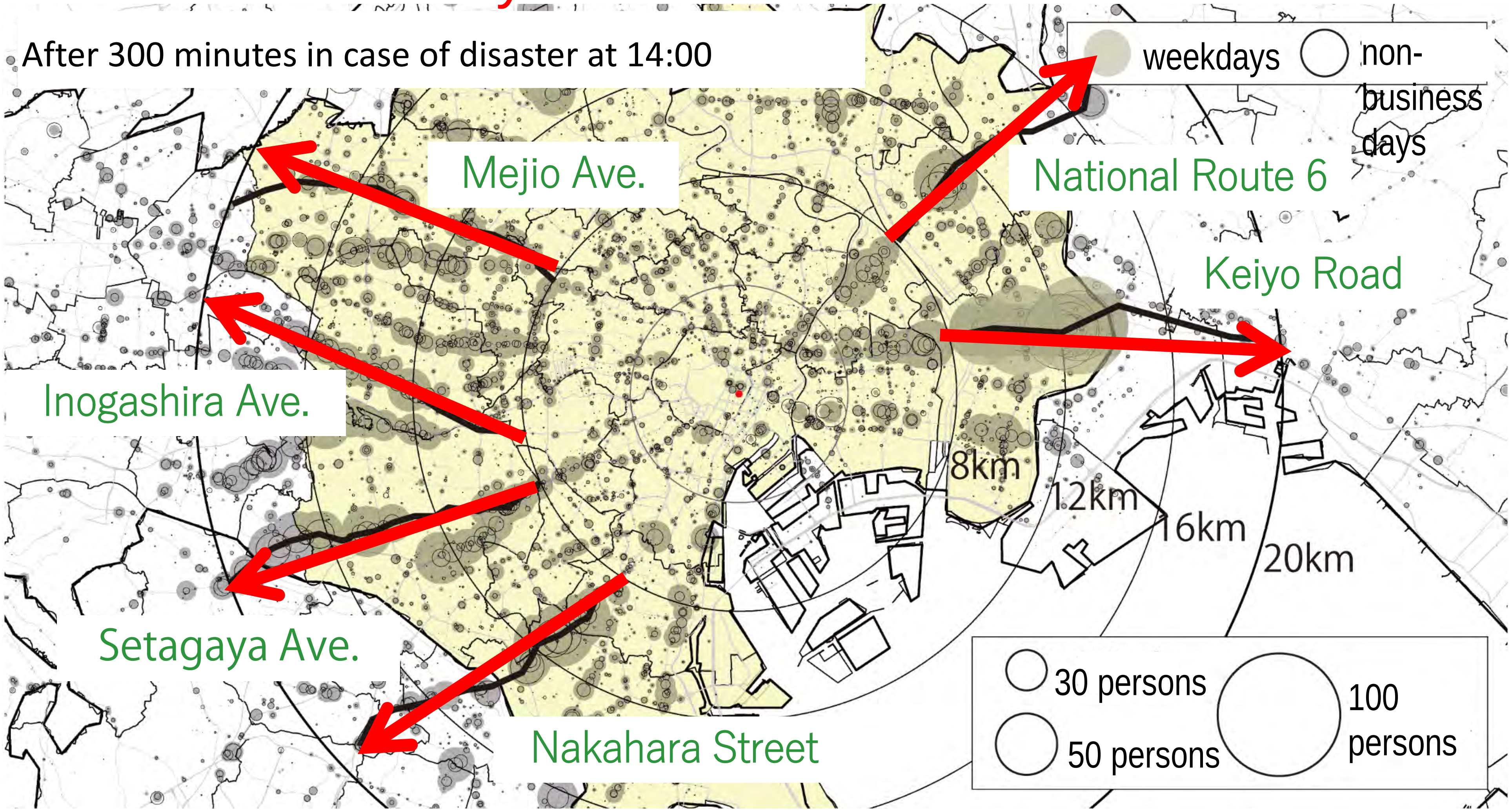
Number of People taking Rest at Support Station



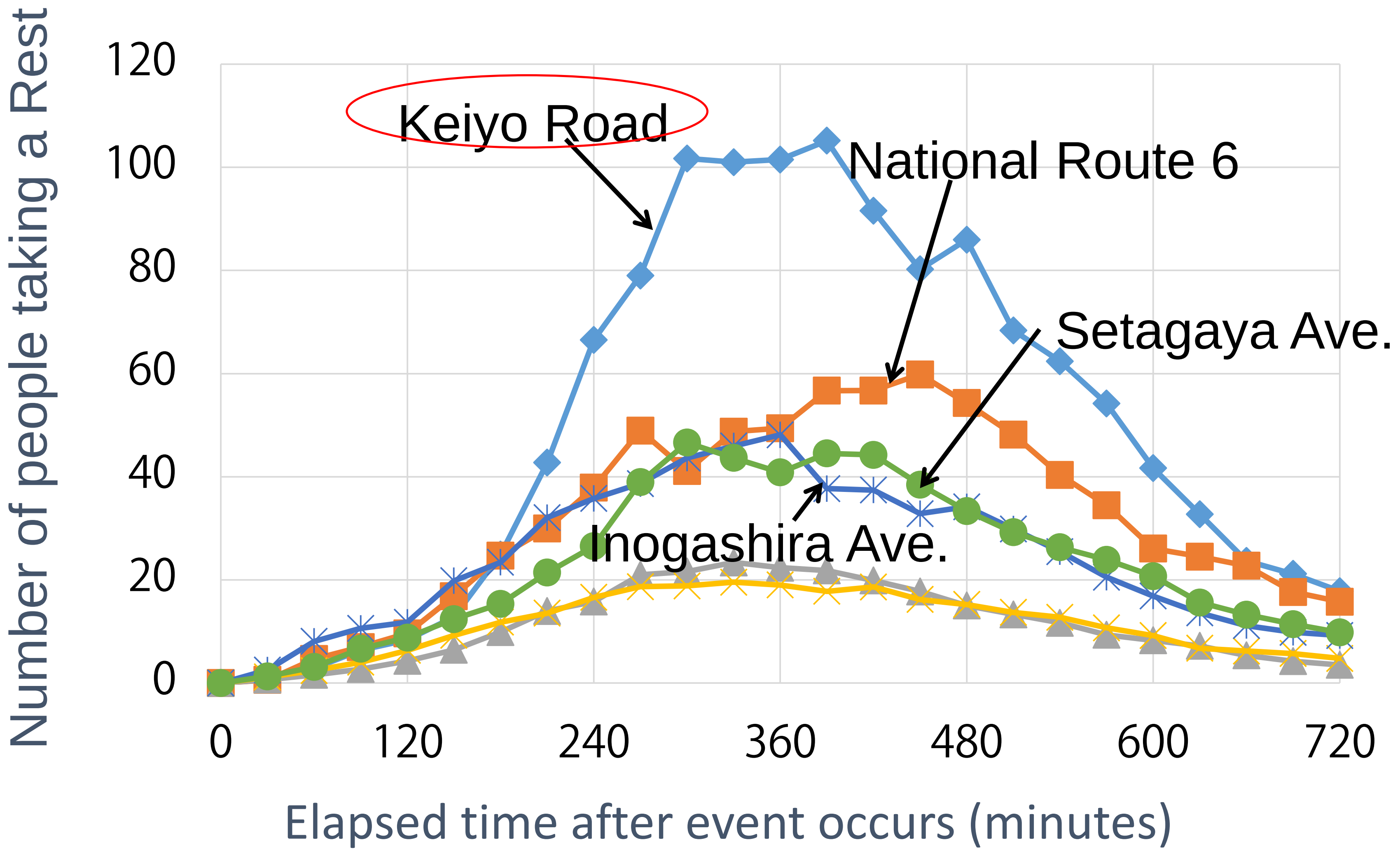
※) Average value of Level of Crowding within 20 km from the city center

Number of People taking Rest at Support Station

The value is high at facilities along the main trunk road from the city center to the suburbs



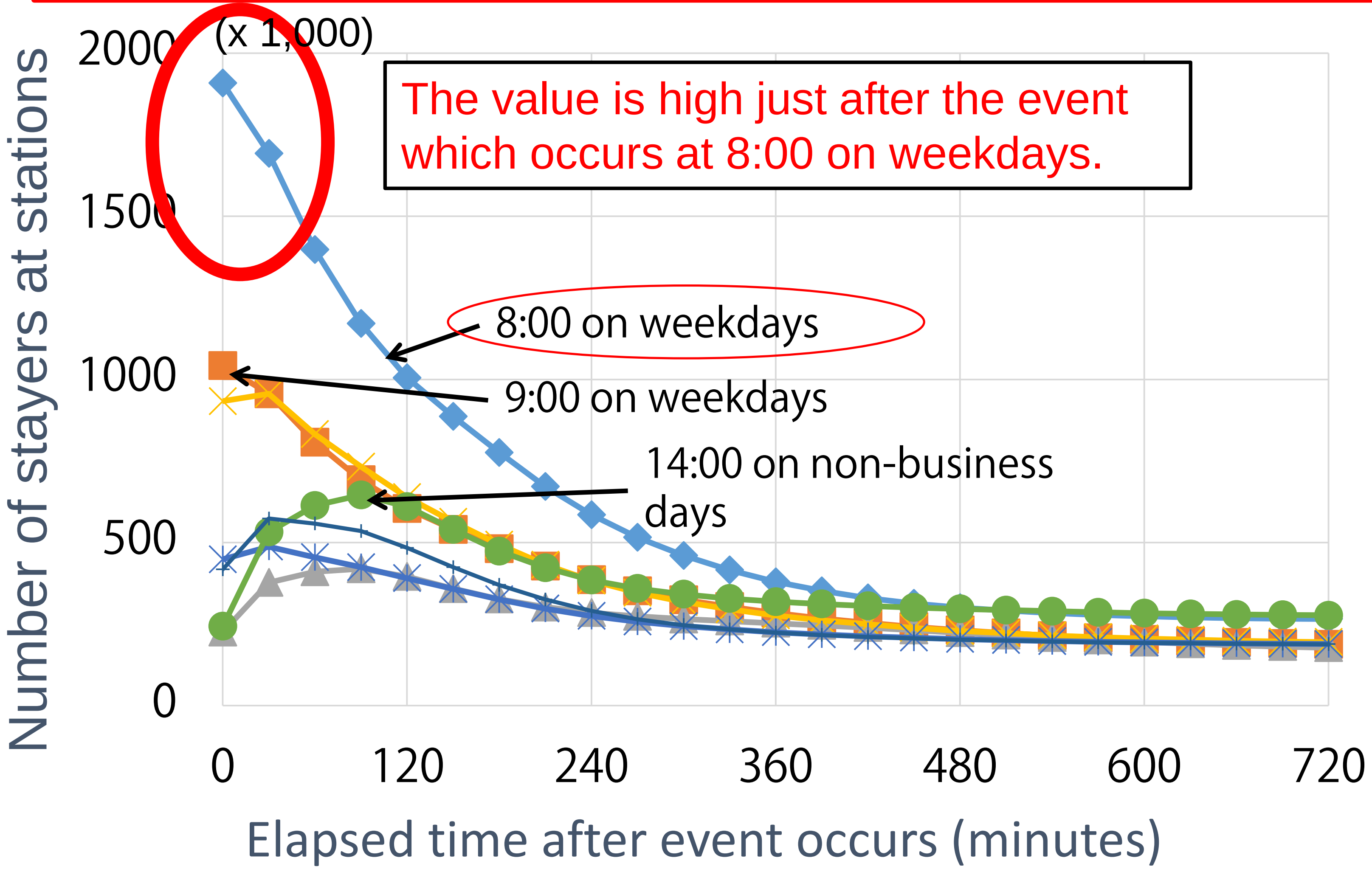
Number of People taking Rest at Support Station



Average value of Level of Crowding of facilities located in the 8 to 20 km section from the city center

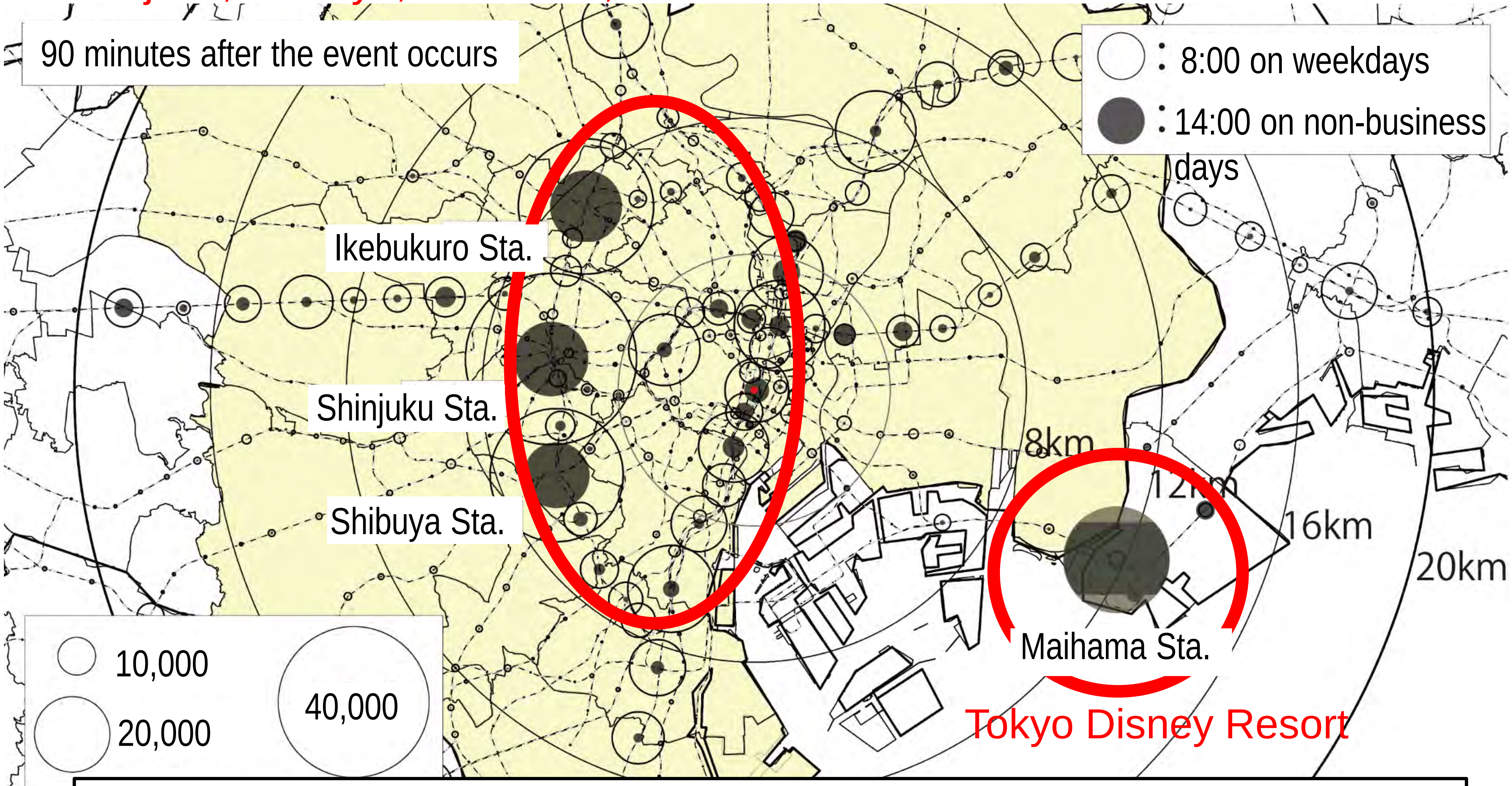
Number of People Staying at Train Stations

Number of stayers = Number of people using (waiting) toilets + taking a rest + staying at stations



Number of People Staying at Train Stations

At 8:00 on weekdays, values are high at large Train stations such as Shinjuku, Shibuya, Ikebukuro, and at stations on the Yamanote line

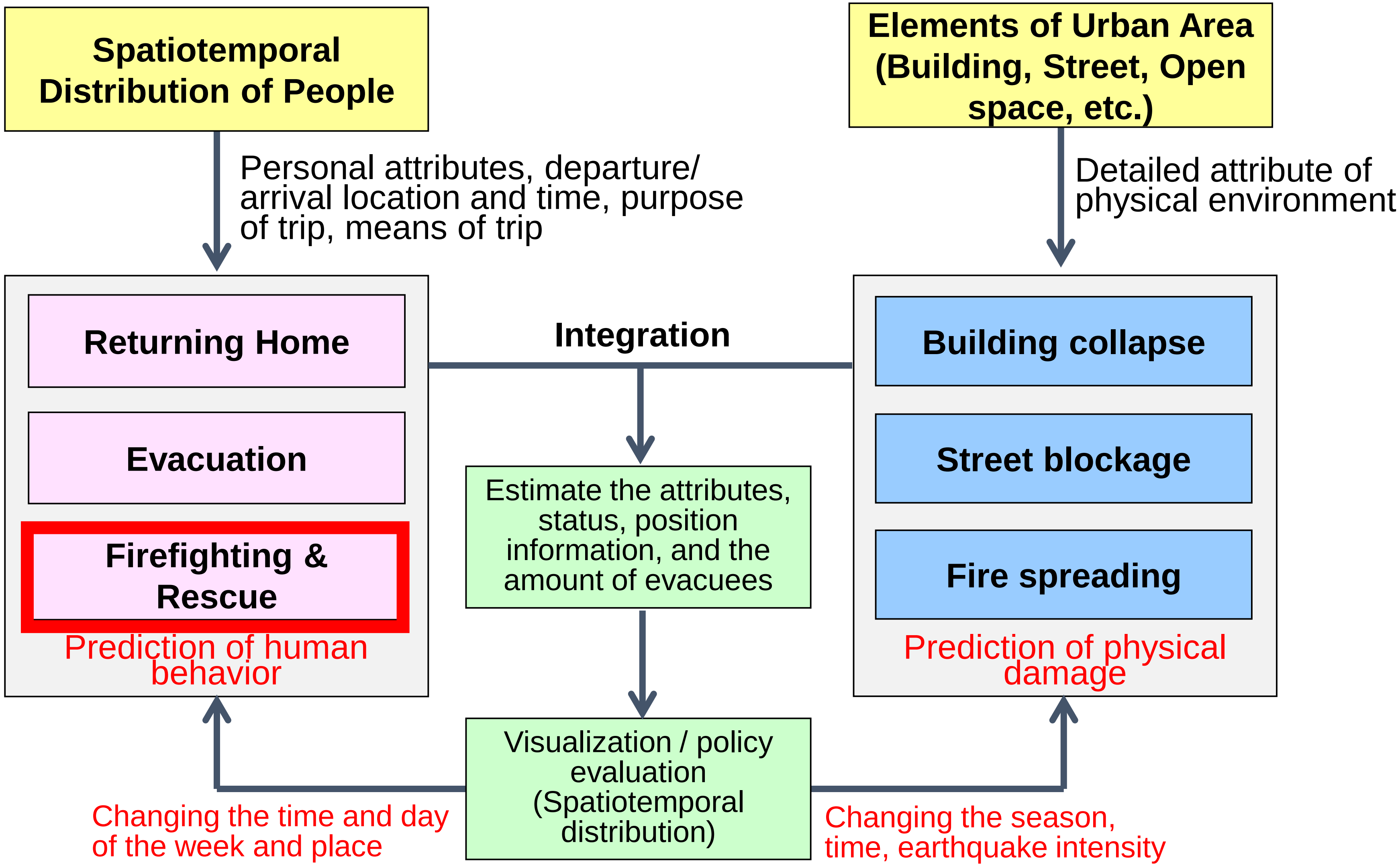


The values are high at Maihama station at 14:00 on non-business days.

Returning Home Behavior in Simulation

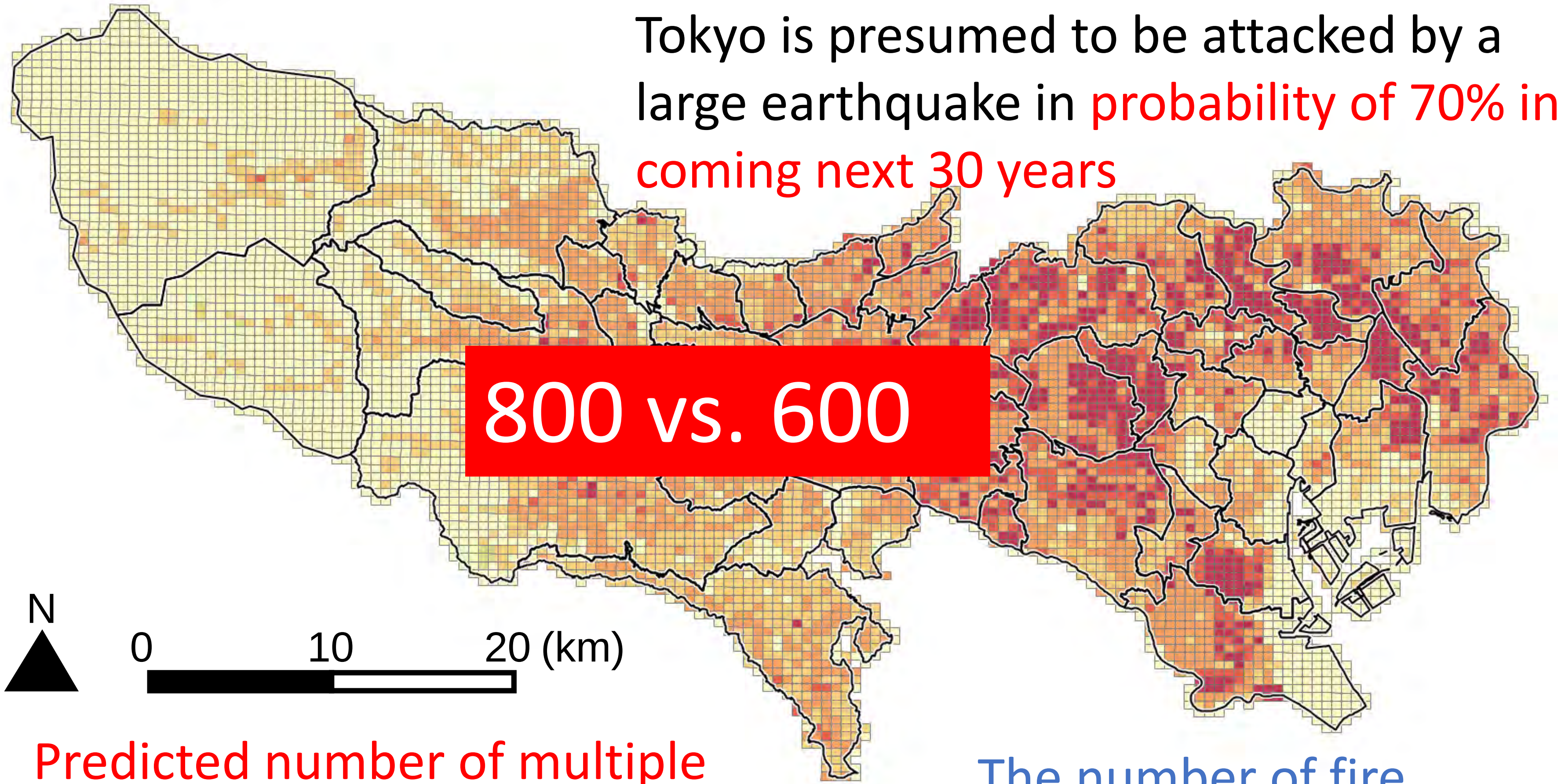
●: Walkers, ●: Level of Crowding at Temporary Shelter,
●: Level of Crowding at Support Station, ●: Number of stayers at Train Station

Framework of Simulation System



Tokyo Metropolitan

Tokyo is presumed to be attacked by a large earthquake in probability of 70% in coming next 30 years



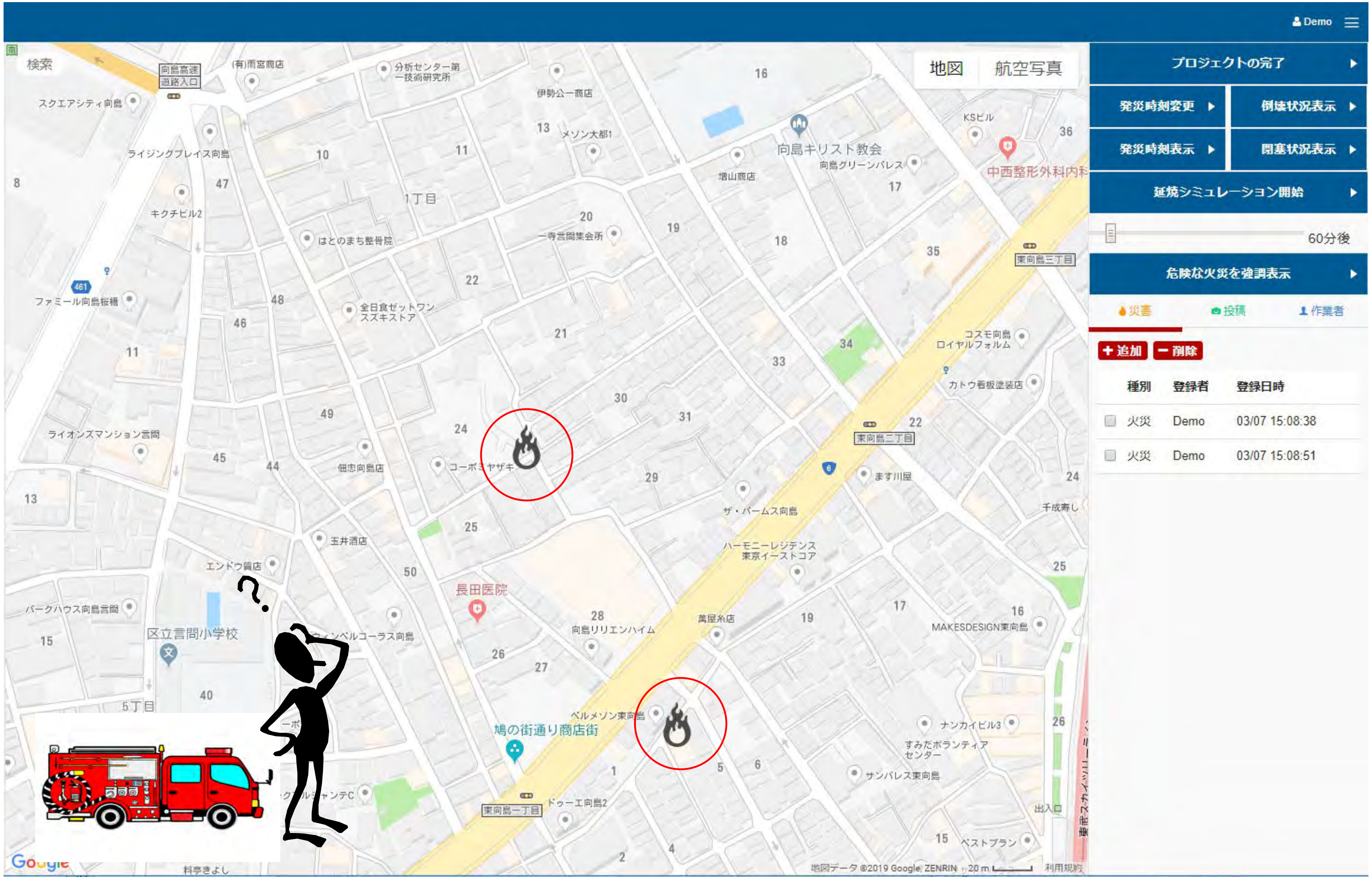
800 vs. 600

Predicted number of multiple simultaneous fires at a large earthquake in Tokyo (Tokyo Metropolitan Government, 2013)

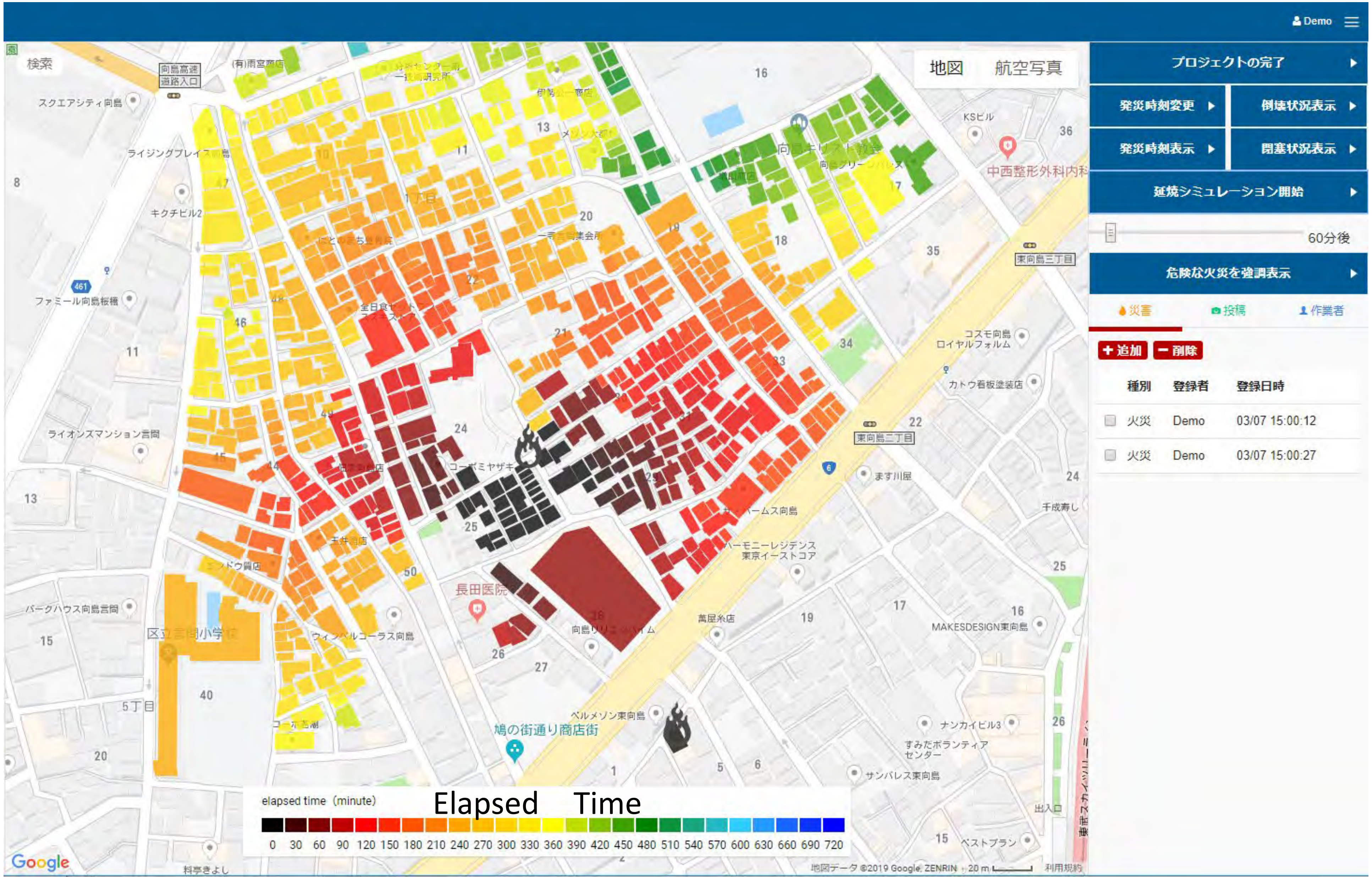
>

The number of fire engines of Tokyo Fire Department

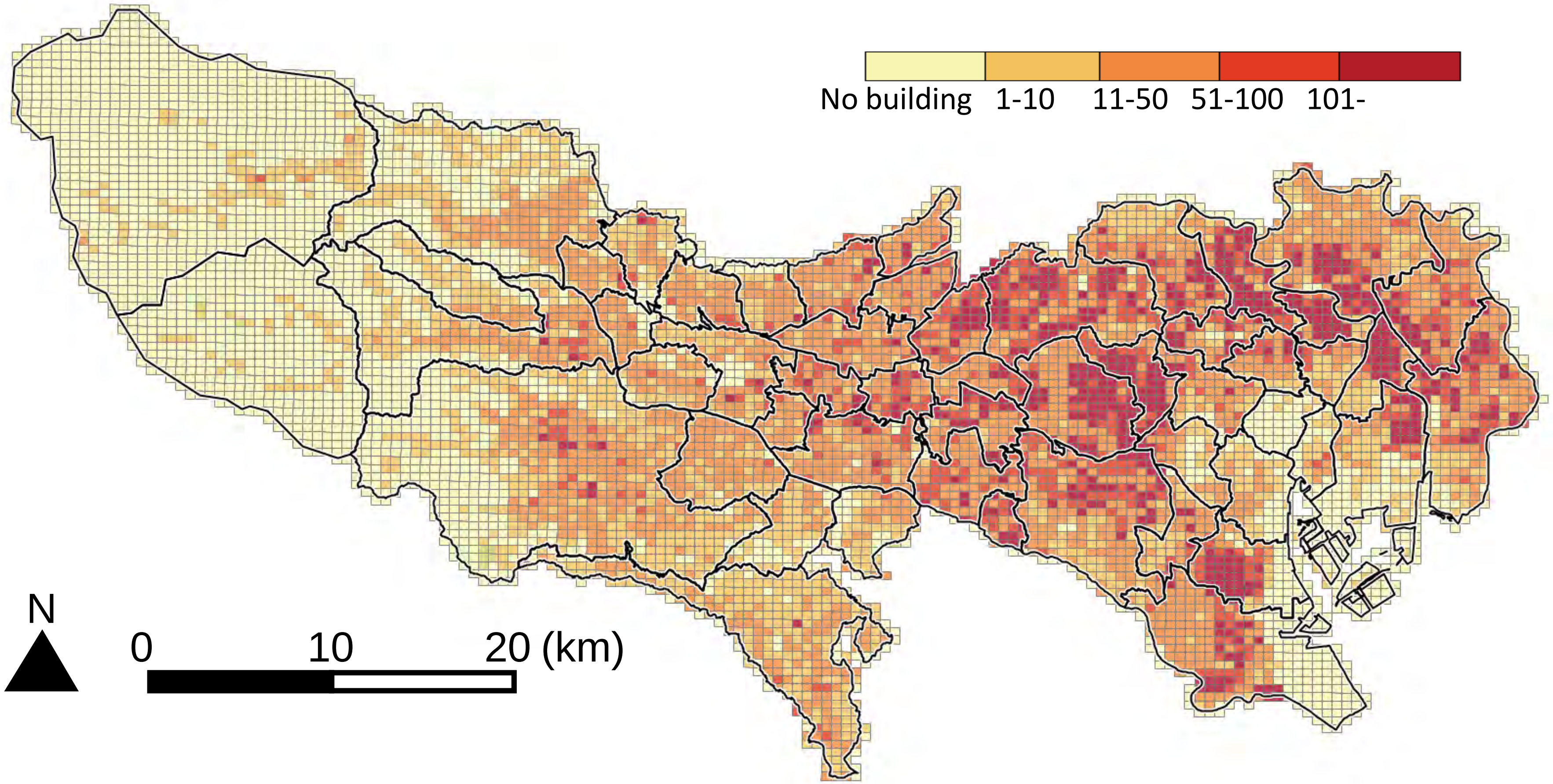
Web Application of Fire-Spread Simulation



Web Application of Fire-Spread Simulation

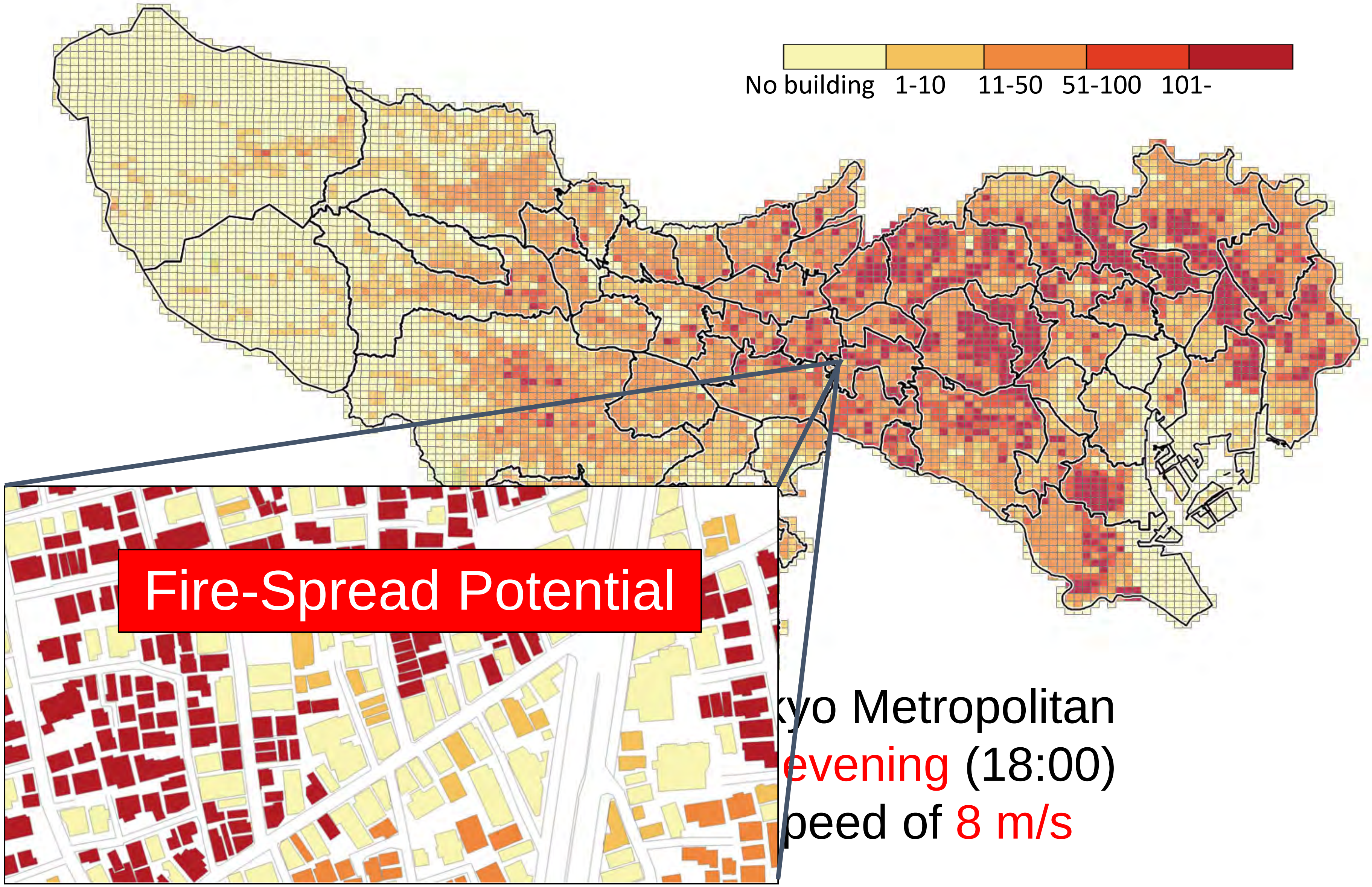


Spatial Distribution of Fire-Spread Potential



1. All buildings (2,784,123) in Tokyo Metropolitan
2. Earthquake occurs in a winter evening (18:00)
3. Wind is from the north with a speed of 8 m/s

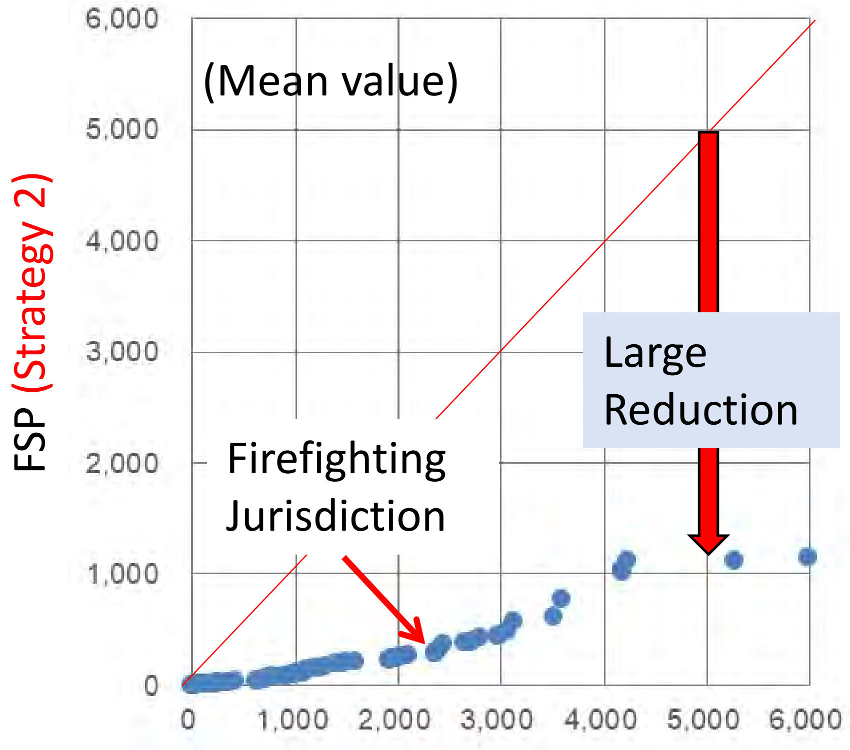
Spatial Distribution of Fire-Spread Potential



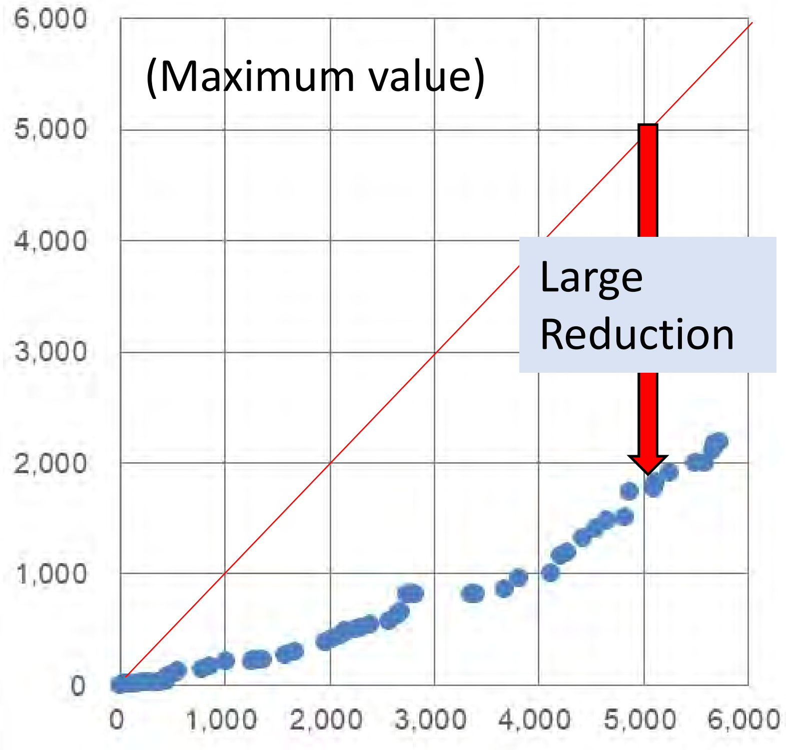
kyo Metropolitan
evening (18:00)
peed of 8 m/s

Reduction of Burnt-down Buildings by FSP

Strategy 2: FSP (μ, σ) and the number of available fire engines in each Firefighting Jurisdiction



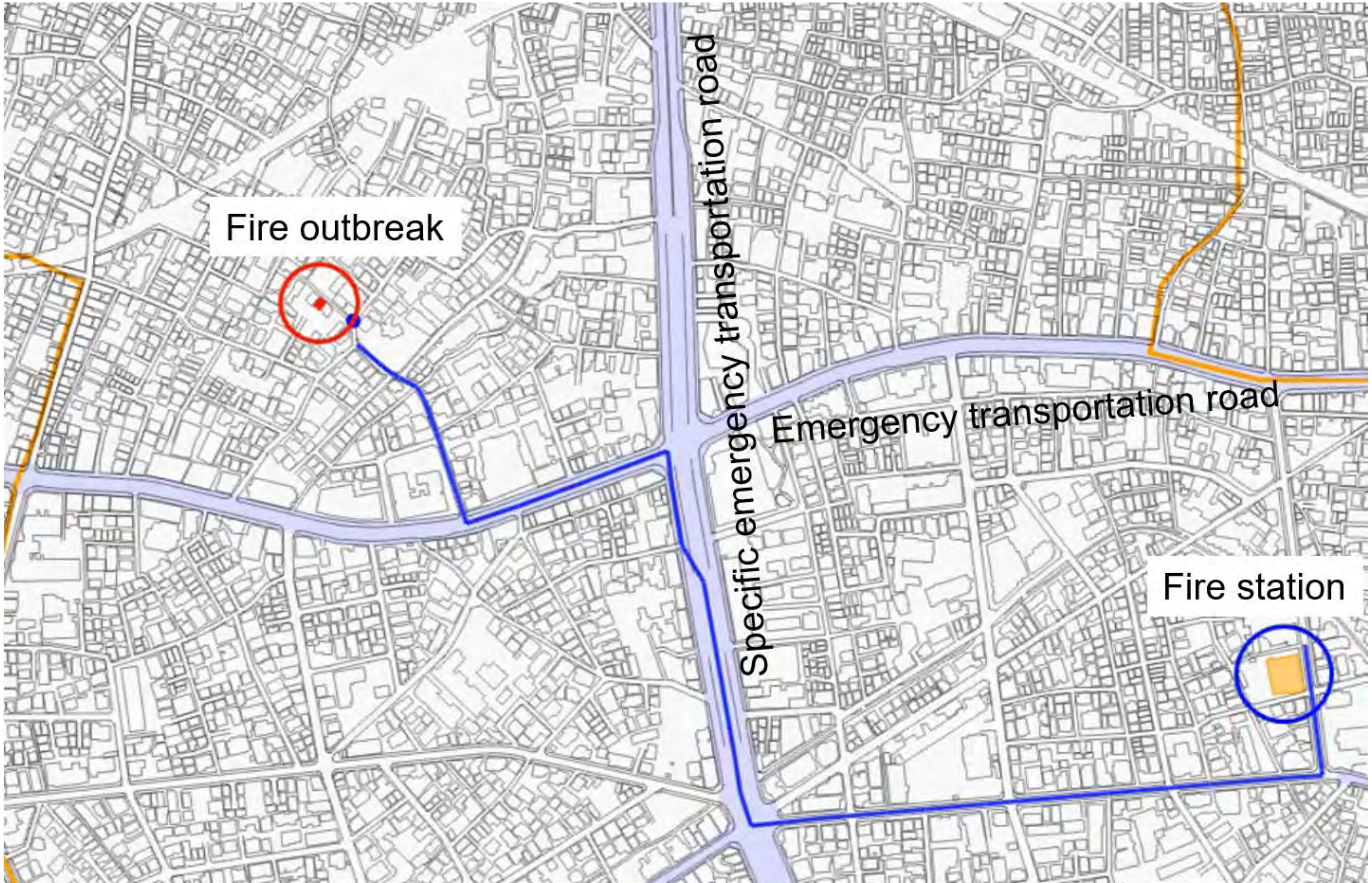
Notification order (Strategy 1)



Notification order (Strategy 1)

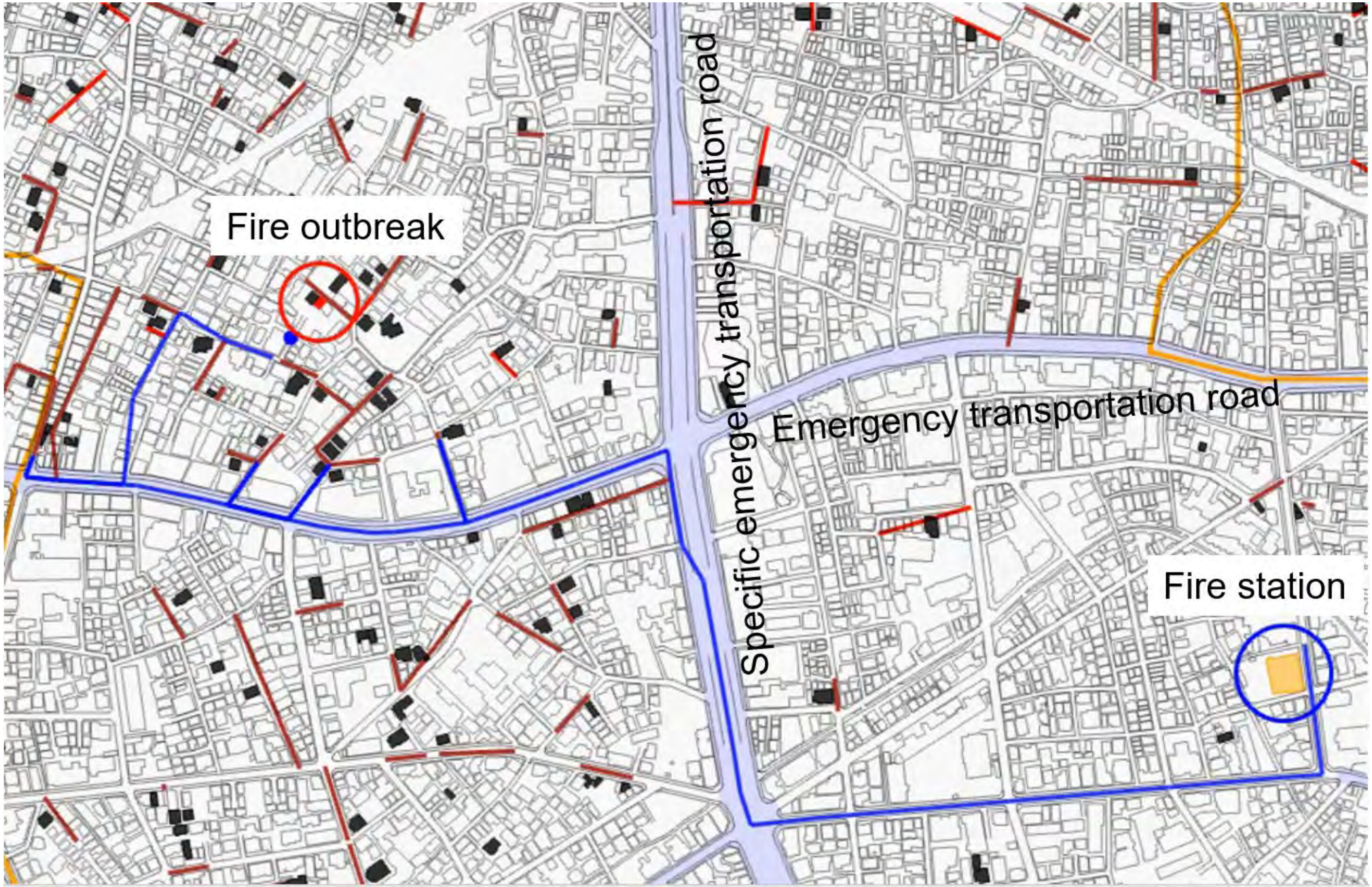
Normal Time (without Blockage)

Access time: 2.1 minutes



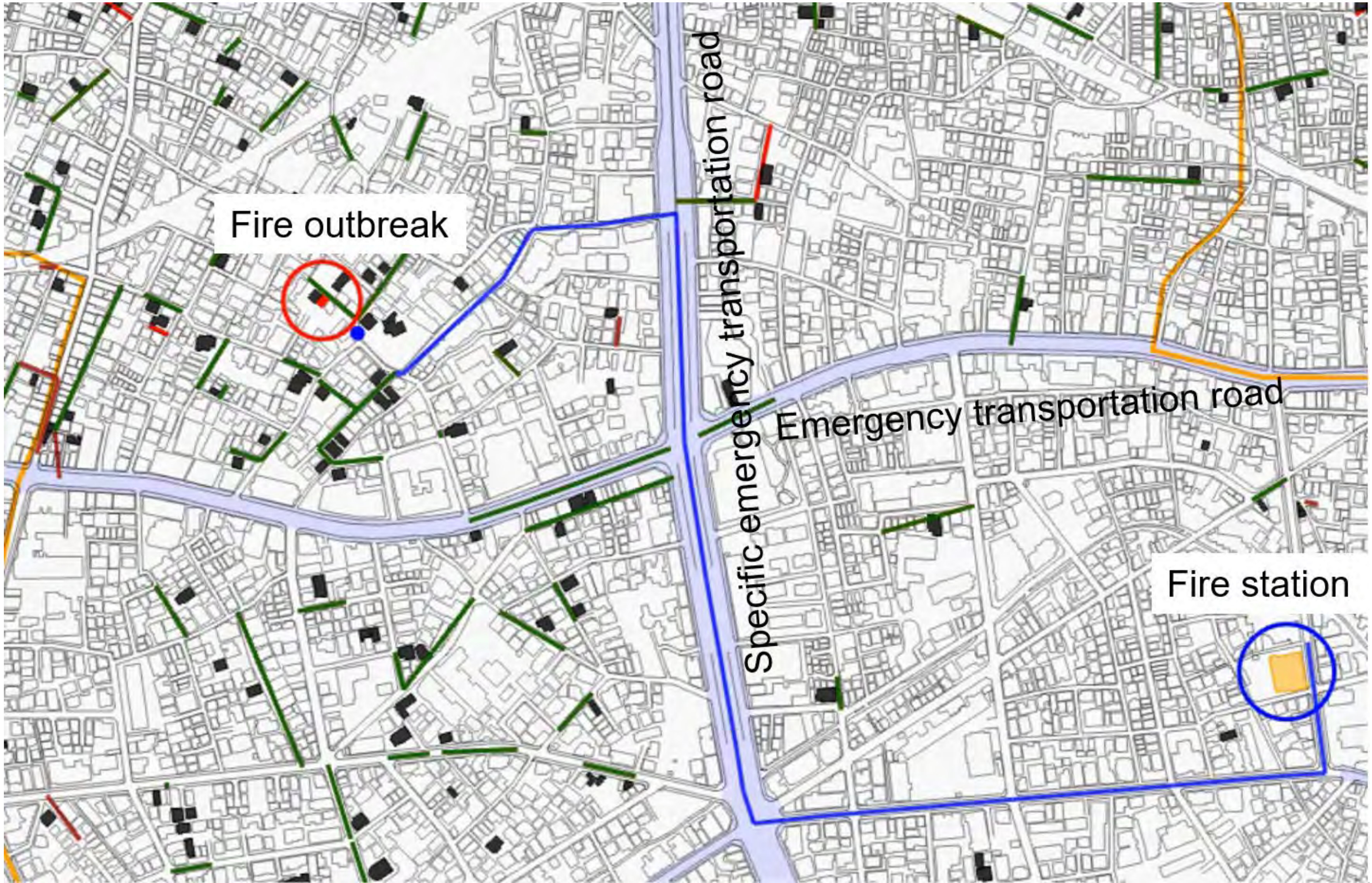
Street Blockage by Collapsed Buildings

Access time: 5.7 minutes

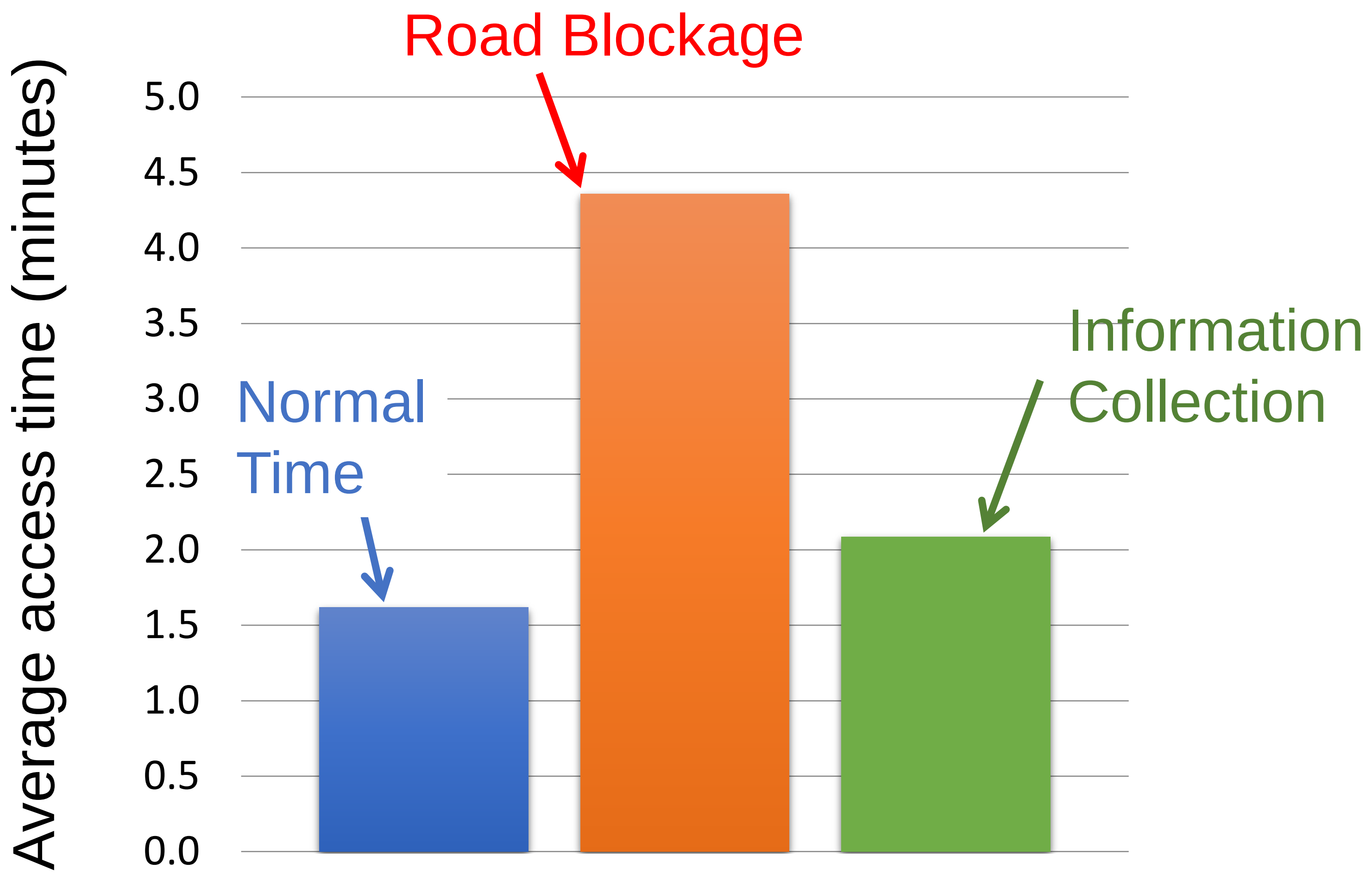


Disaster Information Collection (5 minutes by 0.5% of residents)

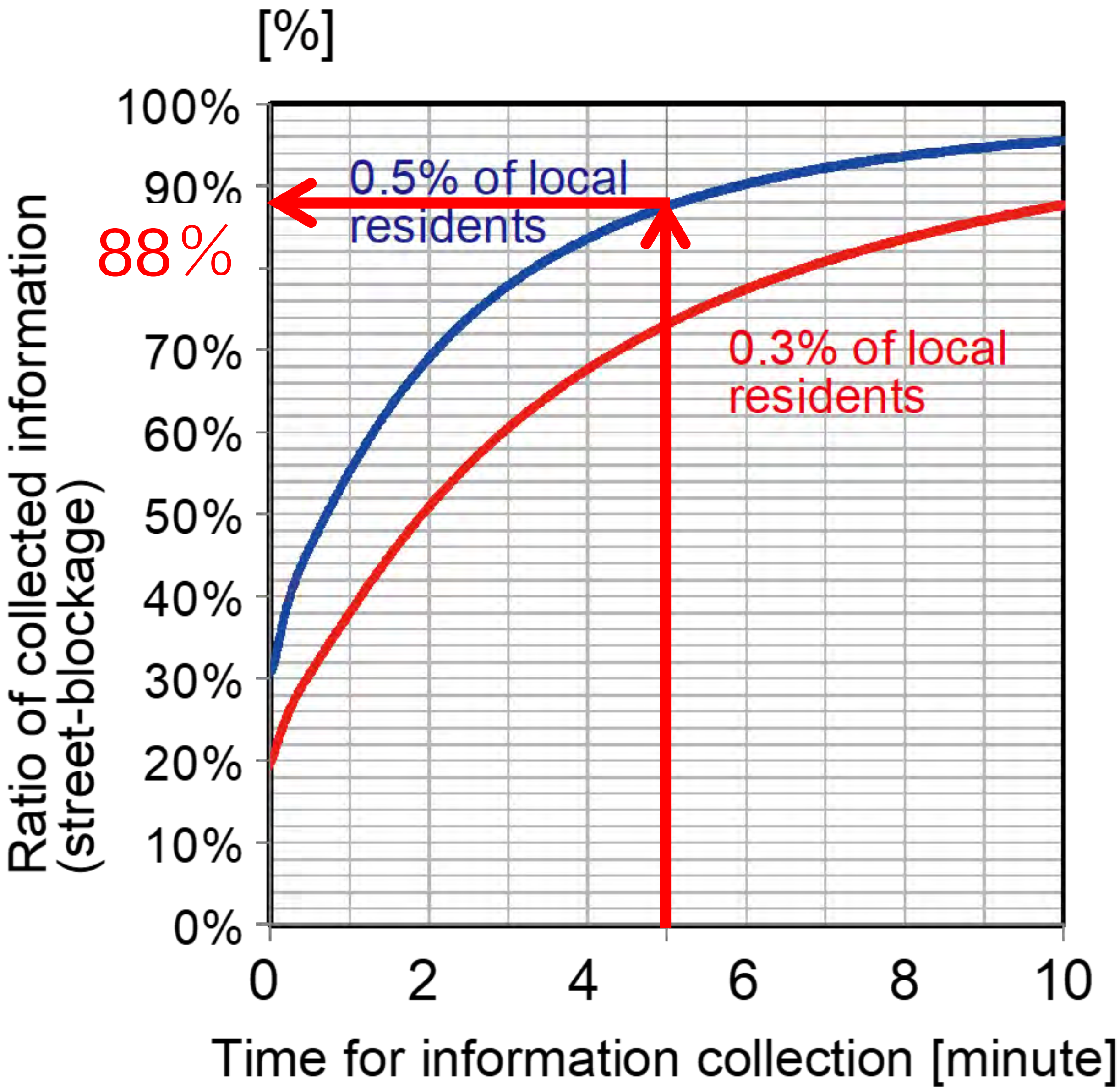
Access time: 2.4 minutes



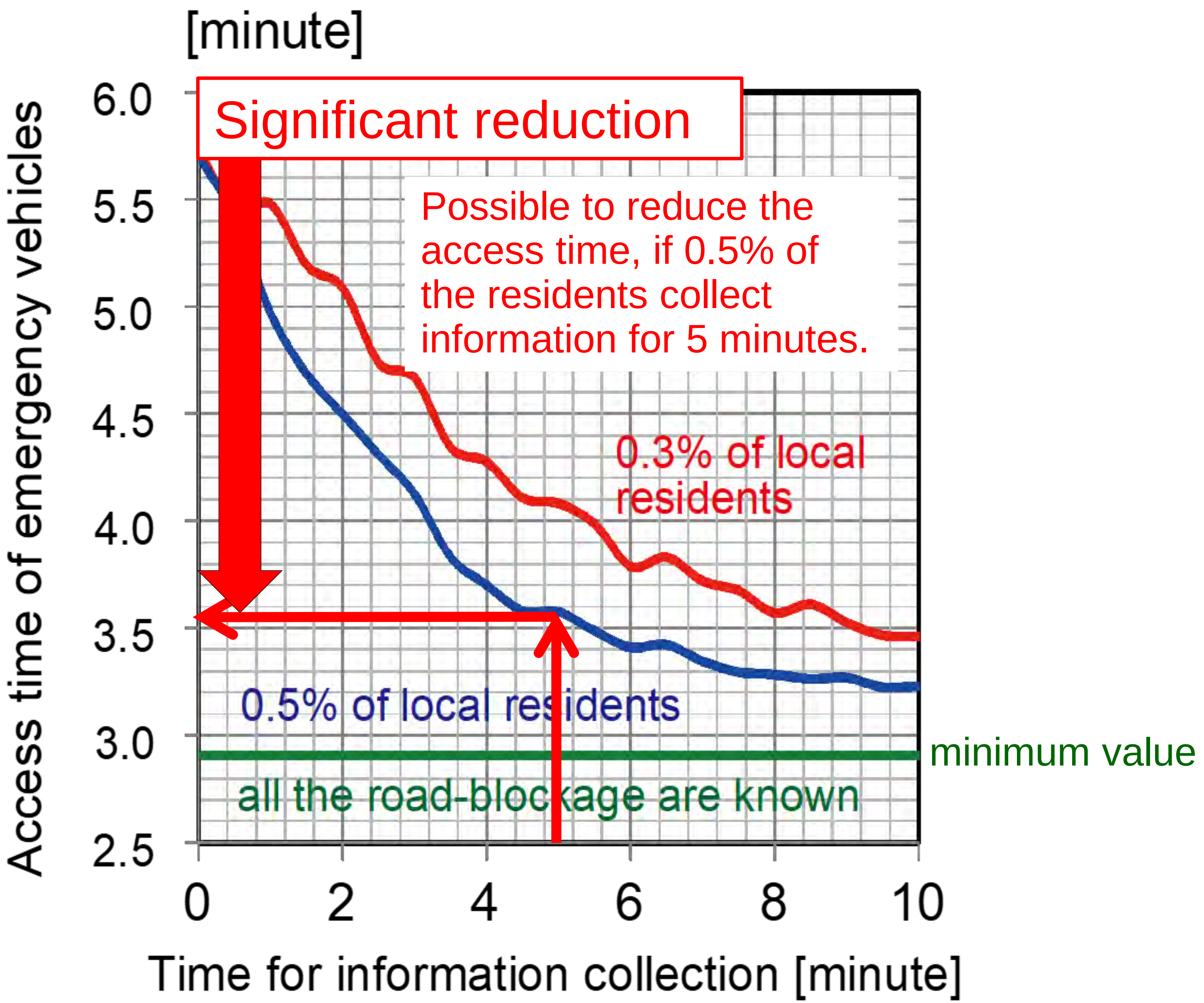
Average Access Time



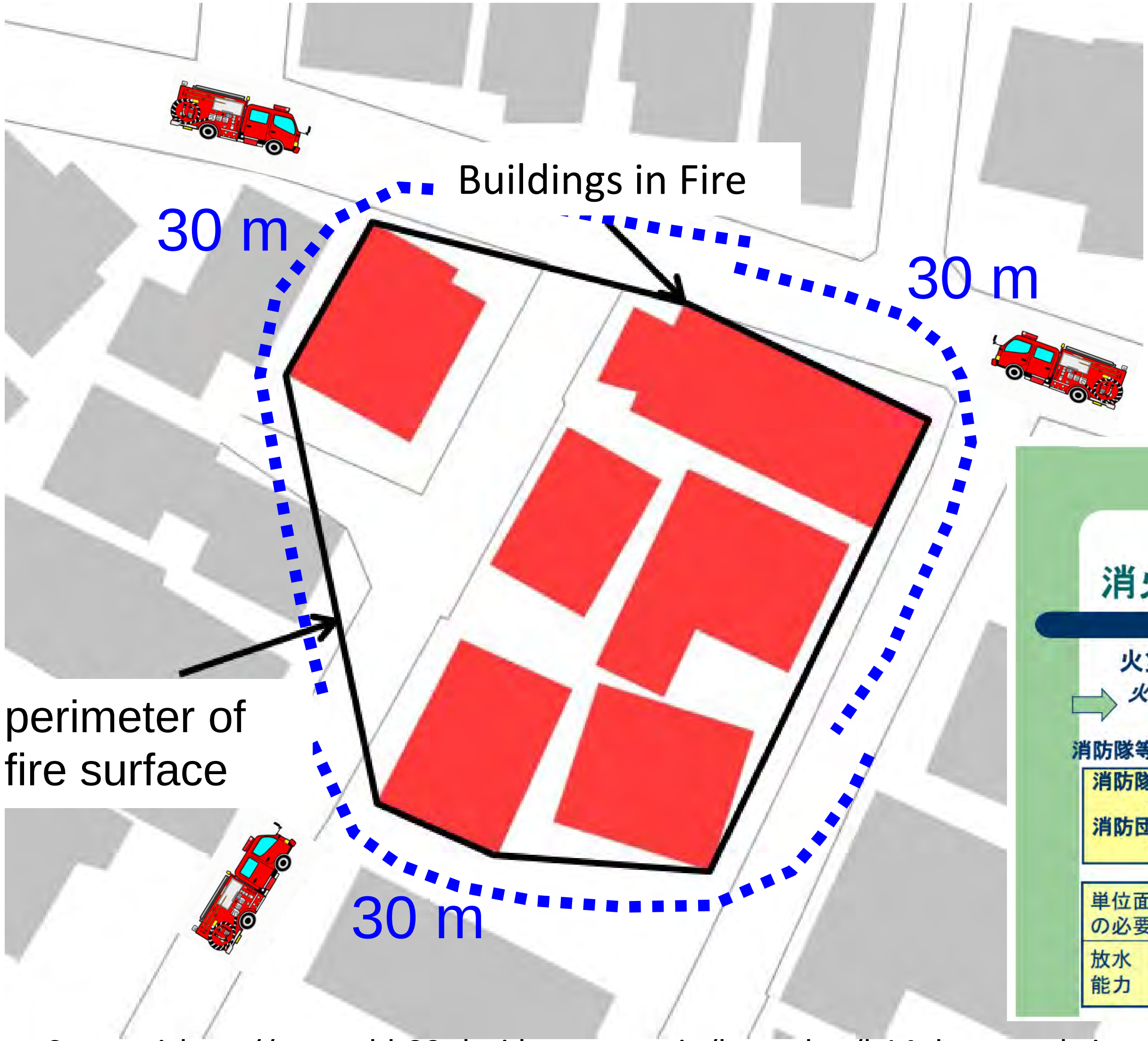
Ratio of Collected Information



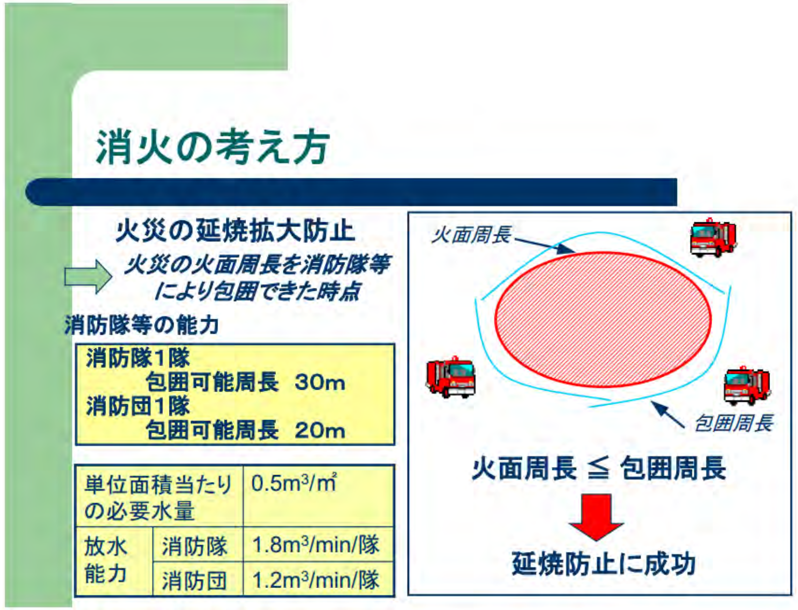
Effects of Information Collection



Flame Circumference and Fire Brigade

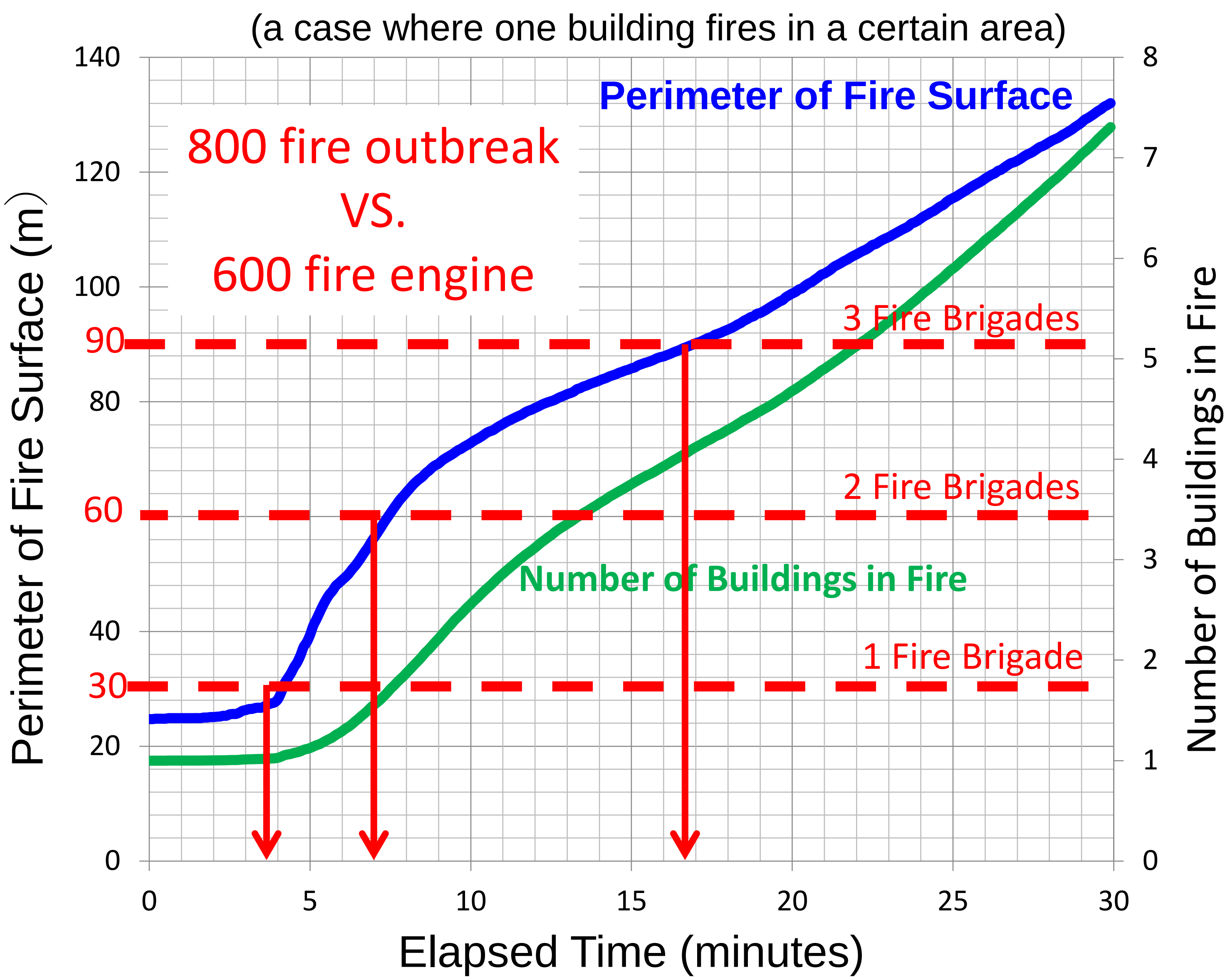


Relation between perimeter of fire surface and surrounding circumference



Source：http://www.ddt33.dpri.kyoto-u.ac.jp/katsudou/h14_happyoukai_pdf/h15_0801_6_2.pdf

Growth of Perimeter of Fire Surface



Outline

- ✓ Background & Motivation
- ✓ Spatiotemporal Demographic Data
  (its potential and limitation)
- ✓ Integration Method (1) for Demographic data
  (building use / purpose / attribute)
- ✓ Integration Method (2) for Demographic data
  (inflow / outflow / static)
- ✓ Applications for Disaster Mitigation Planning
- ✓ Summary and Conclusions

Summary and Conclusions (1)

- We pointed out limitations of the population statistics based on the location information of mobile phone users, in which detailed personal attribute information is being concealed to protect privacy
- We proposed an integration method for enriching the value of the population statistics by adding the detailed information on the attributes and the purposes of their stays
- We demonstrated that it is possible to grasp the spatiotemporal characteristics of population distribution attached with detailed attributes information such as their age, gender, and purposes that vary according to the time, location, and building use where they are

Summary and Conclusions (2)

- We proposed a method for estimating the spatiotemporal distribution of static and transient populations of urban areas by integrating existing demographic data
- We demonstrated an example of urban analysis from new and never-before employed points of view
- We demonstrated the application examples of integrated demographic data, which include simulation analysis on Returning Home Behavior, Evacuation Behavior, Firefighting Behavior.
- There is a growing demand for data that allows highly accurate understanding of the spatiotemporal distribution of both moving and static people in urban areas with detailed attributes

Future Research

- We need to discuss differences and commonalities in population statistics, which are currently available in other countries, in order to expand the availability of the models for other data sources available in other countries
- Construct a model to evaluate the influence of large-scale public events or natural disaster on people's movements, which assists mitigating crowding and avoiding risks, identifying appropriate initial responses, and guiding evacuation