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Summer School of the Behavior Model

Beyond the Travel Behavior Model

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Introduction: Role of the Random Utility Model on the TR-US field

- Discrete choice models (DCMs) are based on **Random Utility Maximization (RUM)**.
- Widely used to explain and predict **individual decision-making**.
- Key applications: transport mode, route, departure time, residential location.
- Increasingly important for **integrated urban and transportation analysis.**

Traditional vs. Activity-Based Models

Traditional 4-step model

- Trip generation → Distribution → Mode choice → Assignment
- Independent steps, trip-level focus.

Activity-Based Model

- Considers entire daily activity schedule.
- Travel demand as derived from activities.
- More realistic representation of interdependencies.

Key Features of ABM

- Tour-based modeling (trip chains).
- Consistent treatment of **mode, destination, and departure time choices.**
- Accounts for **temporal and spatial constraints.**
- Representative models: **DaySim, CEMDAP, ALBATROSS.**

Recent Focus I: Multimodality & New Mobility

- Shared mobility: bike-sharing, car-sharing, ride-hailing, e-scooters.
- Mobility as a Service (MaaS) platforms.
- **Key study:** Mode choice of MaaS users Ali et, al. (2025) , Matowicki, M., et al. (2024)
- **Insight:** Experience and environmental attitudes drive adoption.

- Ali, Nazam, et al. "Modelling the mode choice behaviour of Mobility-as-a-Service (MaaS) users in the Solent of the UK." *Transportation Research Interdisciplinary Perspectives* 29 (2025): 101335.
- Matowicki, Michal, et al. "Complementing or competing with public transit? Evaluating the parameter sensitivity of potential Mobility-as-a-Service (MaaS) urban users in Germany, the Czech Republic, Poland, and the United Kingdom with a mixed choice model." *Transportation* (2024): 1-34.

Recent Focus II: Time Flexibility & Dynamic Behavior

- Impact of teleworking and **flexible schedules on departure time choice.**
  Zubair, Hamza, et al. (2024)
- Real-time route adaptation under congestion or information updates.
- Dynamic Discrete Choice Activity-Based Model (DDCM).
- **Key study**: dynamic activity scheduling Västberg et al. (2020)

- Zubair, Hamza, et al. "Investigating the role of flex-time working arrangements in optimising morning peak-hour travel demand: A survival analysis approach." *Transportation Research Part A: Policy and Practice* 190 (2024): 104229.
- Västberg, Oskar Blom, et al. "A dynamic discrete choice activity-based travel demand model." *Transportation science* 54.1 (2020): 21-41.

Recent Focus III: Micromobility, Environment & Health

- Walking, cycling, e-bikes as sustainable alternatives.
- Links to health benefits and environmental impacts.
- **Key study:** Budapest micromobility choice Abdullah (2025) Machine learning to analyze micromobility choice Sarker et al. (2024)
- **Finding:** Strong preferences for e-bikes.

- Abdullah, Pires, et al. "A discrete choice analysis of user preferences in micromobility transportation." *European Transport Research Review* 17.1 (2025): 26.
- Sarker, Md Al Adib, et al. "Exploring micromobility choice behavior across different mode users using machine learning methods." *Multimodal Transportation* 3.4 (2024): 100167.

Integration of Urban and Transport Systems

- Land Use–Transport Interaction (LUTI) models.
- Residential location choice + commuting behavior.
- Examples: **UrbanSim, ILUTE**.
- Captures feedback loops: land use ↔ transport ↔ household choices.

Extensions: Psychology & AI Integration

- **Hybrid Choice Models**: incorporating attitudes and perceptions.
- **Machine Learning + DCMs**:
  - ML → better predictive accuracy.
  - DCM → behavioral interpretability.
- Key study: TRR (2024) – Comparison of DCM and neural networks for ownership choice.

Conclusion & Outlook

Discrete choice models have evolved:

- From **trip-based demand forecasting**
- To **activity-based daily modeling**
- To **integrated urban–transport systems**

Future directions:

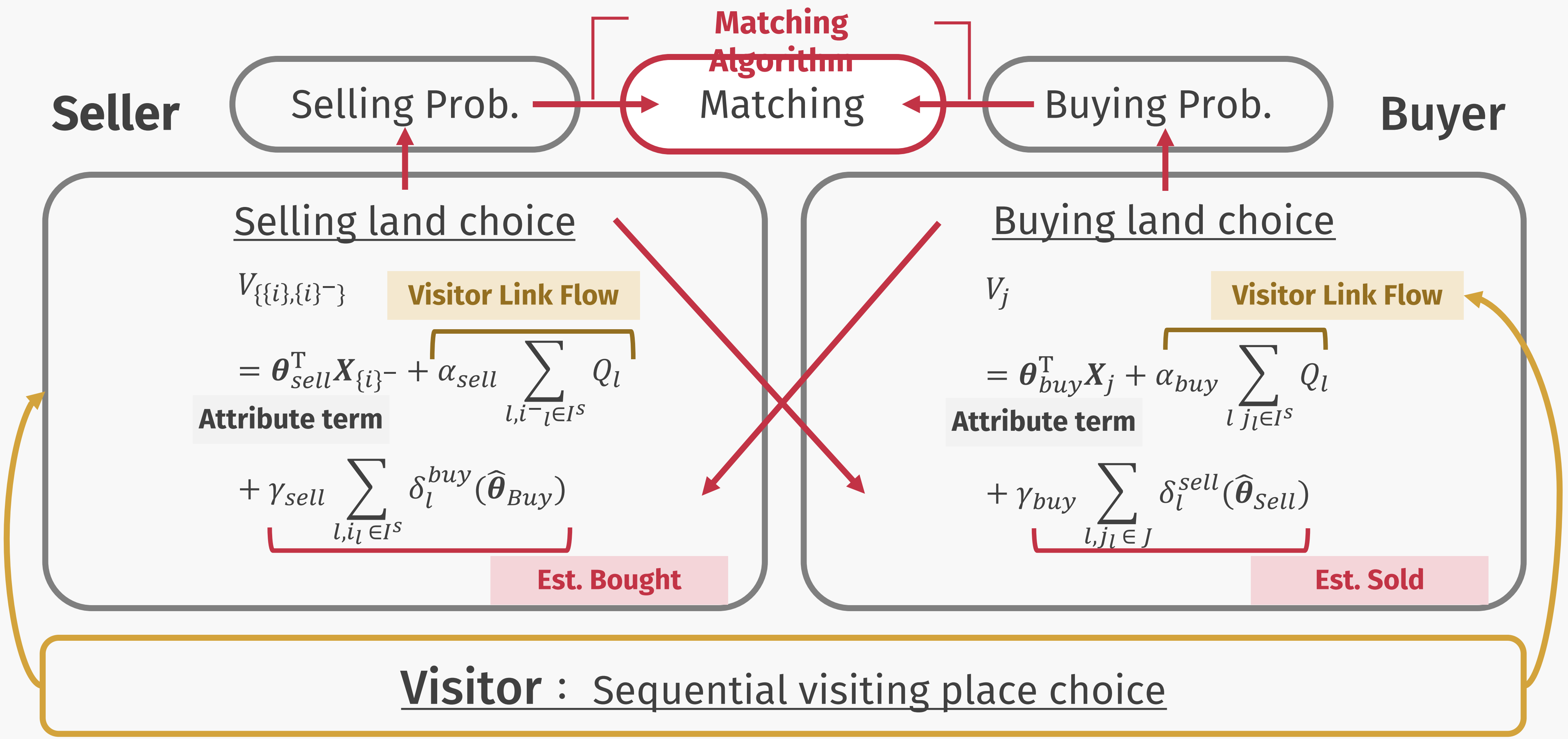
- Use of big data with privacy protection.
- Fairness and sustainability in choice modeling.
- Stronger links to **policy design and evaluation.**

Case of the Land Transaction Model

Model structure, Matching Algorithm

Model Structure

- Integration of a model and matching algorithm between three behaviors



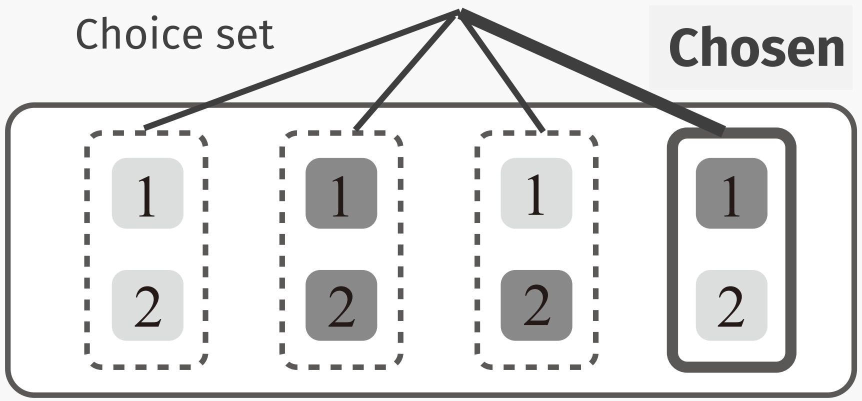
Land Selling Choice Model

- **<u>Choice behavior</u>**

Seller chooses to "sell the set of plots $\{i\}$ " and "keep the set of plots $\{i\}^-$ "

- **<u>Choice set</u>**

<u>Choice set</u> is owned land **<u>combination.</u>**



- **<u>Deterministic term</u>** of utility function

Attribute term; Trip volume term; Inference term

$$V_{\{\{i\},\{i\}^-\}} = \boldsymbol{\theta}_{sell}^{\mathrm{T}} \boldsymbol{X}_{\{i\}^-} + \alpha_{sell} \sum_{l, i^-{}_l \in I^s} N\, Q_l + \gamma_{sell} \sum_{l, i_l \in I^s} \delta_l^{buy}(\hat{\boldsymbol{\theta}}_{buy})$$

- l refers to link
- $\hat{\boldsymbol{\theta}}_{Buy}$ is estimates of the buy model
- Parameter is $\boldsymbol{\theta}_{Sell} = (\boldsymbol{\theta}_{sell}, \alpha_{sell}, \gamma_{sell})$

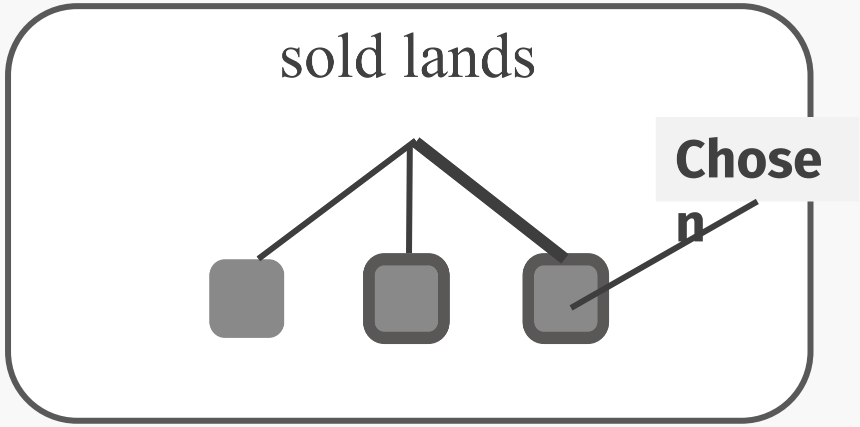
Land Buying Choice Model

- **Choice behavior**

Buyer chooses to buy the plot j

- **Choice set**

All of the sold land



- **Deterministic term** of utility function

Attribute term

Trip volume term

Inference term

$$V_j = \boldsymbol{\theta}_{buy}^{\mathrm{T}} \boldsymbol{X}_j + \alpha_{buy} \sum_{l\ j_l \in I^s} N\,Q_l + \gamma_{buy} \sum_{l, j_l \in J} \delta_l^{sell}(\hat{\boldsymbol{\theta}}_{Sell})$$

- l refers to link
- $\hat{\boldsymbol{\theta}}_{Sell}$ is estimates of the sell model
- Parameter is $\boldsymbol{\theta}_{Buy} = (\boldsymbol{\theta}_{buy}, \alpha_{buy}, \gamma_{buy})$

Sequential Visit Place Choice Model by dRL model

Choice behavior

Agents choose a place s_τ to visit according to Markov process and **trip chain**

Choice set

Network of states (places to visit) transitions

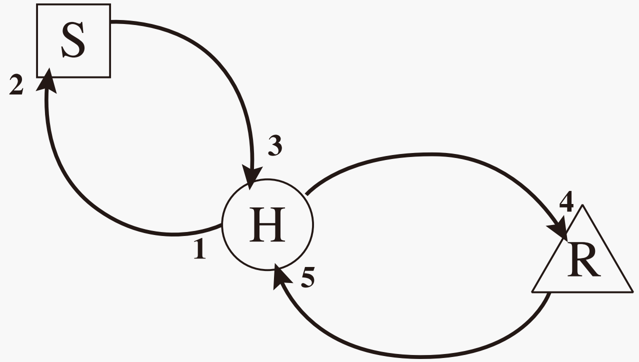


Fig: Diagram of Sequential Visit Place Choice Model

Expected utility (Bellman equation)

$$V^d(s_\tau) = \mathbb{E}\left[\max_{s_{\tau+1}\in\mathcal{S}(s_\tau)}\left\{v(s_{\tau+1}|s_\tau) + \beta V^d(s_{\tau+1}) + \mu_{s_\tau}\varepsilon(s_{\tau+1})\right\}\right] \quad (1)$$

Expected maximum utility

Instantaneous utility

Error term

- Transition probability of place $s_{\tau+1}$ from s_τ

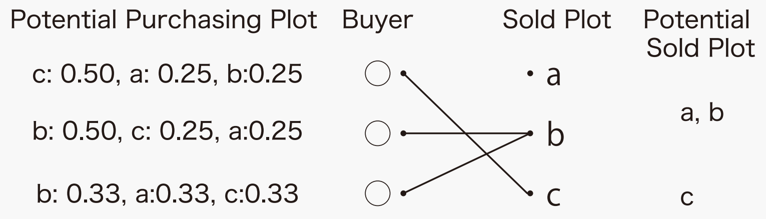
$$P^d(s_{\tau+1}|s_\tau) = \frac{e^{\frac{1}{\mu}\{v(s_{\tau+1}|s_\tau;\theta)+\beta V^d(s_{\tau+1})\}}}{\sum_{s'_{\tau+1}\in\mathcal{S}(s_\tau)} e^{\frac{1}{\mu}\{v(s'_{\tau+1}|s_\tau;\theta)+\beta V^d(s'_{\tau+1})\}}} \quad (2)$$

Matching Algorithm：Summary

- DA algorithm by Gale– Shapley can achieve “stable matching”
- The stable matching is the equilibrium
- Estimation result of land selling model and buying model make each probability of choosing an alternative
- Also, estimation result can estimate the preference rank of the other side

Matching Algorithm based on DA Algorithm

1. The "free" buyer makes an offer for the plot with the highest choice probability among his alternatives (potential purchasing plots).



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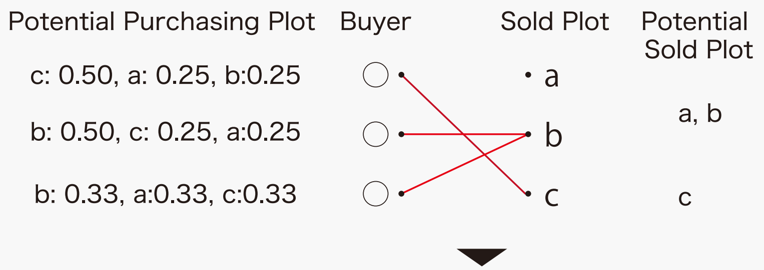

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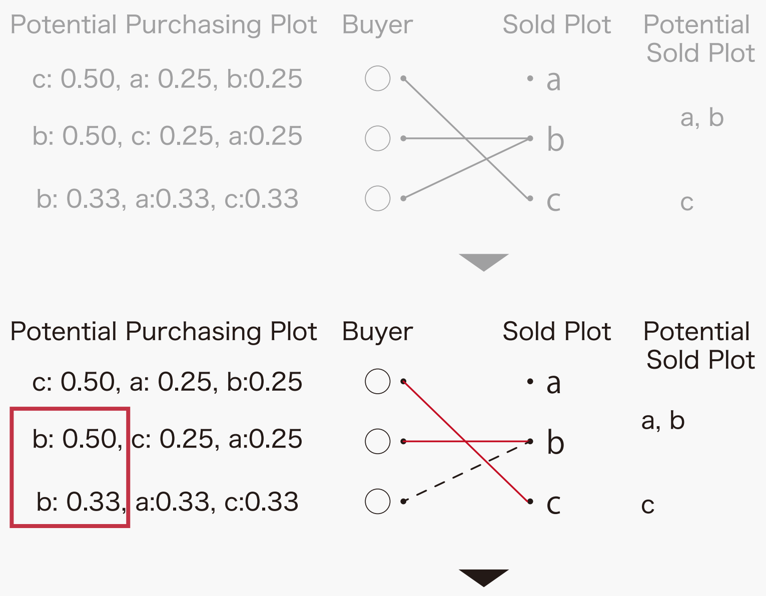

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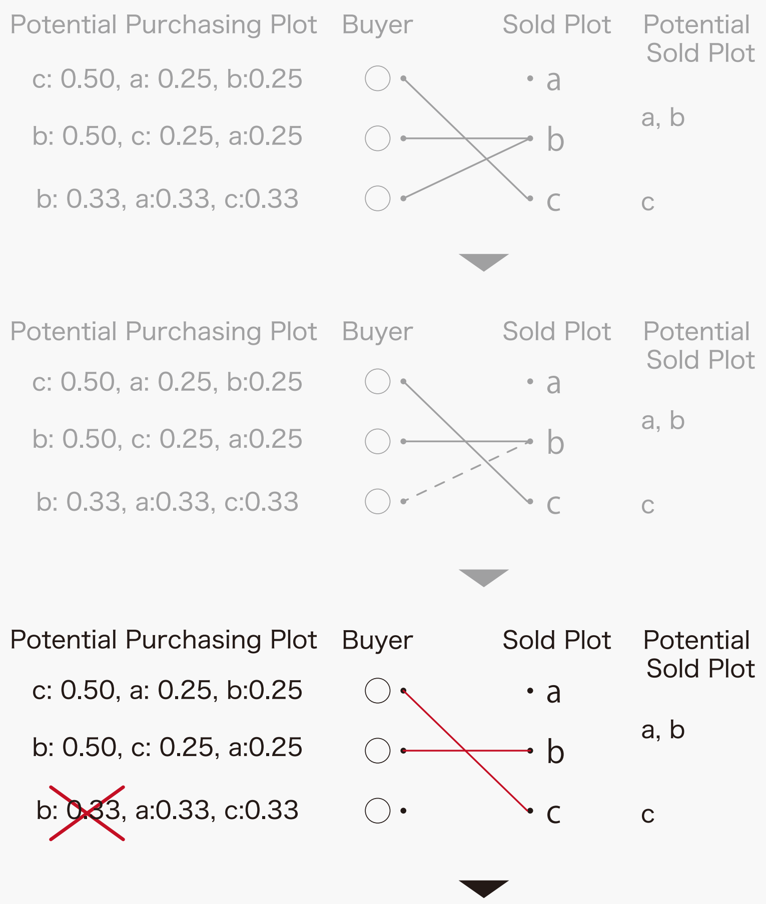
4. If the "tentative matching" with the seller is resolved, the buyer removes the resolved seller’s land from his preference list and becomes free.



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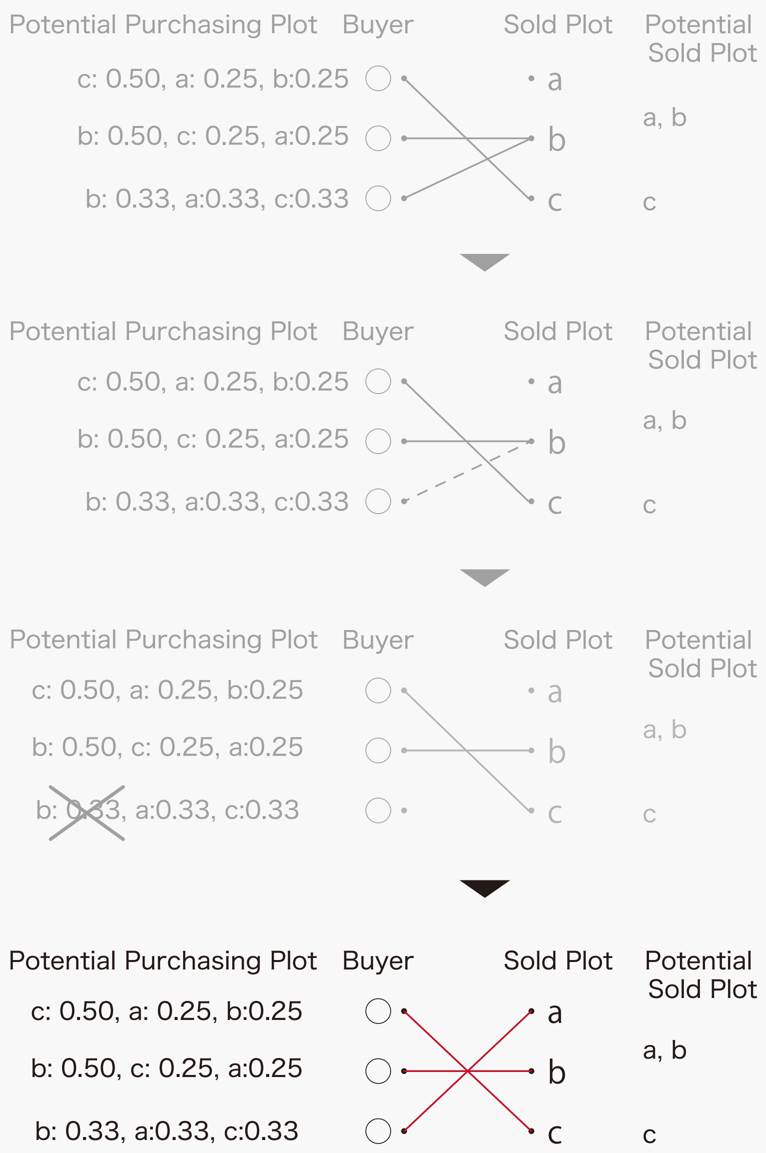
4. If the "tentative matching" with the seller is resolved, the buyer removes the resolved seller’s land from his preference list and becomes free.
5. The above procedure is repeated until there are no more buyers who have not been tentatively matched.



Case Study

Context, Estimation Result, Simulation

Utilizing the Land Registration Document

➢ For observation of the land transaction relationship

- Pros: Official, public data, uniform format, highly covered in domestic
- Cons: Need for tabular databases, complementing geographic information

Document based data

２０２１／０１／１９　１４：４６　現在の情報です。

表　題　部　（土地の表示）		調製	平成６年５月２６日	不動産番号	５０００００１４３６９０
地図番号	１３７４ Ｓ４・２１－２	筆界特定	余　白		
所　在	松山市道後湯之町				余　白
①　地　番	②地　目	③　地　積　㎡			原因及びその日付〔登記の日付〕
甲[redacted]	宅地	９９：１７			余　白
余　白	余　白	余　白			昭和６３年法務省令第３７号附則第２条第２項の規定により移記 平成６年５月２６日
余　白	余　白	１０７：３９			③錯誤 地図作成 〔平成１８年３月１４日〕

権　利　部　（甲　区）　（所　有　権　に　関　す　る　事　項）			
順位番号	登　記　の　目　的	受付年月日・受付番号	権　利　者　そ　の　他　の　事　項
１	所有権移転	昭和２３年５月１０日 第４９５９号	原因　昭和２３年３月１９日売買 所有者　松山市[redacted] 順位１番の登記を移記
	余　白	余　白	昭和６３年法務省令第３７号附則第２条第２項の規定により移記 平成６年５月２６日
２	所有権移転	平成１１年２月５日 第４７１１号	原因　平成１０年４月５日相続 所有者　松山市[redacted]
３	所有権移転	平成２４年１２月５日 第３８９９０号	原因　平成１８年７月３０日相続 所有者　松山市[redacted]
４	所有権移転	平成２７年１２月１７日 第３６９１４号	原因　平成２７年８月６日買収 所有者　松　山　市

fig. Land Registration Document in Japan

Tabular database

Attribute of plot with owner

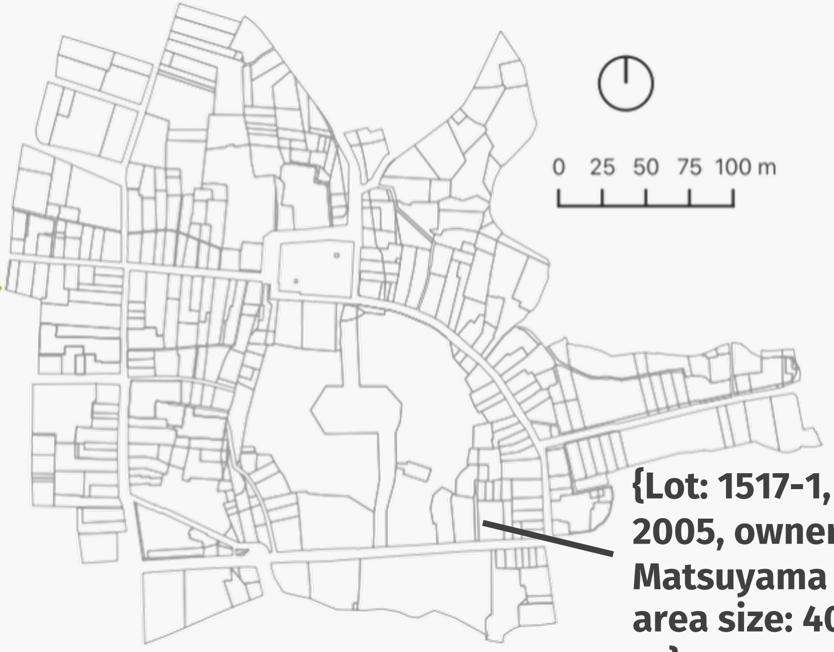
Lot. No	Year	Name
1517-1	2004	Xxx, xxx
1517-1	2005	Matsuyama city
1517-1	2006	Matsuyama city
...	...	...
1517-2	2005	Matsuyama city

Combine

Relationship of Buyer - Seller

Year	**Seller**	**Buyer**
2004	Xxx, xxx	Matsuyama city
...	...	...

Surveyed Plot (Cadastral) Map: Geo data



{Lot: 1517-1, year: 2005, owner: Matsuyama city , area size: 40m2, … }

Specification for Land Side Model

- **Land Selling Choice Model**

$$V_{\{\{i\},\{i\}^-\}}$$

$$= \theta_{sell2} CC_{\{i\}^-} + \theta_{sell3} FL_{\{i\}^-} + \alpha_{sell4} \sum_{l, i^-{}_l \in I^s} N\,Q_l + \gamma_{sell1} \sum_{l, i_l \in I^s} \delta_l^{buy}(\widehat{\boldsymbol{\theta}}_{buy})$$

Centroid distance of the **Clustered plots**

Opening width

Assignment results of **Sequential Visit Place Choice Model**

Estimated num. from **Buying Choice Model**

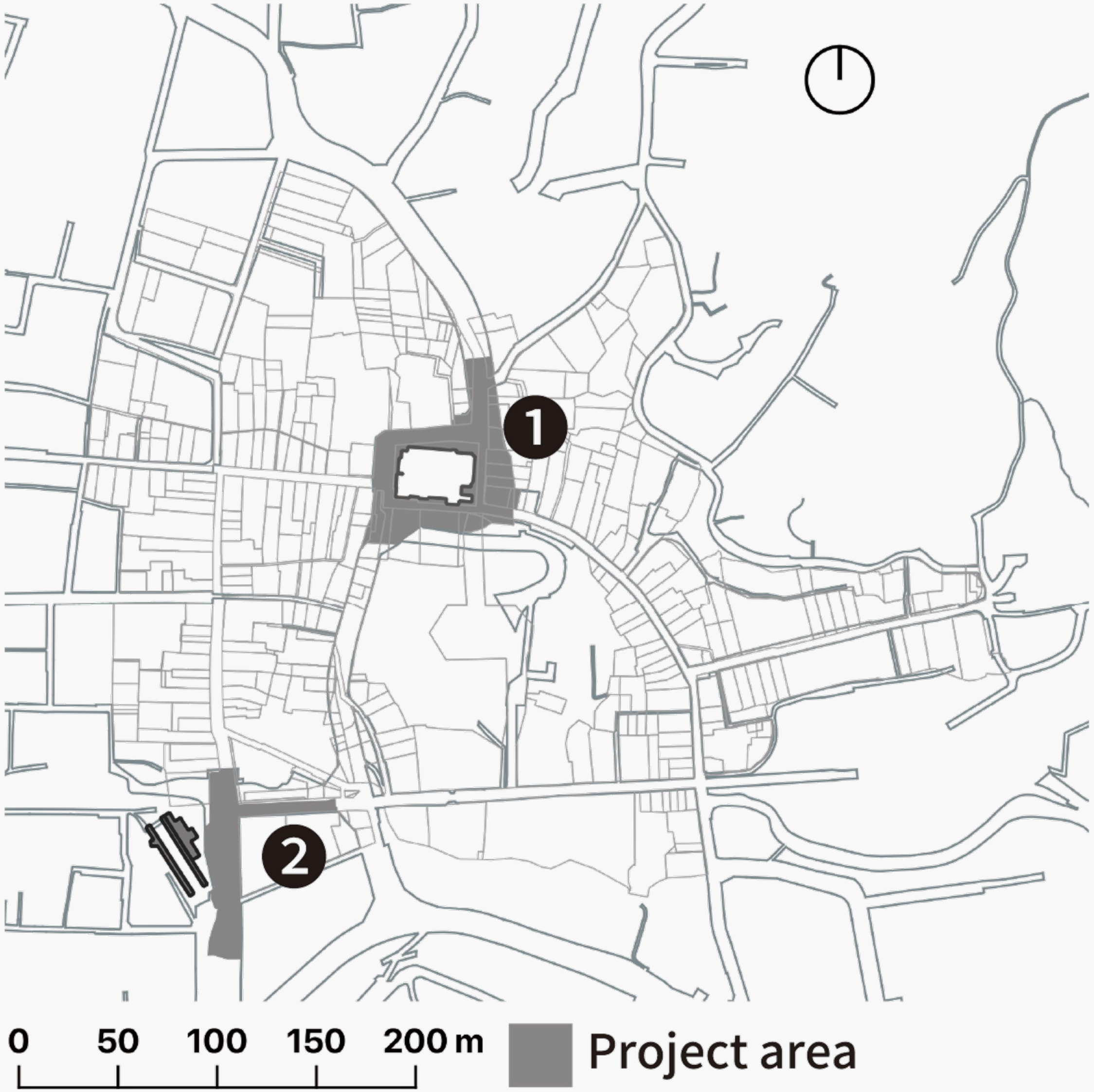
- **Land Buying Choice Model**

$$V_j = \theta_{buy2} CC_j + \theta_{buy3} FL_j + \alpha_{buy4} \sum_{l\ j_l \in I^s} N\,Q_l + \gamma_{buy1} \sum_{l, j_l \in J} \delta_l^{sell}(\widehat{\boldsymbol{\theta}}_{Sell})$$

Specification for Sequential Visit Place Choice Model

Variable name	Description	
Spa Dummy	Dummy variable with spa site as 1	Type of place
Hotel Dummy	Dummy variable with hotel as 1	
Shop Dummy	Dummy variable for souvenir shops as 1	
Heritage site Dummy	Dummy variable for temples, shrines or historical sites	
Project for the square of the main bldg.	Dummy variable where 1 is the visited place within the 50m buffer of the plaza project in front of the main building completed in 2007.	Project-related Dummy
Project for square of station Dum	Dummy variable where 1 is the visited place within the 50 m buffer of the Dogo Onsen Station Square project completed in 2009	
Project for new bath bldg. Dum	Dummy variable where 1 is the visited place within the 50 m buffer of the New Public Bathhouse project completed in 2017	
Art installation Dum	Dummy variable where 1 is the visited place where the artwork is officially settled in the Festival 2018	
Transaction num. (2004-2009)	Amount of land transactions by link to which the visited place belongs	Land transaction and distance
Transaction num. (2013-2017)		
Distance	Distance between places to stay	

The Detail of Urban Renewal Project



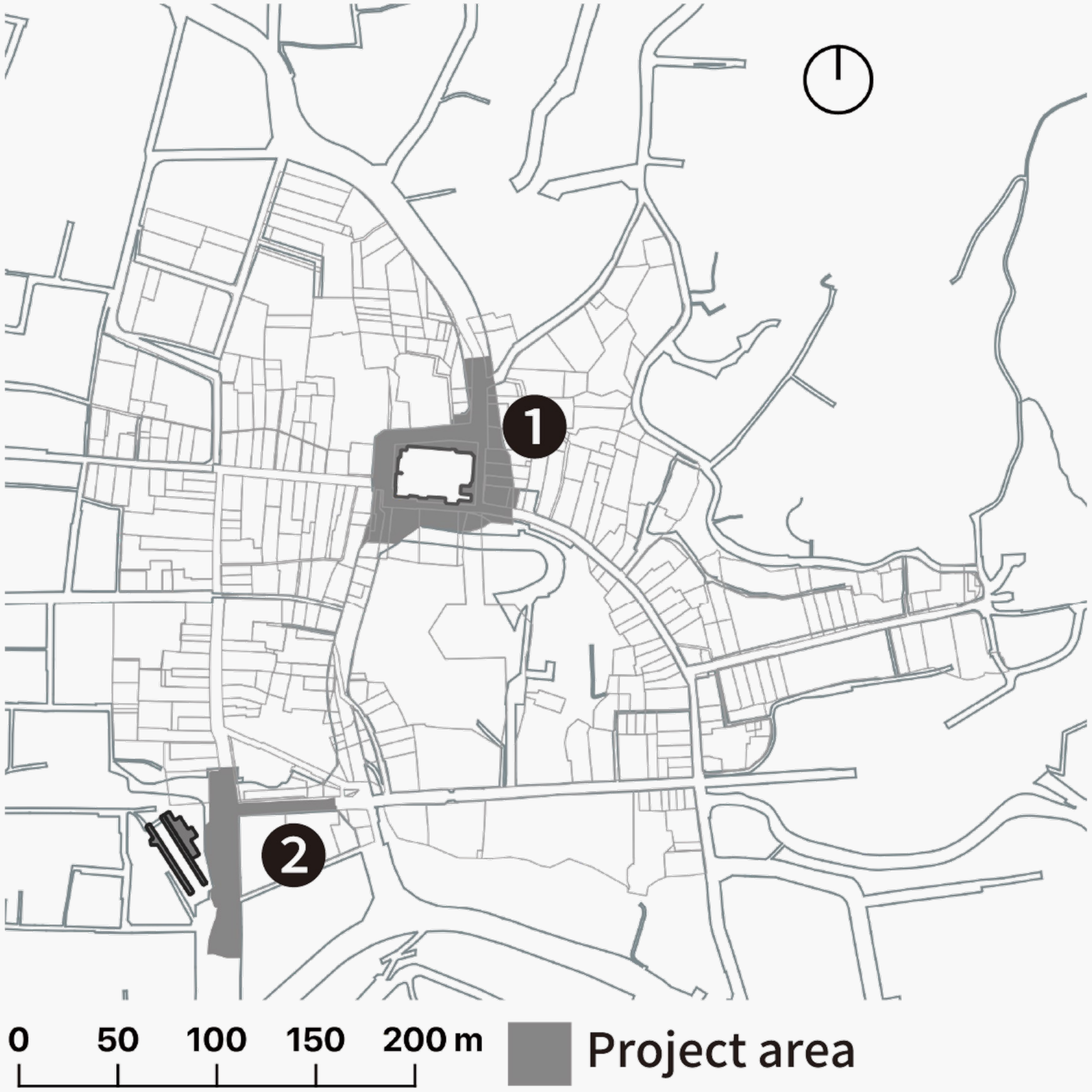
❶ Project for square of main building

Create a pedestrian-only square

09. 2007　complete to build

ref：http://www.estfukyu.jp/pdf/sohatsu_chugoku_shikoku4.pdf

The Detail of Urban Renewal Project

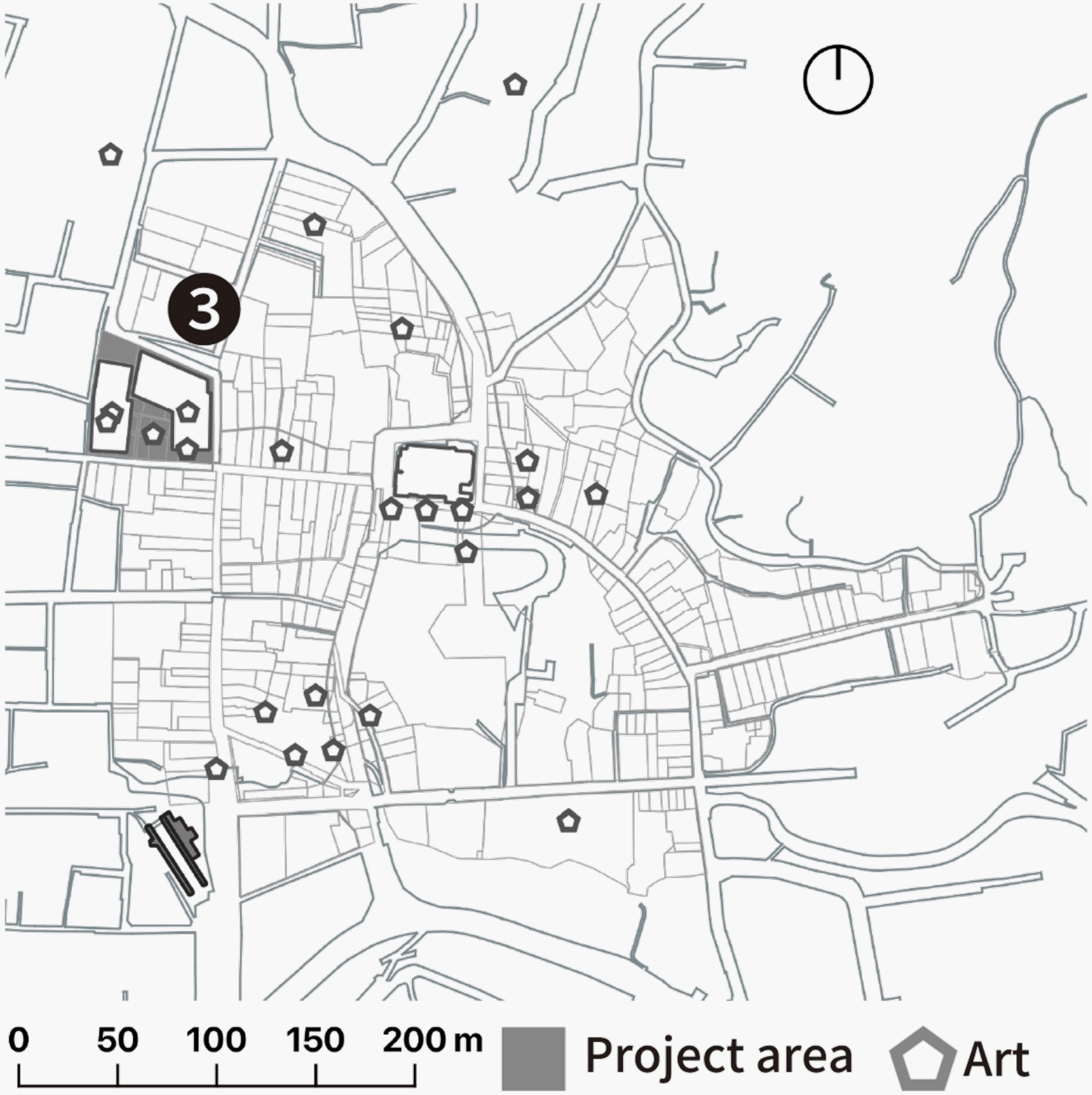


❷ Project for square of station

Enhance pedestrian-only square

03. 2009　complete to build

The Detail of Urban Renewal Project



❸ Project for new bath building

01.2013 – 09.2017 Construction

⬠ Public Art installation: 09.2017 -

Estimation Result in Land Side

- Sellers keep the plot with visitors staying and sell the plot with the less estimated bought

	2004-2009		2009-2013		2013-2017		2017-2021	
	Sell	Buy	Sell	Buy	Sell	Buy	Sell	Buy
Cluster size	-2.459***	-1.219***	-3.29***	-2.97***	-3.16***	-1.66***	-1.11	-30.65
Opening width (/10m) Est	0.86***	0.13	1.42***	0.36	1.52***	-0.16	1.86***	0.1
Estimated visiting num	4.13***	0.04	2.41***	3.04	0.73*	-24.75	0.9*	-20.41
Estimated bought land num	-0.14***	-	-0.84***	-	-0.47***	-	-0.34***	-
Estimated sold land num	-	-0.1***	-	-0.16*	-	-0.02	-	-0.087
Final Log-likelihood	-1205.43	-109.16	-563.47	-37.06	-496.89	-48.22	-407.98	-25.6
Adj Likelihood ratio ρ^2	0.29	0.53	0.55	0.72	0.49	0.6	0.422	0.736
Sample	2093	98	1607	57	1230	51	884	42

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

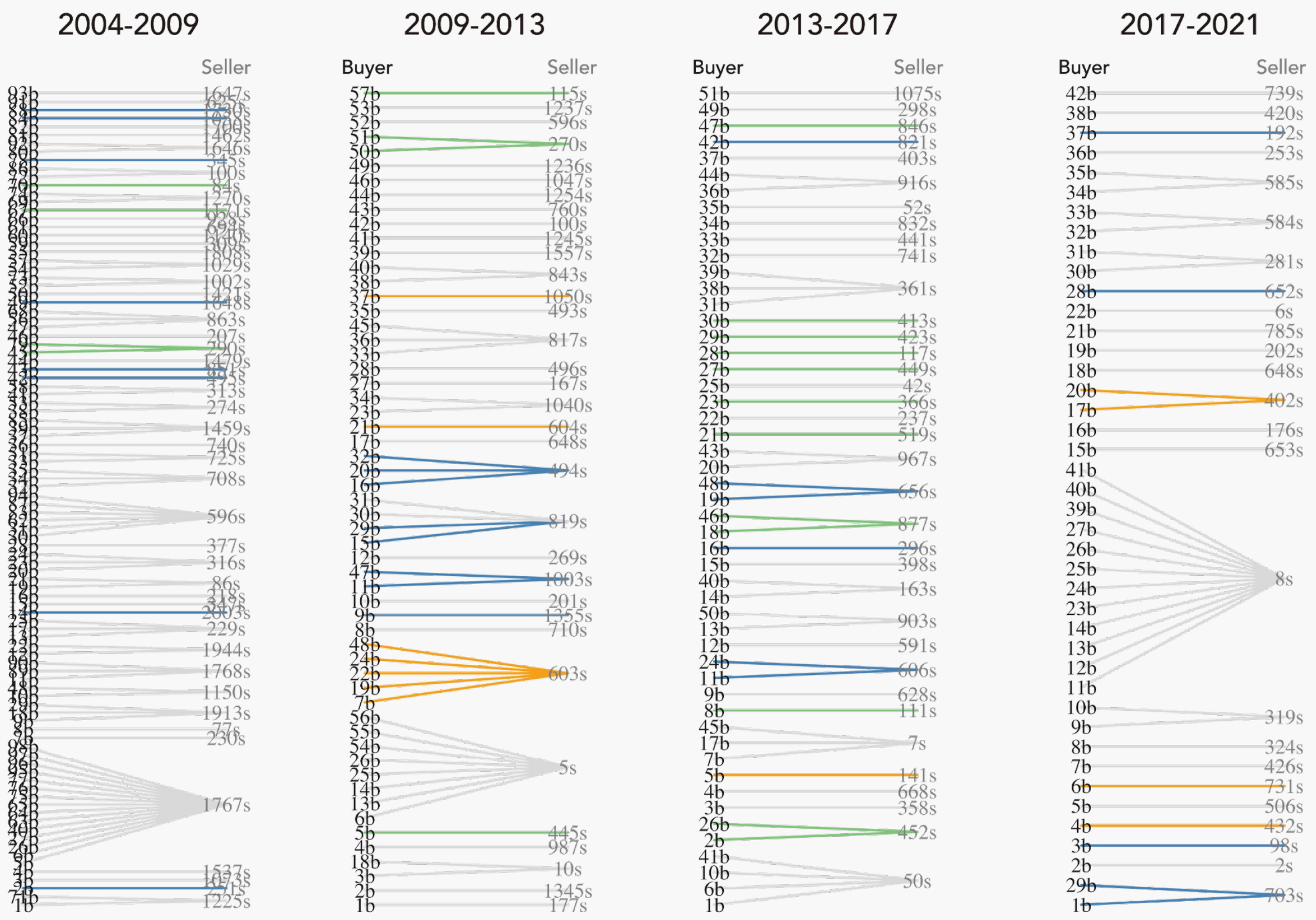
Estimation Result in Visitor Side

	2009 Est. Param.	2017 Est. Param.
Spa Dummy	1.59**	1.91
Hotel Dummy	-0.54	2.80***
Shop Dummy	1.39***	3.87***
Heritage site Dummy	1.66***	3.05***
Transaction num. (2004-2009)	0.04	0.07
Transaction num. (2013-2017)	-	-0.25
Project for the square of the main bldg. Dum	0.85***	0.55
Project for square of station Dum	1.26***	-0.94
Distance	0.00	0.18*
Art installation Dum	-	1.59**
Project for new bath bldg. Dum	-	3.15
Time discount rate β (fixed)	0.10	0.10
Final Log-likelihood	-315.36	-89.36
Adj. Likelihood ratio ρ2	0.19	0.2

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

- Excursion behavior is not affected by the frequency of land transactions.
- Renewal of public space stimulates the staying behavior around it
- Permanent renewal, as well as art installations, promote stay behavior

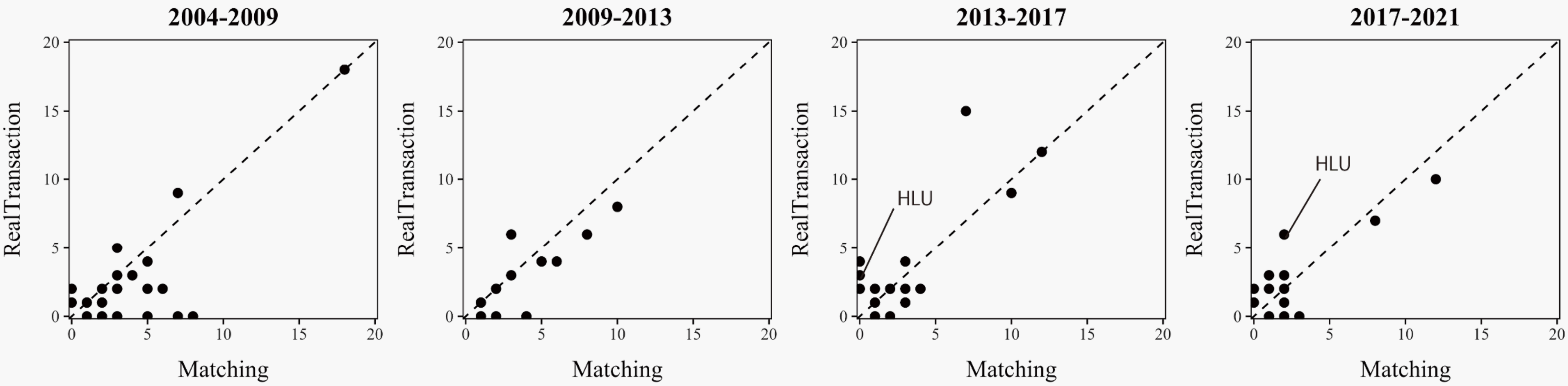
Result of Matching Algorithm based Estimated Probability



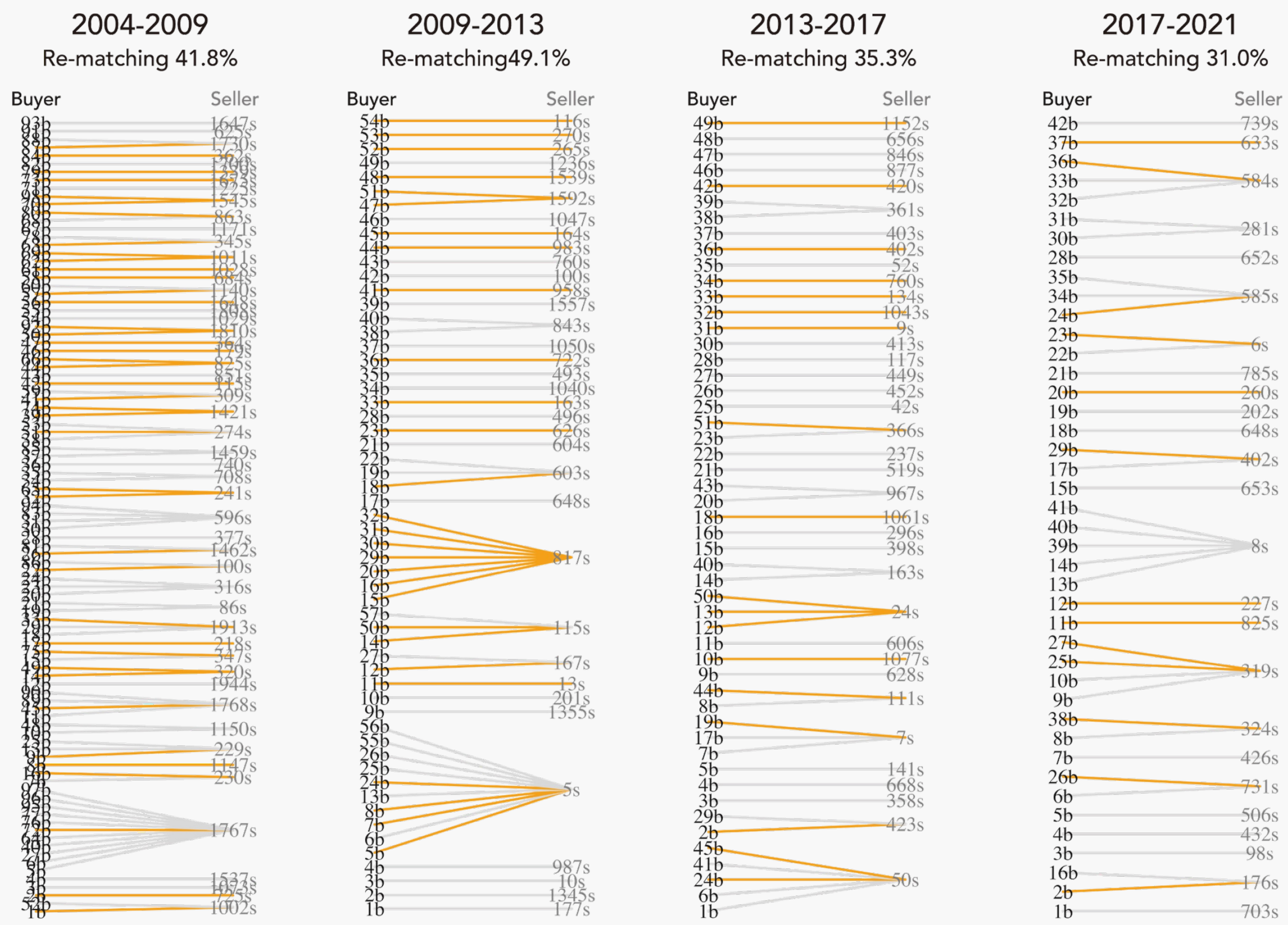
- Buyer-proposal matching converges
- Concentration of buyers on specific sites: Matching based on preference suggests higher demand for residential use
- The surrounding plot was not matched immediately after the renewal

Result of Matching Algorithm based Estimated Probability

- Actual transaction frequency and the matching number generally accord.
- Low - utilized land is included in links with higher actual transaction frequency than the matching number, indicating the possibility of low-price trading



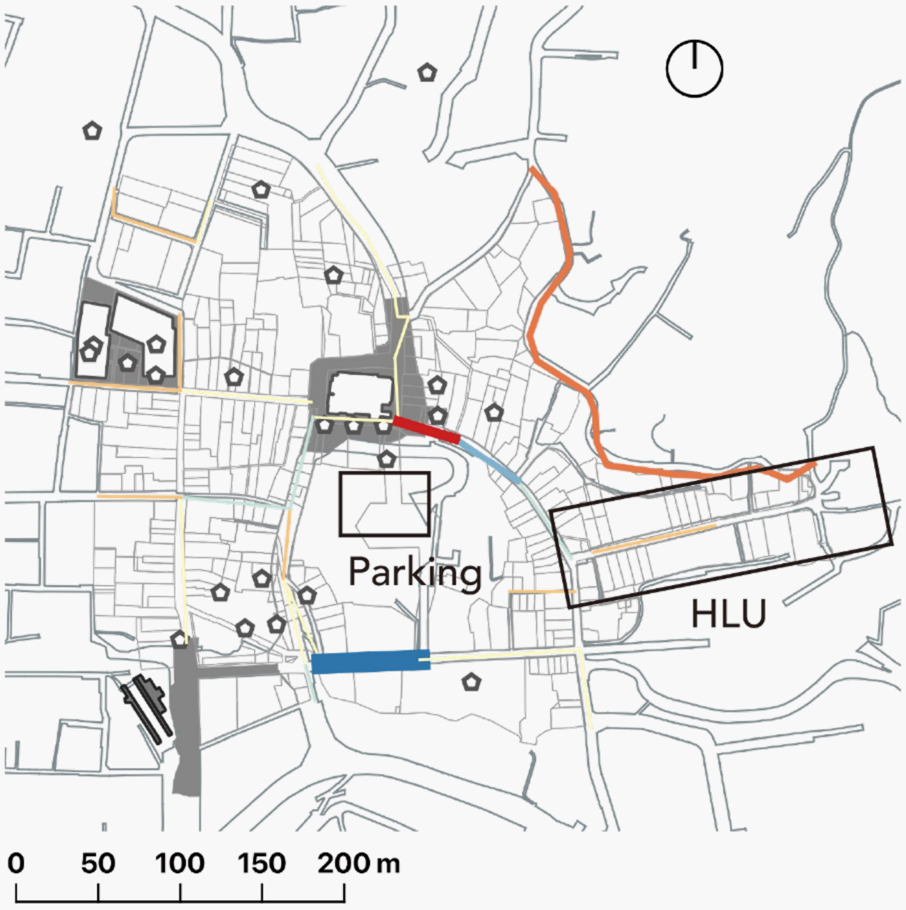
Simulation of Matching from Changes in Excursion Behavior



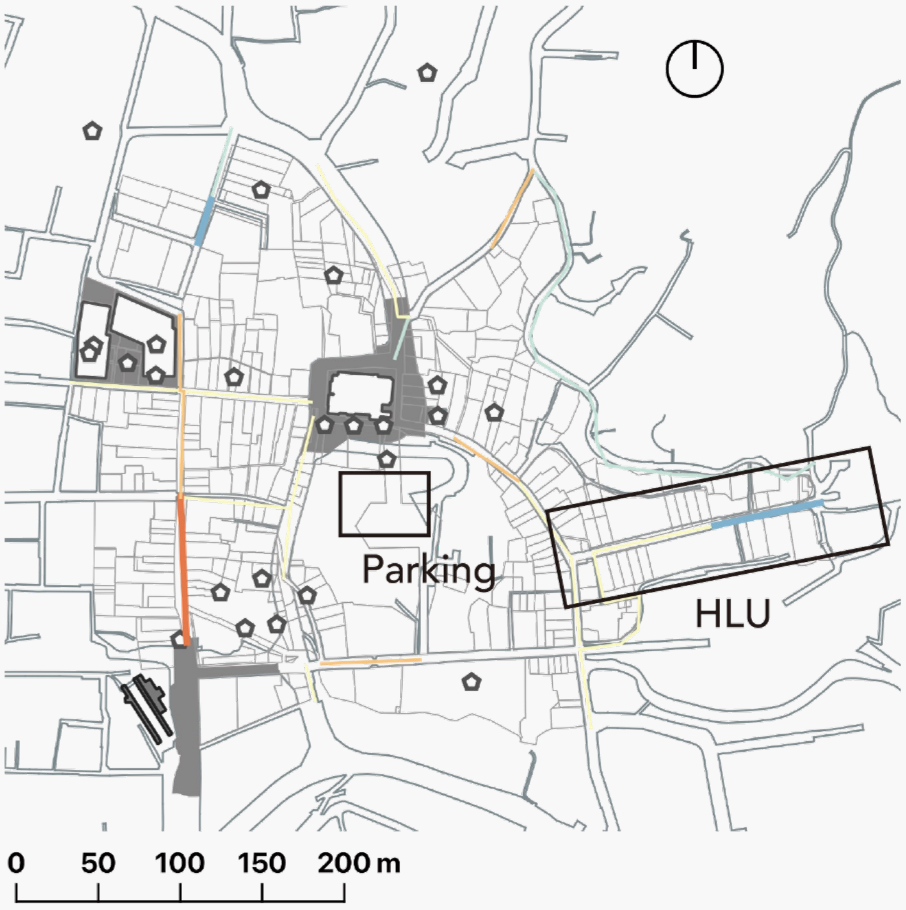
- Simulation Condition: New public spaces where people can stay were developed in links with low-utilized plots.
- Development of new places to stay re-matches about 31% - 50% of lands.
- Changes in excursion behavior resulting from the development of public space affect land transactions

Simulation of Matching from Changes in Excursion Behavior

2004-2009 Total Surplus: 51.17→51.96 1.54%up



2009-2013 Total Surplus: 26.13→28.94 10.75%up



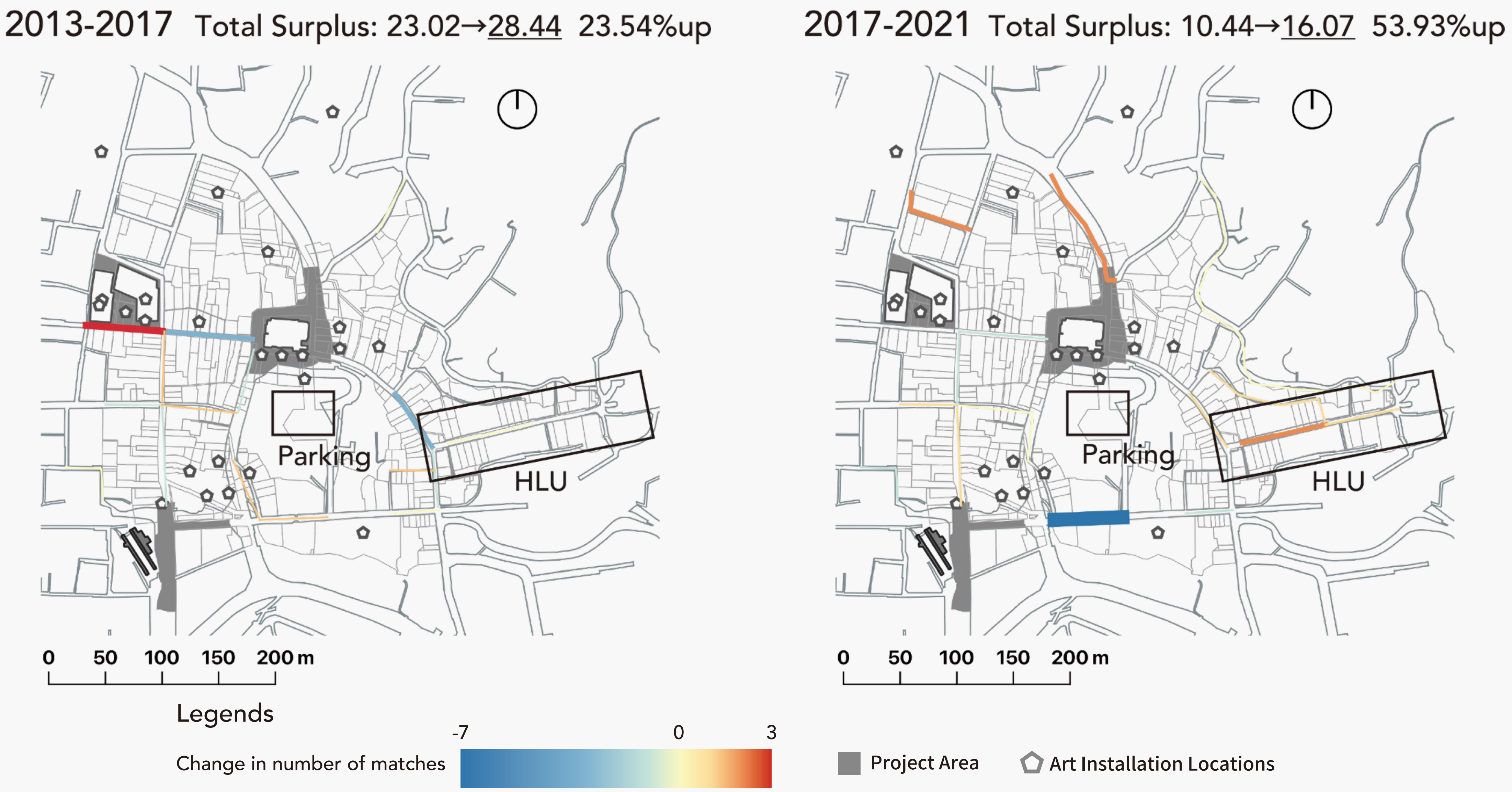
Legends

Change in number of matches: -7 … 0 … 3

Project Area

Art Installation Locations

Simulation of Matching from Changes in Excursion Behavior



Conclusion and Future Works

Conclusion

- **Modeling of sequential excursion travel behaviors due to renewal development and land matching affected by these changes**
  - ✓ Regardless of the method, public space renewal encourages staying there, including in the surroundings.
  - ✓ Urban renewal projects that encourage visits to specific low-utilized streets indicated an increase in the total surplus of matching in the neighborhood.

Fruit of This Lecture

- Behavior models are not limited to transportation.
- It is important to design models with policy objectives in mind.

Thank you for listening

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