Modeling and Simulation

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Project: Evacuation

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Introduction

- Problem Statement:

How to better manage the pedestrian evacuation of a population on a beach in a tsunami context?

Introduction

Descriptions

- Only **10%** of the population is aware of the threat at beginning.
- A person observing someone evacuating (at 10m) have 10% of evacuating in turn.
- The simulation ends when the tsunami strikes or people are all evacuated.

Introduction

Extensions

- **Extension 1**: **10%** of the informed people known the location of shelter, 90% will wander in the roads to **inform the others** and seek for the shelter.
- **Extensions 2**: Support **multiple modalities** of evacuation (car, motocycle, walking) and the possibility of blocking roads.
- **Extensions 3**: Experiment with **different strategies** of informing the threat: those furthest from shelter, those closest to the shelter, or randomly selected.

Introduction

Note that in this model, flooding will not be modeled by itself, **just the behaviour of residents in the face of the threat.** The goal is to inform and save as much people as possible in different informing strategies.

Implementation

Base model includes these species:

- **Inhabitant**: Represented as people.
- **Buildings**: Represented as static objects where people can stay or move to for shelter.
- **Roads**: Represented as paths that people can use to move around the area.
- **Shelter**: Represented as the largest building in the area where people can evacuate to.

Implementation

My extension:

- **People don't revisit the same place they have been before**, so they will not wander around the same place, to increase the chance of finding the shelter.

Implementation

Inhabitant

```
reflex find_shelter when: target = nil and is_evacuating {
    if (shelter distance_to self < 1#m) {
        number_evacuted_people <- number_evacuted_people + 1;
        total_evacuation_time <- total_evacuation_time + time;
        do die;
        return;
    }

    building target_building <- known_shelter ? shelter : nil;
    if (target_building = nil) {
        if (shelter distance_to self < 20#m) {
            target_building <- shelter;
        }
        target_building <- one_of((building - visited_buildings) where each.is_safe);
    }
    visited_buildings << target_building;
    target <- any_location_in(target_building);
}
```

Implementation

Traffic congestion

```
species road {

    float capacity  <- 1 + shape.perimeter/10;
    float total_traffic_weight  <- 0.0 update: sum((inhabitant at_distance 1) collect each.traffic_weight);
    float speed_rate <- 1.0 update:  exp(-total_traffic_weight/capacity) min: 0.1;
```

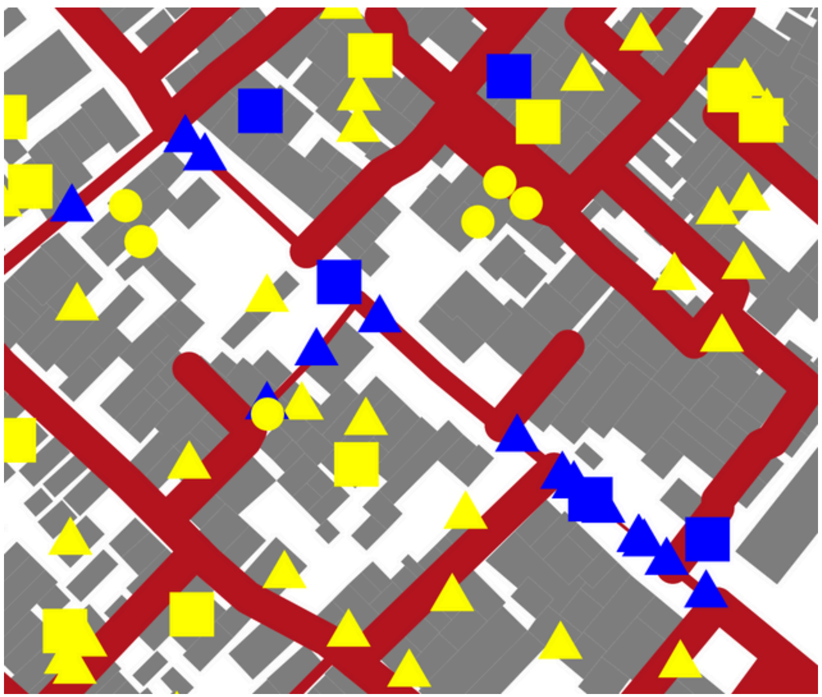
Implementation

Traffic congestion

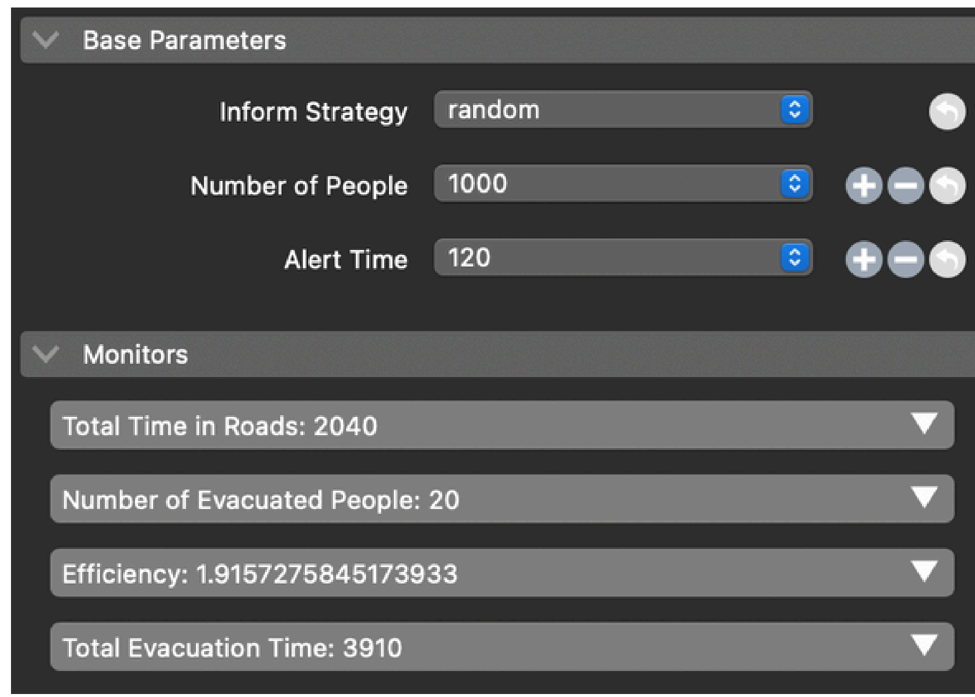
```
if (initial_inform_strategy = "random") {
    write("Strategy: Random");
    ask nb_informing_people among inhabitant {
        do evacuate();
    }
} else if (initial_inform_strategy = "furthest") {
    write("Strategy: Furthest");
    ask nb_informing_people first (inhabitant sort_by -distance_to(shelter, each)) {
        do evacuate();
    }
} else {
    write("Strategy: Closest");
    ask nb_informing_people first (inhabitant sort_by distance_to(shelter, each)) {
        do evacuate();
    }
}
```

Experiments

Multiple evacuate mobilities



Model parameters



Metrics

The **Total Time in Roads** can be calculated by the formula:

$$\text{Total Time in Roads} = \sum_{i=1}^{N} \text{T\_roads}_i$$

$$\text{T\_roads}_i = \begin{cases} \text{t\_evacuated}_i - \text{t\_informed}_i & \text{if the inhabitant reaches the shelter} \\ \text{t\_current} - \text{t\_informed}_i & \text{if the inhabitant is still on the road} \end{cases}$$

$$\text{Efficiency} = \frac{\text{Total Evacuation Time}}{\text{Total Time in Roads}}$$

My proposed formula

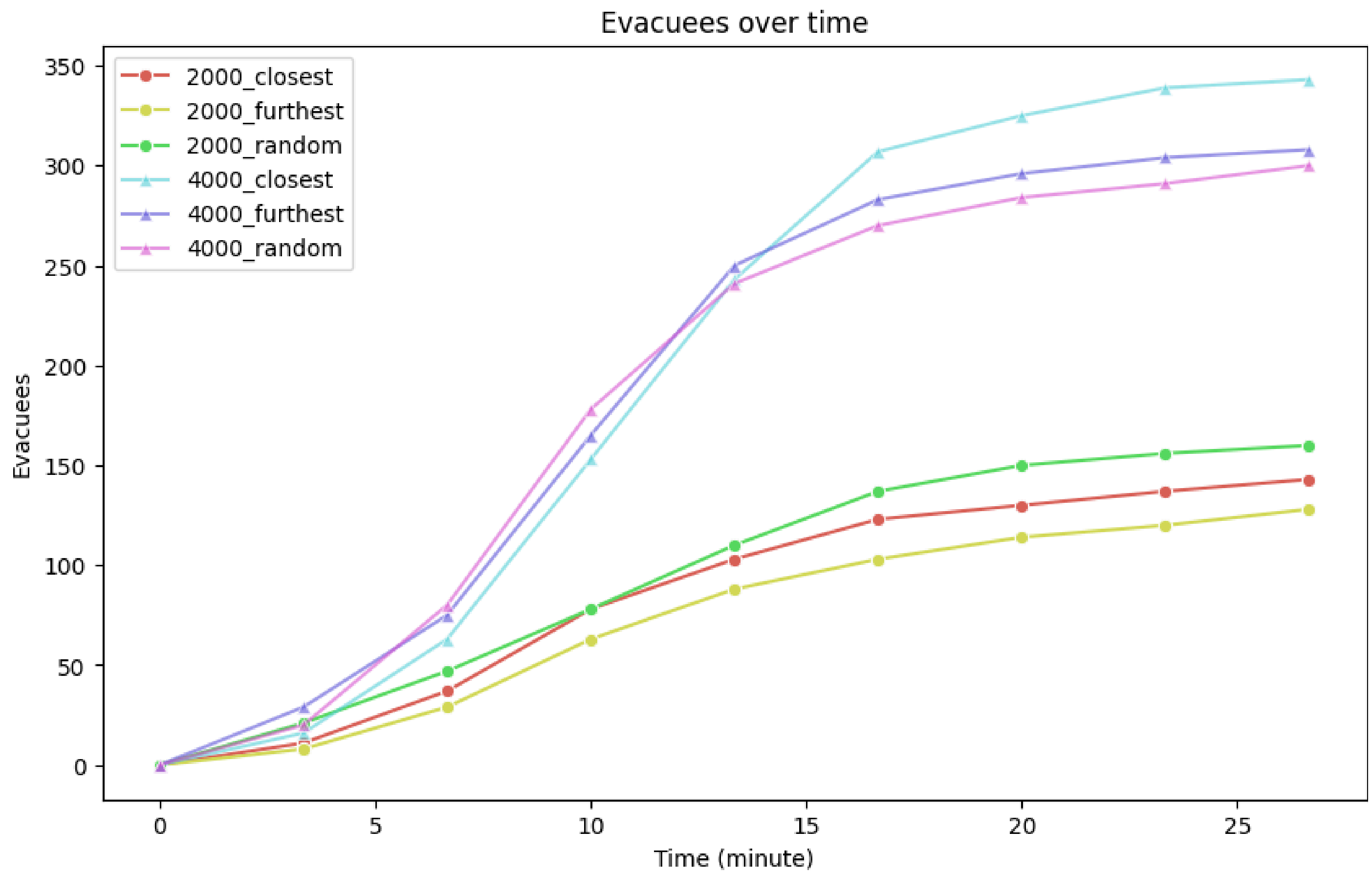
$$\text{Efficiency} = \frac{\text{Total Evacuated people} \times \text{Alert Time}}{\text{Total Time in Roads} + 1}$$

GIS Data

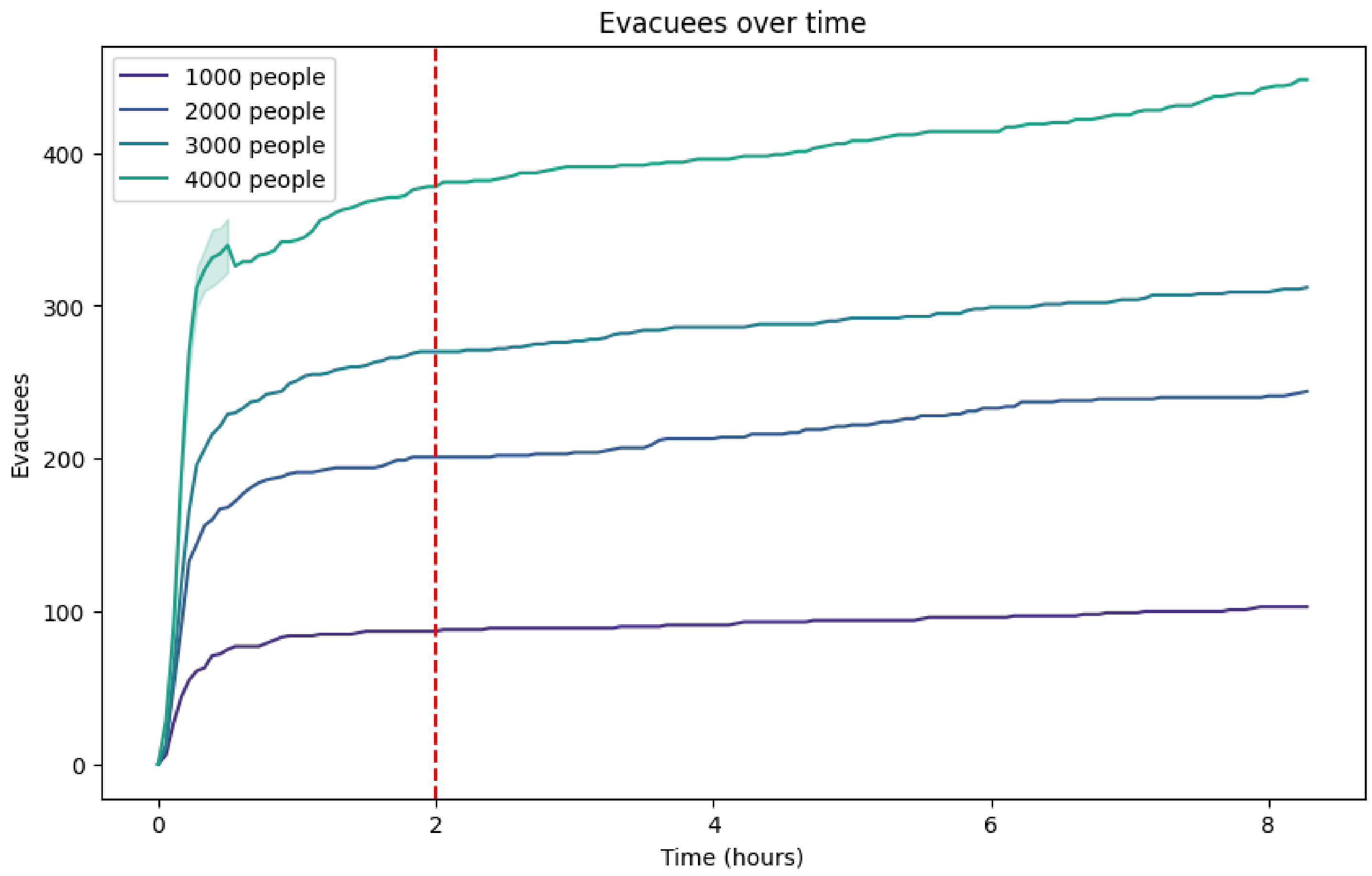
- The largest building is the green one.
- Changing the shelter from the green one to red one increases the change of saving people by 20%.
- Eliminate the lucky factor involved in finding the shelter.

Evacuees over time

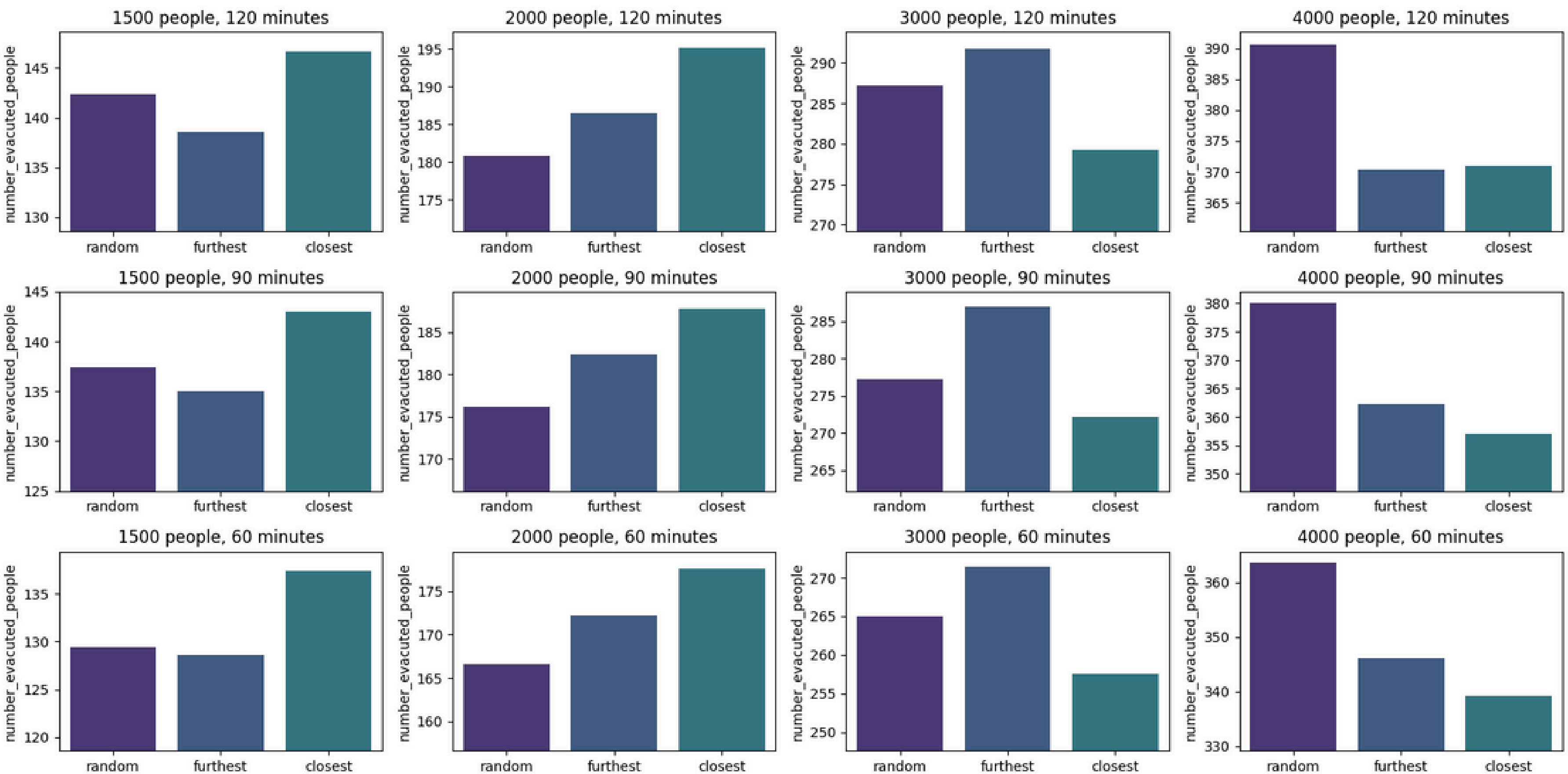
Study about traffic congestion



Alert time findings

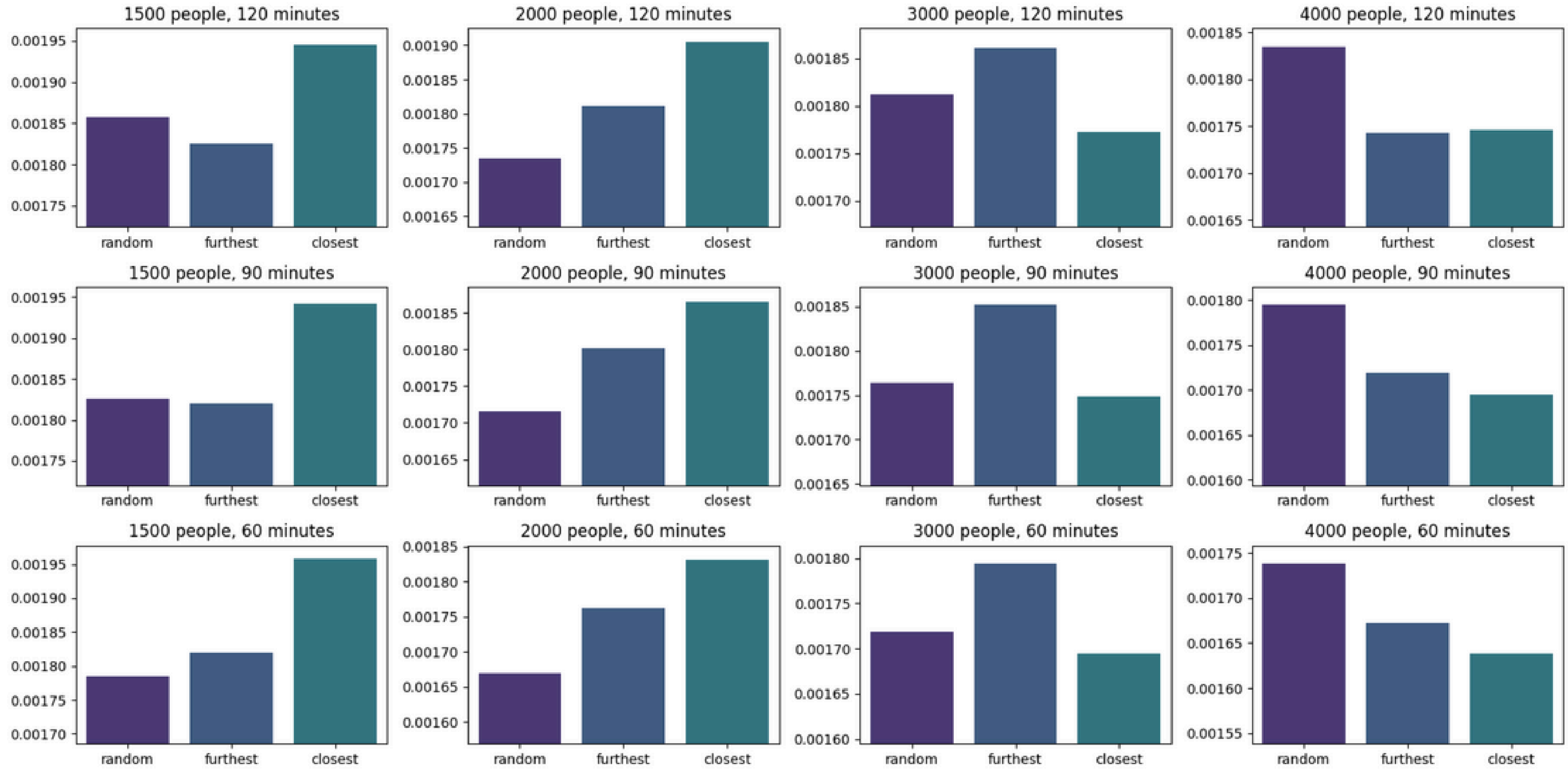


Most effective strategy



Total evacuated people

Most effective strategy



Efficiency

Conclusion

How to better manage the pedestrian evacuation of a population on a beach in a tsunami context?

- With the smaller number of people, the **closest** strategy is the best choice.
- With the larger number of people, the **random** or **furthest** is the best.

Conclusion

What I've done?

- Built an agent-based model of people evacuation in a tsunami context
- Implemented 3 extensions
- Identified **the most critical time range** during which the evacuation process is most impacted.
- **Evaluate the efficiency of the strategies** using batch exploration.

Conclusion

Future extensions

- Add more interactions between the inhabitants to tranfer the knowledge of threat
- More diversity in mobilities and behaviors
- More GIS data

Thank you