

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



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Summary & Takeaways

Issues

- In depopulating societies, post-disaster recovery requires **downsizing housing stock and public facilities in line with municipal financial capacity**.
- However, existing recovery models rarely incorporate spatial shifts in facility and housing locations that occur throughout the recovery process.

Method

- Developing a simulation model that explicitly **represents temporal changes in the locations of housing and public facilities** during recovery.
- Modeling household relocation intentions using an agent-based model (ABM)** in which accessibility changes influence residential choice.
- Employing a Sequential Monte Carlo (SMC)**-based Bayesian updating approach to ensure empirical validity, for estimating model parameters from actual data.

Implications

- Findings suggest that **accessibility to public facilities can significantly influence population dynamics** during recovery.
- Further refinement is needed to identify more appropriate accessibility indexes and to improve how accessibility is incorporated into recovery models.

1. Introduction | Need for Flexible Recovery

Time-Limited Decision Making

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

Dynamic Spatial Change

Living environments shift throughout the recovery phases



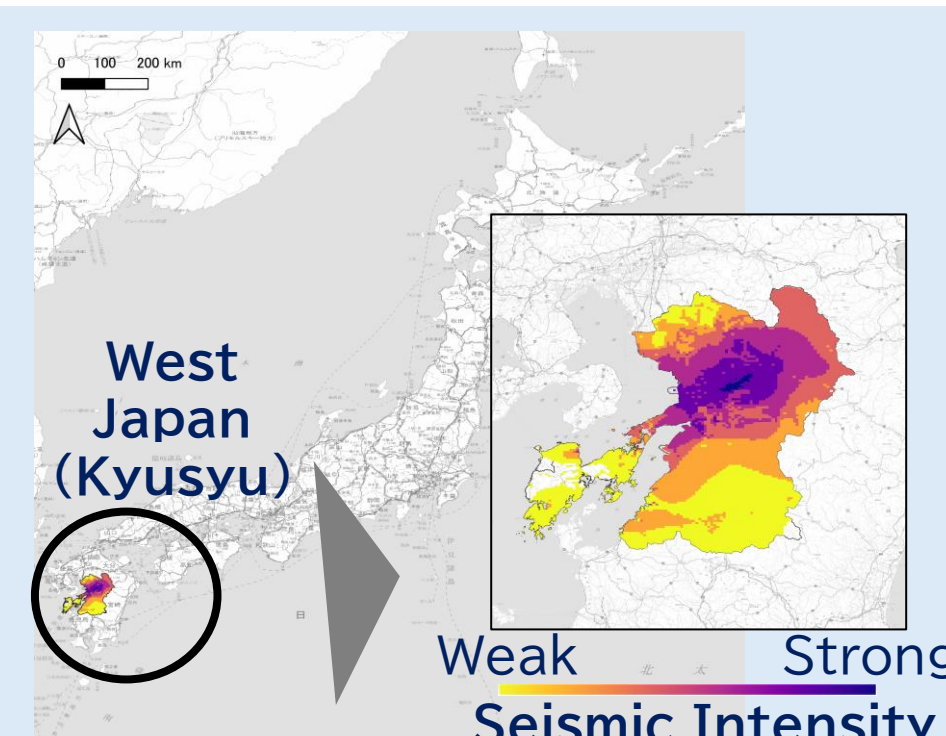
Financial Limitations

In depopulating areas, downsizing housing stock and public facilities should be considered in terms of finance

- 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)**.

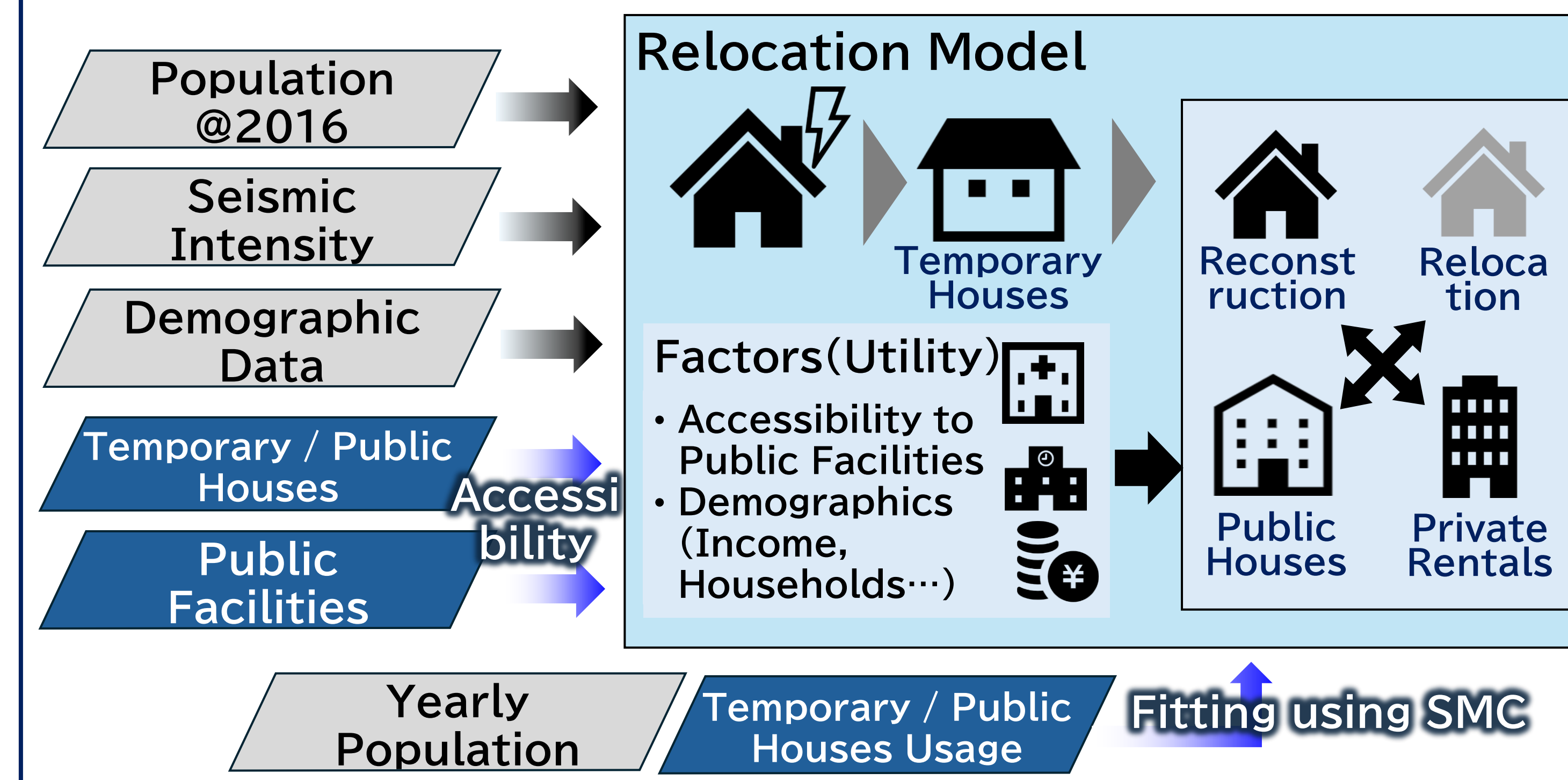
Kumamoto Earthquake

- Occurred in 2016
- 2 earthquakes occurred sequentially (M6.5, M7.3)
- 273 people died, 2,809 people injured
- Residential and Municipal Areas were damaged



2. Research Method | ABM with Accessibility

Simulation Engine (Sim-Eng)



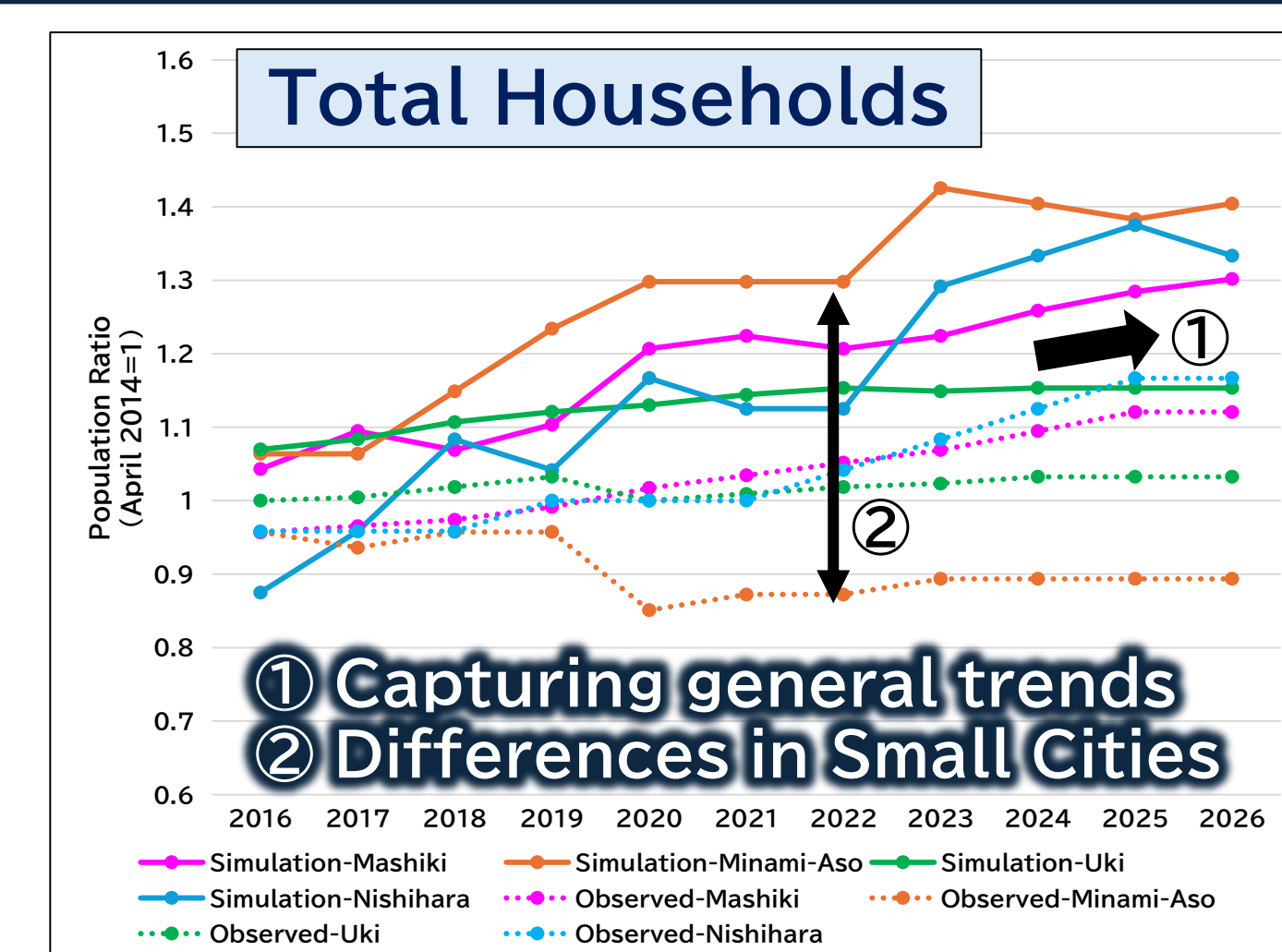
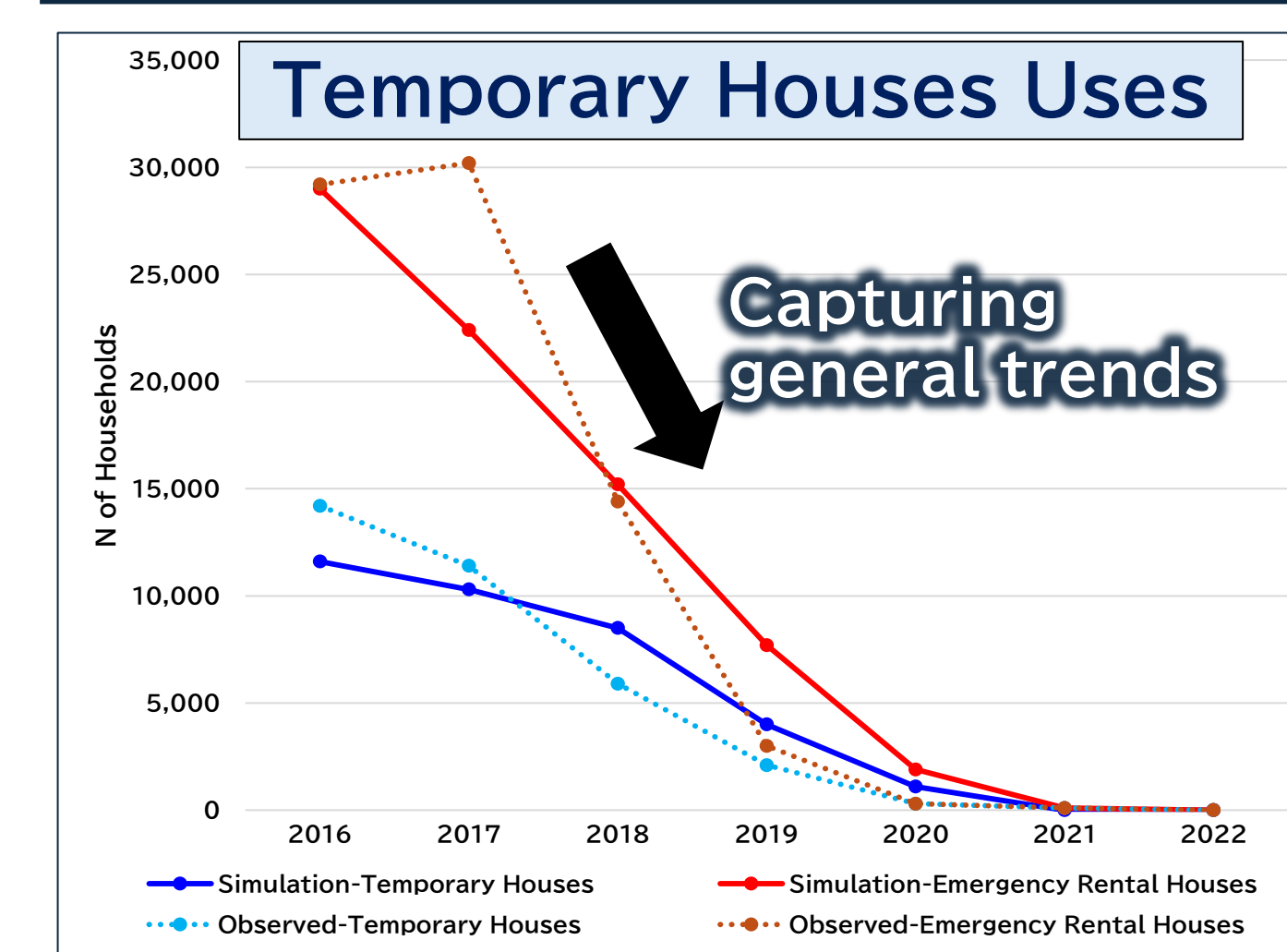
Utility Calculation

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

Demographics Accessibility

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
β	Estimated coefficients

3. 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)	0.28	0.33
RMSE (Number of Temporary Houses)	17.79	15.99

Case Study of Kumamoto EQ, 2016

1. General Trends

The model reproduced **key patterns in population change and temporary housing demand**, capturing the main direction and timing of recovery.

2. Facility Impact

Accessibility improved population simulation accuracy, though **its effect on temporary housing was limited due to predetermined emergency siting**.

3. Scale Issue

Smaller municipalities showed larger deviations because **small demographic or spatial shifts have proportionally greater impacts**.

4. Conclusion

1. Valuable Approach

Facility accessibility enhances dynamic simulation, though methods should be improved

2. Framework

Establishes a foundation for **sequential, dynamic recovery modeling**

3. Next Step

Introduce **what-if analyses to balance facility scaling with municipal financial capacity**

5. Applications | Flexible Modeling

1. Policy & Governance

Appropriate placement of temporary and public housing is vital for maintaining accessibility, and the spatial configuration of public facilities shapes the resilience of recovery. These decisions must **also align with the financial capacity of municipalities**.

2. Modeling Strength

The model supports a shift from **static recovery plans to an adaptive system that responds to changing conditions**, while also enabling assessment of how spatial interventions influence social network continuity.

3. Beyond Recovery

This approach extends to climate adaptation and flood-risk management, and **it can be incorporated into urban development** as a dual-use planning tool.

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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Materials

