Modeling Spatial Conflict through Mobility and Points of Interest: An Agent-Based Approach

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Abstract

This project explores how mobility and spatial interaction structures influence the dynamics of spatial conflict between opposing groups. Building on the classical Clifford-Sudbury model, we developed an agent-based model where agents move through a set of urban Points of Interest (POIs), and conflicts occur when opposing agents co-occupy these locations.

We systematically varied POI density and conflict probability to assess their effects on conflict intensity and group balance. The results indicate that increasing POI density reduces conflict levels, while group sizes remain stably balanced under symmetric model rules. These findings highlight the potential role of mobility and spatial design in mitigating interaction-driven tensions and promoting coexistence in urban social systems.

Limitations and avenues for future work are discussed, including the introduction of asymmetric behaviors, structured mobility patterns, and dynamic conflict consequences.

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1 Introduction

Spatial conflict between social groups is a phenomenon that has been studied in both theoretical and applied contexts, ranging from models of segregation to political competition and resource disputes. One of the earliest and most influential models in this area is the lattice-based spatial conflict model proposed by Clifford and Sudbury (1973). Their work demonstrated how local interactions between agents of different types can lead to either consensus or persistent spatial fragmentation, depending on the dimensionality of the system.

While the Clifford-Sudbury model provided valuable theoretical insights, it relied on a simplified representation of space: agents occupied fixed positions on a lattice and interacted only with their immediate neighbors. In contrast, many real-world spatial conflicts occur in dynamic urban environments where individuals are mobile and interactions are concentrated in specific shared locations, such as markets, schools, transportation hubs, and workplaces.

Recent research in agent-based modeling has begun to incorporate these aspects of mobility and spatial heterogeneity. For example, Topîrceanu (2024) demonstrated how Points of Interest (POIs) can structure interaction patterns in urban epidemic models. Similarly, the broader literature on spatial agent-based models emphasizes the importance of representing space and movement realistically (Manson et al., 2020). However, few models have extended the spatial conflict framework specifically to incorporate mobility through POIs.

This project aims to address this gap. We investigate the following research question:

> *How does individual mobility and spatial clustering around Points of Interest (POIs) affect the persistence and resolution of spatial conflicts between opposing groups?*

To explore this question, we extend the Clifford-Sudbury model by introducing mobile agents who move through a set of urban POIs. Agents interact only when they co-occupy a POI, and conflicts are modeled probabilistically. We systematically vary the number of POIs and the intensity of conflict to assess how these factors influence group coexistence and spatial balance.

2 Methodology

2.1 Model Description

We implemented an agent-based model using the Mesa framework in Python. The model simulates two opposing groups of agents (Group A and Group B) moving and interacting within a simplified urban environment. Unlike the static lattice of the original Clifford-Sudbury model, our agents are mobile and interact only at predefined Points of Interest (POIs).

At each time step, every agent selects a POI to visit. If agents from opposing groups are present at the same POI, a conflict may occur with a certain probability. The outcome of conflicts does not affect group size in this version of the model; all agents persist throughout the simulation.

2.2 Agent Behavior

Each agent is initialized with the following attributes:

- **Group**: either A or B.
- **Home location**: an initial position on a 2D grid (used internally but not displayed).
- **Mobility behavior**: agents select a POI randomly from a predefined set at each step.
- **Conflict interaction**: if agents from different groups are present at the same POI, a conflict occurs with probability p_c. Conflict events are counted for analysis but do not remove or convert agents.

2.3 Model Parameters

The key model parameters used in the experiments are shown in Table 1.

Parameter	**Values tested**
Population size (N)	20 agents (10 per group)
Number of POIs (n_{POI})	3, 5, 10
Conflict probability (p_c)	0.2, 0.5, 0.8
Grid size	20×20 cells
Simulation steps	20 steps per run
Iterations per configuration	3 runs

Table 1: Model parameters used in the experiments.

2.4 Data Collection and Analysis

We used Mesa's `DataCollector` and the `batch_run()` function to systematically run simulations across parameter combinations. For each run, we recorded:

- Total number of conflicts.
- Final size of Group A.

- Final size of Group B.

We performed batch runs varying the number of POIs and conflict probability, running each configuration 3 times to compute average outcomes.

Statistical analysis was performed using Pandas. We computed group means and produced visualizations using Matplotlib and Seaborn. The key metrics visualized include:

- Average number of conflicts as a function of POI density and conflict probability.
- Average final group sizes (Group A vs Group B) across parameter settings.
- Group dominance heatmap showing size differences between groups.

3 Results

This section presents the results of our batch simulations, with a focus on how the number of Points of Interest (POIs) and the conflict probability affect both the intensity of spatial conflict and the balance between opposing groups.

3.1 Conflict Trends

Figure 1 shows the average number of conflicts observed in each simulation setting, plotted as a function of the number of POIs and the conflict probability.

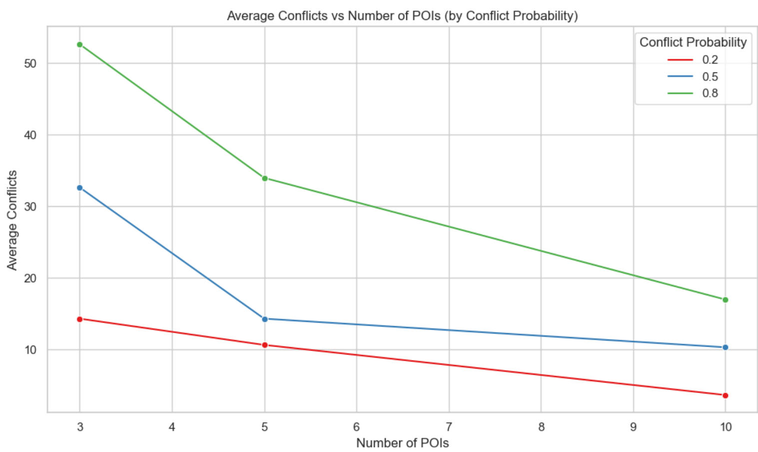

Figure 1: Average number of conflicts vs number of POIs, across different conflict probabilities.

3.2 Group Balance

Figure 2 shows the average final sizes of Group A and Group B across different POI densities and conflict probabilities.

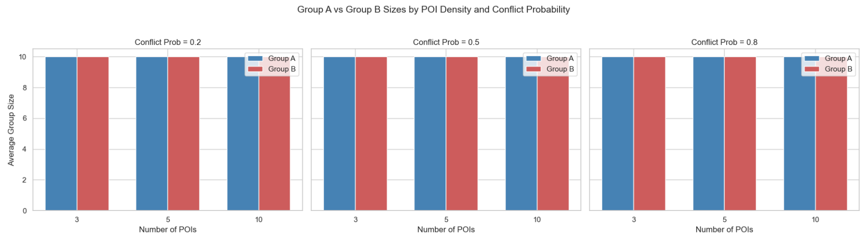

Figure 2: Average final sizes of Group A and Group B across POI densities and conflict probabilities.

3.3 Group Dominance Heatmap

Figure 3 presents a heatmap of group dominance scores, defined as the difference between the average final sizes of Group A and Group B.

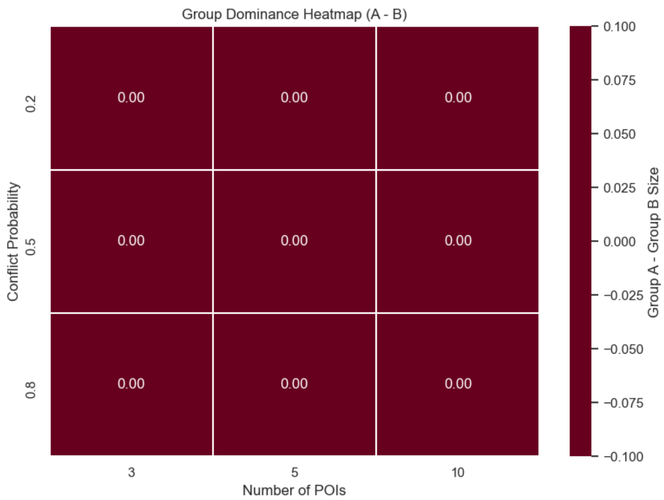

Figure 3: Heatmap of group dominance (Group A size minus Group B size) across parameter combinations.

4 Discussion

Our results provide several insights regarding the dynamics of spatial conflict under mobility-based interaction structures.

First, the clear trend observed in Figure 1 supports the intuition that increasing the number of POIs reduces the overall level of conflict. This is consistent with previous findings in the mobility literature (Topîrceanu, 2024), which emphasized that distributed points of contact can reduce the concentration of interactions and thus limit opportunities for undesirable outcomes—in that case, disease transmission; in our case, conflict events.

Second, the stable group sizes shown in Figure 2 and the near-zero dominance scores in Figure 3 suggest that POI-based mobility promotes coexistence under symmetric conditions. These results differ from the behavior of the original Clifford-Sudbury model, where lattice-based local interactions could lead to the dominance of one group in certain dimensions.

Our findings also align with broader theoretical perspectives in the spatial ABM literature (Manson et al., 2020), which argue that incorporating realistic spatial structures—such as POIs—can influence emergent system behavior. In our case, the introduction of mobility and heterogeneous interaction points appears to have balanced the opportunity structure between groups, preventing systematic dominance.

5 Limitations

While our model provides useful insights into how mobility and POI density influence spatial conflict dynamics, several limitations should be acknowledged.

First, the model assumes completely symmetric behavior between the two groups. Agents have identical mobility patterns, conflict rules, and no intrinsic behavioral differences apart from group identity.

Second, the current implementation of conflict interactions is purely probabilistic and does not affect agent populations.

Third, the POI selection mechanism is randomized at each step, with agents selecting POIs uniformly at random.

Finally, the spatial environment used in the model is a simple toroidal grid with uniformly distributed POIs.

6 Conclusion

This project explored how mobility and interaction through Points of Interest (POIs) influence the dynamics of spatial conflict between two opposing groups.

Our results show that increasing POI density reduces conflict, while symmetric interaction rules promote stable coexistence between groups.

These findings highlight the importance of mobility and spatial design in shaping conflict dynamics and suggest promising directions for future extensions.

References

[1] Clifford, P. and Sudbury, A. (1973). *A model for spatial conflict.* Biometrika, 60(3), pp.581–588.

[2] Topîrceanu, A. (2024). *A Spatial Agent-Based Model for Studying the Effect of Human Mobility Patterns on Epidemic Outbreaks in Urban Areas.* Mathematics, 12(17), 2765.

[3] Manson, S. et al. (2020). *Methodological Issues of Spatial Agent-Based Models.* Journal of Artificial Societies and Social Simulation, 23(1), Article 3.

[4] De Luca, G., Dittrich, P., and Broekema, W. (2022). *A Literature Review on the Usage of Agent-Based Modelling to Study Policies for Managing International Migration.* Social Sciences, 11(8), 356.