# Modeling relocation dynamics under shifting spatial conditions for adaptive post-disaster recovery planning

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## Introduction | Need for Dynamic Models

### ◻Time-Limited Decision Making

Disaster recovery requires rapid choices under strict time constraints[1]

### ◻Dynamic Spatial Change

Living environments shift throughout the recovery phases:

Temporary Houses in Japan (by Author)

Public Houses in Japan (by Kumamoto Pref.)

- While various recovery models have been developed(e.g.[2][3][4]), spatio-temporal dynamics were overlooked
- lack of models that integrate evolving spatial conditions over time into long-term recovery simulations

- To clarify how evolving spatial conditions impact residential choice behavior through a Dynamic Agent-Based Model (ABM).

## References

[1] Olshansky et al. (2012), Disaster and Recovery: Processes Compressed in Time, Natural Hazards Review, Vol.13 No.3
[2] Moradi and Nejat (2020), RecovUS: An Agent-Based Model of Post-Disaster Household Recovery, Journal of Artificial Societies and Social Simulation, 23(4) 13
[3] Miles and Chang (2006), Modeling Community Recovery from Earthquakes, Earthquake Spectra, Vol.22 No.2
[4] Park et al. (2024), Post-disaster recovery policy assessment of urban socio-physical systems, Computers, Environment and Urban Systems, 114

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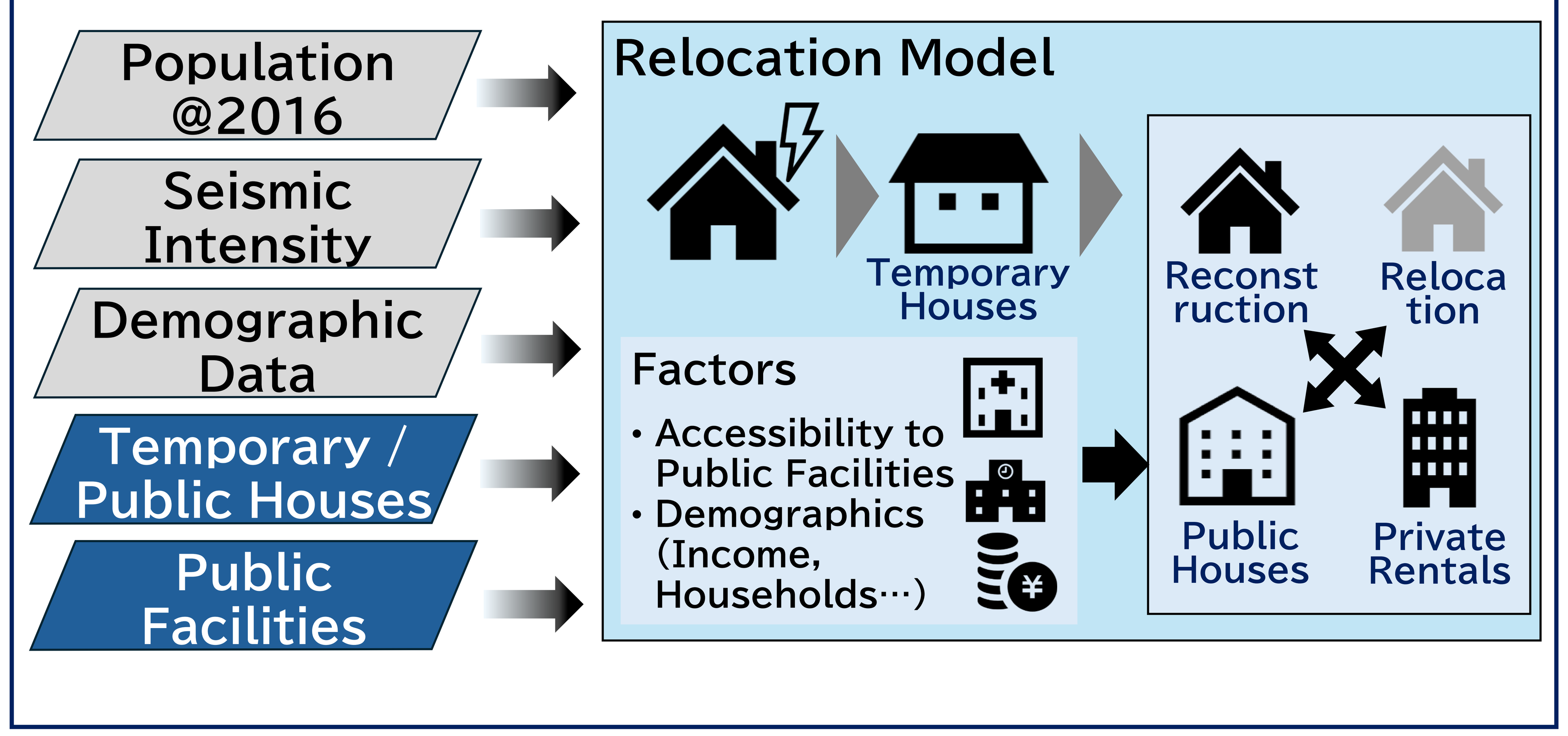
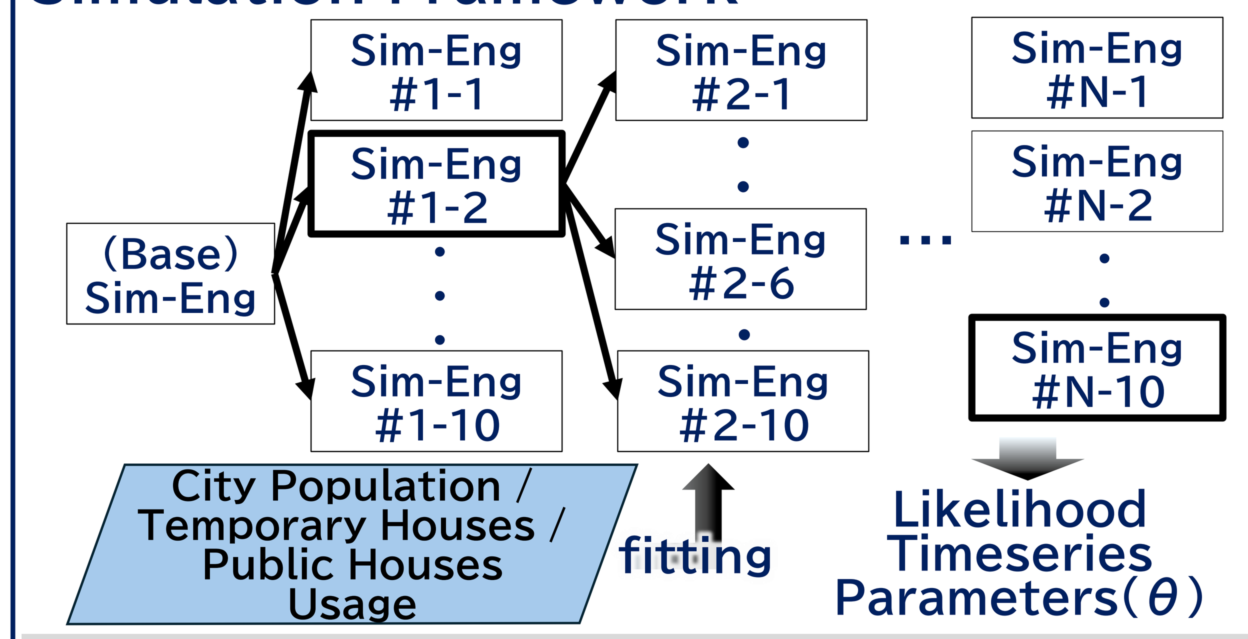
## Research Method | Agent-Based Modeling with Spatial-Shifts

**Case Study of Kumamoto EQ, 2016**

### Simulation Engine(Sim-Eng)




### Simulation Framework




Validation | Root Mean Squared Percentage Error(RMSPE)

$$\min_{\theta} \mathrm{RMSPE}_{total} = \mathrm{RMSPE}_T + \mathrm{RMSPE}_P + \mathrm{RMSPE}_{Pop}$$

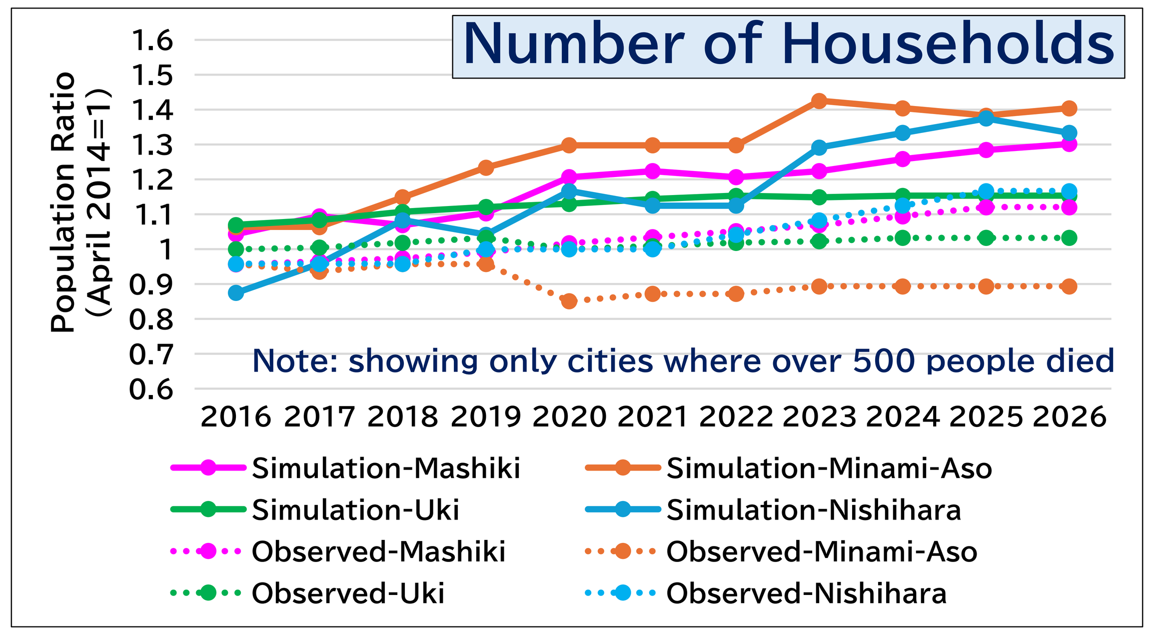
Where $T$, $P$, and $Pop$ denote temporary housing, public housing, and population variables, and $\theta$ represents the parameter set to be estimated.

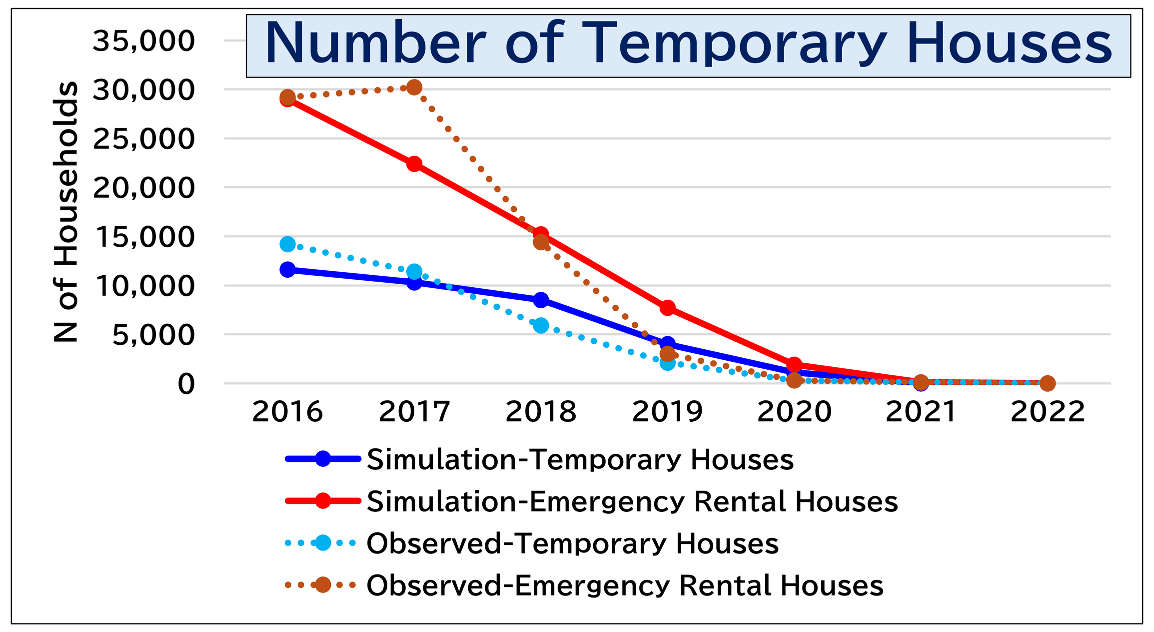
### Utility Calculation

$$U_{t,a,c} = \sum_k \beta_{t,k} x_k + \sum_k \beta_{a,k} x_k + \sum_f \beta_{a,acc} z_{f,c}^{acc}$$

| Symbols | Explanation |
|---|---|
| $t, a, c$ | Target household type, area, city (area: in-city, in-prefecture, out) |
| $k$ | Attributes (e.g., age, income, damage level) |
| $f$ | Public facility types |
| $acc$ | Accessibility Type (Proximity, N of facilities) |
| $x_k$ | Attribute dummy variables |
| $x_{h,k}$ | Attribute dummy variables |
| $z_{f,c}^{acc}$ | Accessibility to facilities f in City c |
| $\beta$ | Estimated coefficients |

## Results | Key Role of Accessibility




**Accuracy** RMSE(Root Mean Squared Error): Smaller, More Accurate

| Index | With Facilities | Without Facilities |
|---|---|---|
| RMSE (Number of Households) | 14.62 | 14.67 |
| RMSE (Composition Rate of Households : each city in the Prefecture) | 0.28 | 0.33 |
| RMSE (Number of Temporary Houses) | 17.79 | 15.99 |

### ◻ General Trends

Effectively captured for both population and temporary housing

### ◻ Facility Impact

Improved population simulation accuracy, but had little effect on temporary housing due to strict siting constraints

### ◻ Scale Issue

Smaller municipalities showed slight deviation from observed data due to high sensitivity

## Conclusion

◻ **Valuable Approach:**
Facility accessibility enhances dynamic simulation, though methods should be improved

◻ **Framework:**
Establishes a foundation for sequential, dynamic recovery modeling

◻ **Next Step:**
Introduce what-if analyses to balance facility scaling with municipal financial capacity

## Applications | Flexible Recovery

### ◻Policy & Governance

- **Location Matters:** Careful placement of temporary and public housing is essential to ensure accessibility
- **Infrastructure:** Adjusting public facility layouts is a core element of resilient recovery
- **Finance:** Maintaining public facilities requires municipal financial resources

### ◻Modeling Strength

- **Dynamic Framework:** Transitioning from static plans to adaptive, "Living System"
- **Social Continuity:** Tools to evaluate the maintenance of social networks through spatial intervention

### ◻Beyond Recovery

- **Cross-Domain Use:** Applicable to climate adaptation and flood risk management
- **Dual-Use Planning:** Integrating recovery strategies into daily urban development