Vulnerable and Resilient cities: Modeling the Response to Urban Disasters

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Context

A rise in magnitude, frequency and complexity of urban disasters / catastrophes:

Terror attacks (9/11, suicide bombings)

Natural disasters (tsunami, earthquake)

Urban disturbances (major traffic accidents, riots)

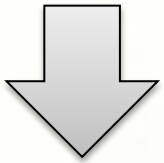
Simultaneous events (earthquake & tsunami in Japan)

Current Literature

- Extensive literature on cities' vulnerability and resilience to shocks:
  - Risk assessment – vulnerability and effects.
  - Increasing resilience – decision making & engineering.
  - Studying effects – urban equilibrium, effects on population and business.
- Focus on the macro level.
- Post active research.

Research issues

How can cities increase their resilience and decrease their vulnerability to urban disasters?



- What kind of effects do different temporary shocks have on cities?
- Which effects, if any, are permanent?
- Do cities bounce back to the same or a new equilibrium?
- How fast do cities bounce back to equilibrium?

The Urban Response Problem

- A disturbance to urban equilibrium:
  - A disaster as a temporary disruption of urban life.
- Flexible response vs. inflexible environment:
  - The city as a result of previous fixed investments.
  - Responding to different and evolving threats.
- Bouncing back:
  - Temporary disturbance can cause permanent effect.
  - Longer response times can increase the probability to long term results.

The Needs

- Identification of vulnerable spots in the urban fabric.
- Minimization of response times.
- Minimization of impacts.
- Real time management of different forces and different responses.
- Getting pre-active.

Dynamic Simulation Tool for Response to Urban Disasters

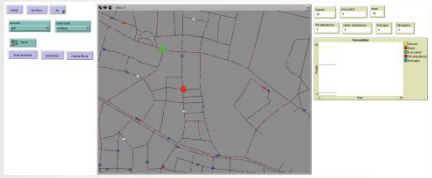
Objectives:

- Real time management of events:
  - Incorporating different intervention forces and protocols.
  - Flexible response to different types and sizes of events.
- Learning and training abilities:
  - Decision making training.
  - User controlled parameters.
  - Re-run abilities.
- Understanding results and impacts:
  - Statistical outputs.
  - Cartographic outputs.

Tool's Characteristics:

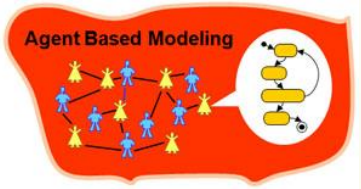
- Generic.
- User friendly.
- Integrating existing components (e.g. GIS, urban databases).
- Applicable in both micro and macro types of urban spaces.
- Multiple responses to threat ability.

Framework

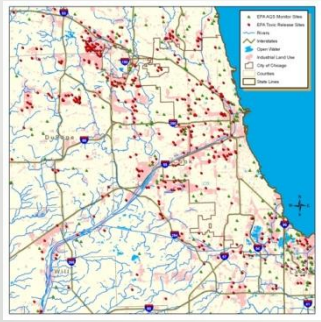


User Interface

Agent Based Simulator



Work space



GIS

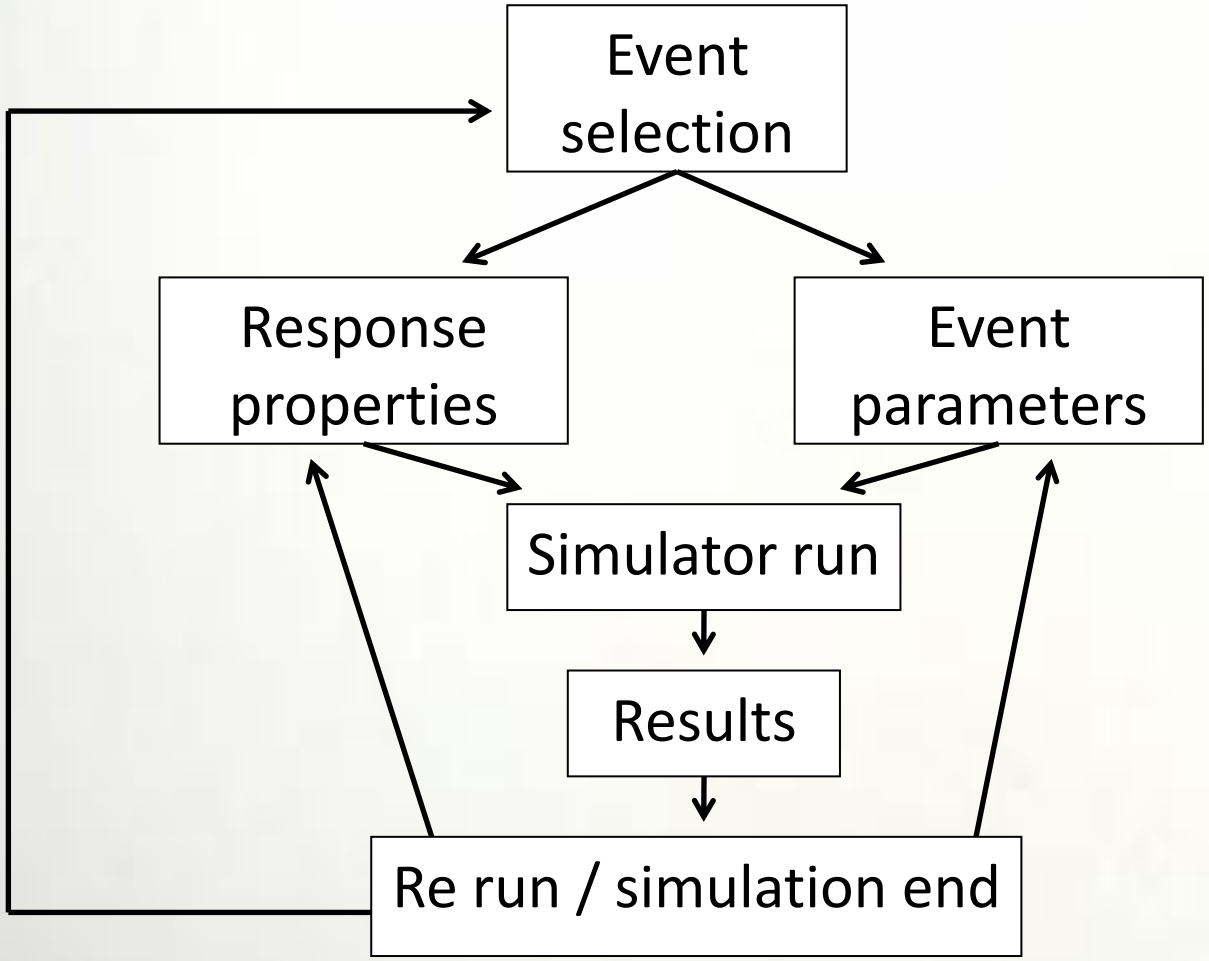
Database

Simulation's characteristics:

- Agent based simulation:
  - Different sets of agents with different protocols.
  - Agents are not only intervention forces (e.g. civilians, casualties).
- User Controlled:
  - Definition of location.
  - Situation of evacuation points.
  - Allocation of units.
- Generation of impacts according to user parameters:
  - Civilians' behavior simulation.
  - Generation of infrastructure overloads.
  - Evacuation times and efficiency.

* The movement of the agents in the model and the GIS layers in use are based on Nick Malleson's RePast City2 model.

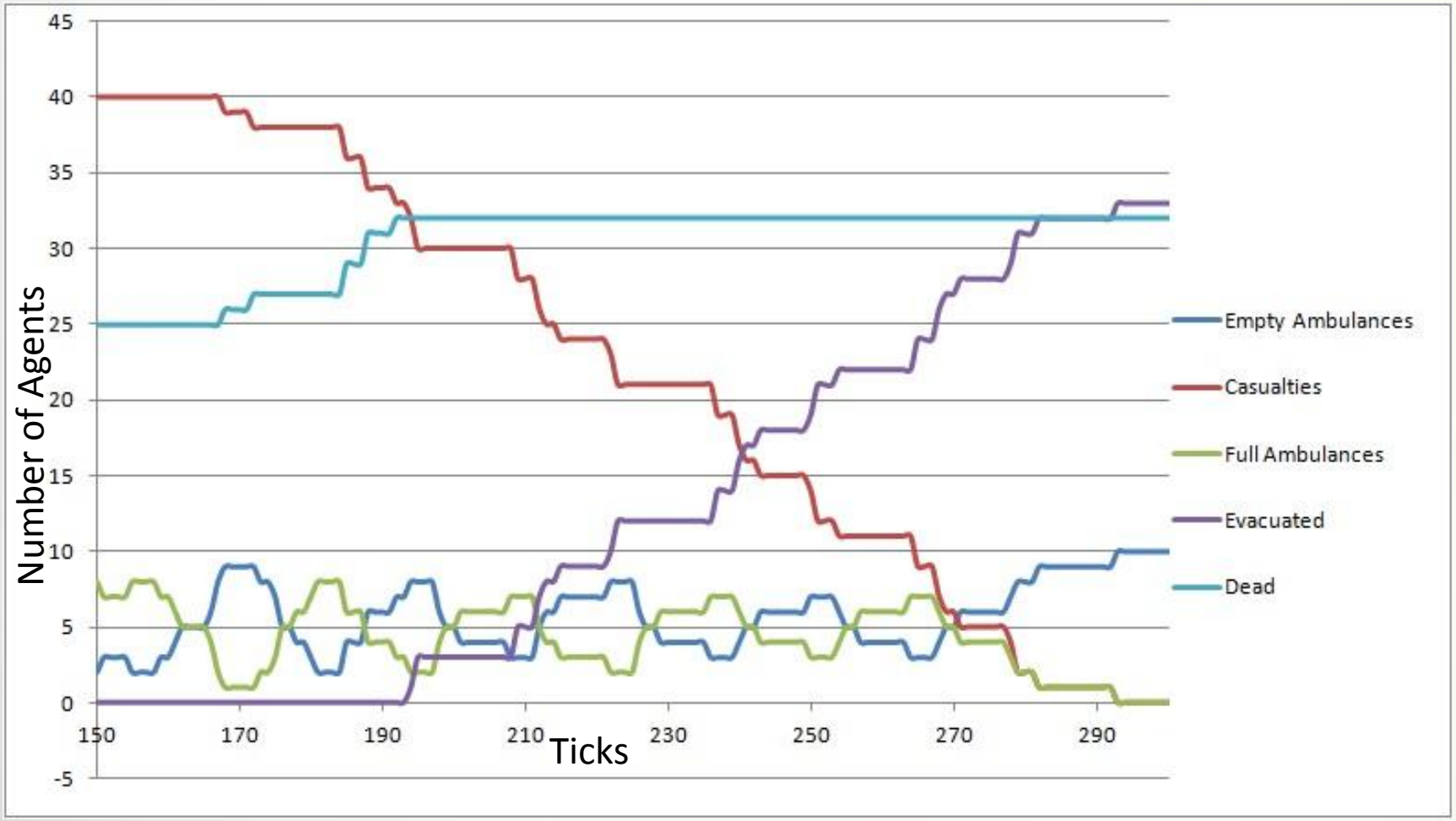
Interface Outline



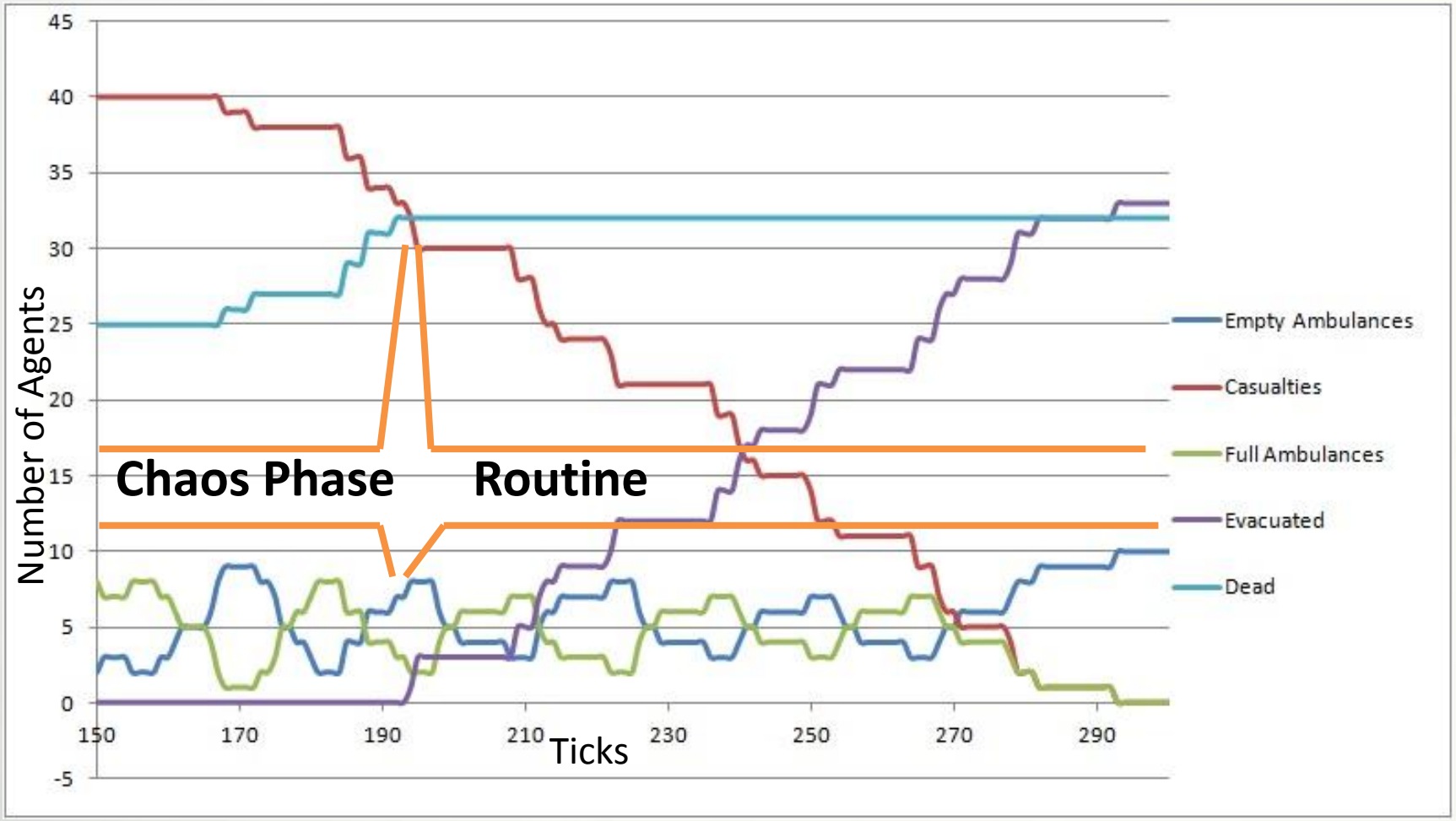
Outputs

- Outputs for decision making assistance:
  - Maps.
  - Graphs.
  - Summary tables.
- Re-run:
  - Different parameters.
  - Add event:
    - Secondary event.
    - Multiple simultaneous events scenario.
- End of simulation.

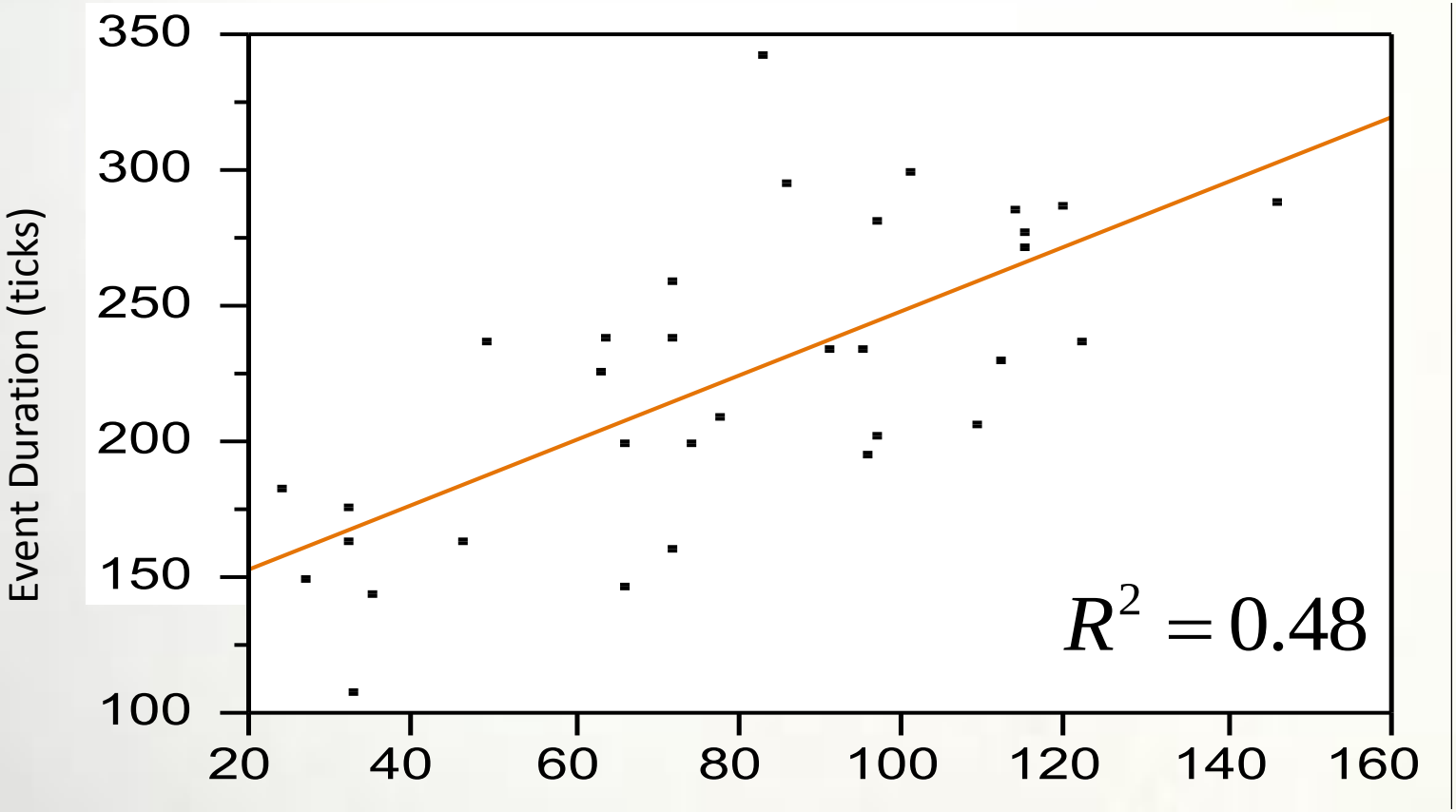
Scenario 1 – Static & Short Duration Chaos phase and event length



Scenario 1
Chaos phase and event length

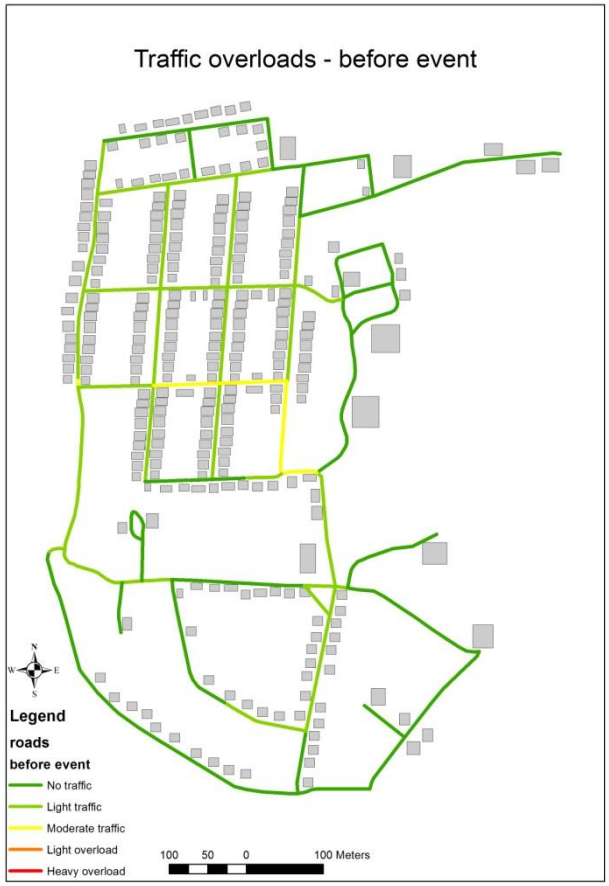


Scenario 1
Event Duration by Chaos Phase Duration



Number of runs = 33

Scenario 1
Average Change in Traffic Volume



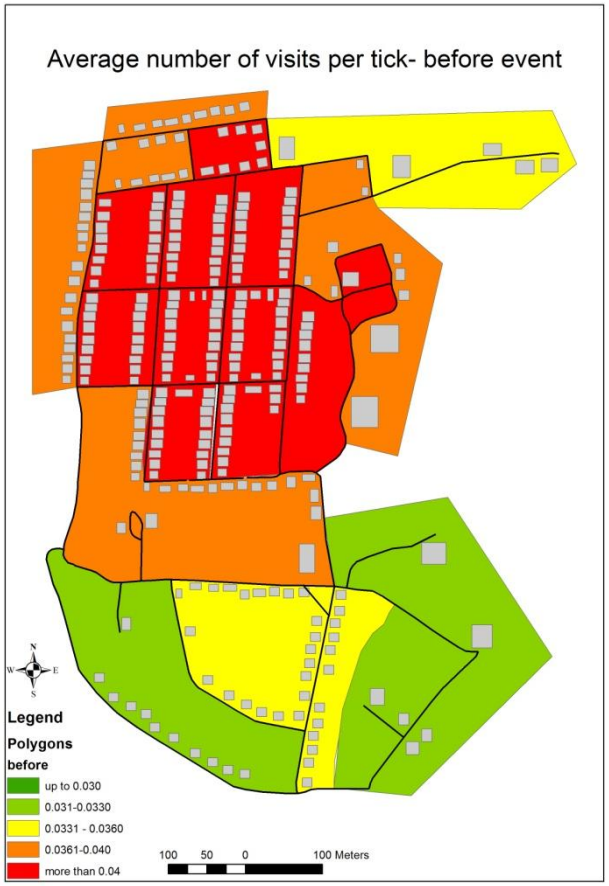
Average number of civilians on road per tick, per meter

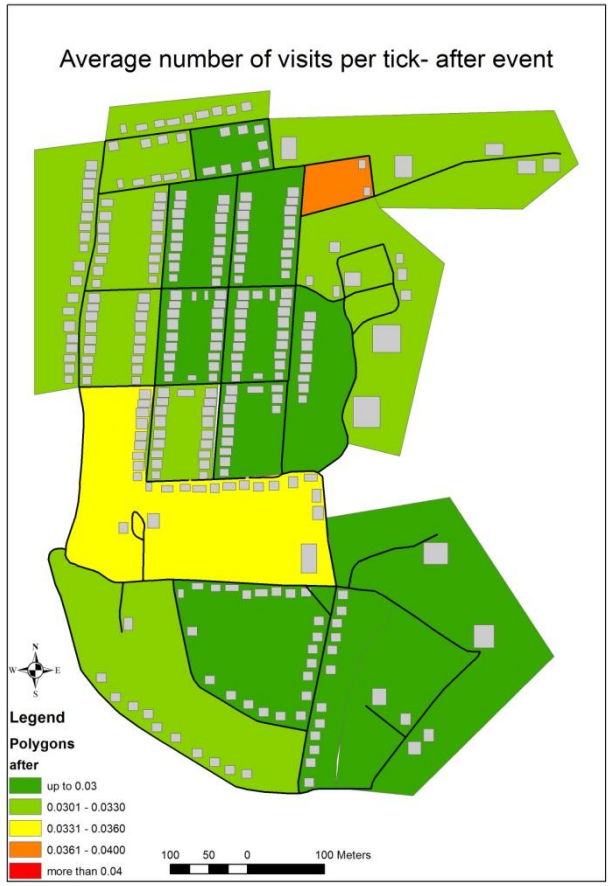
Number of runs = 50

Scenario 1
Traffic Volume Difference

Number of runs = 50

Scenario 1
Average Change in Visits

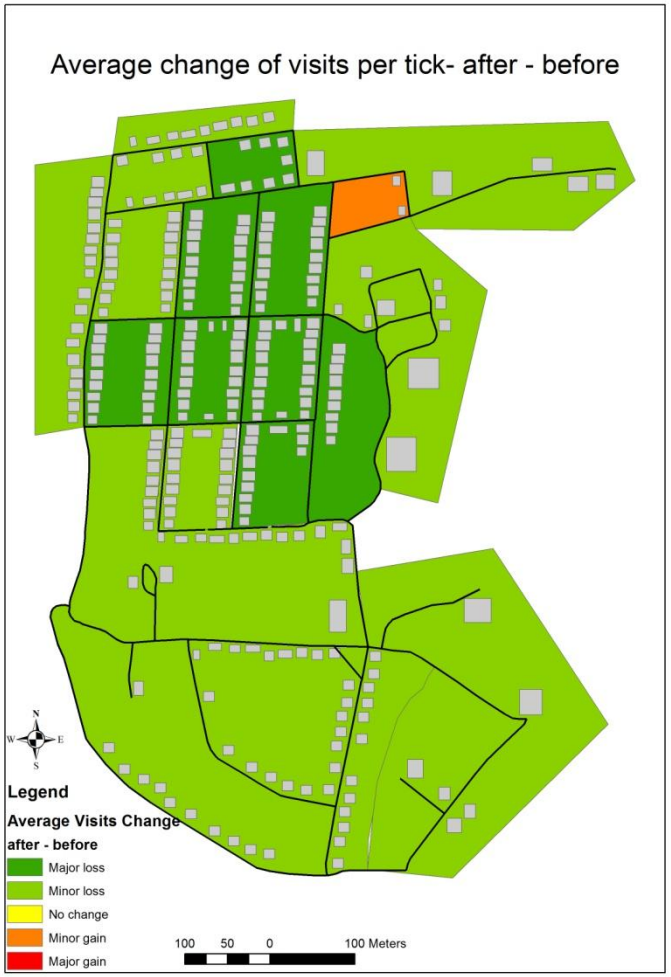




Average of average number of visits per house inside polygon, per tick

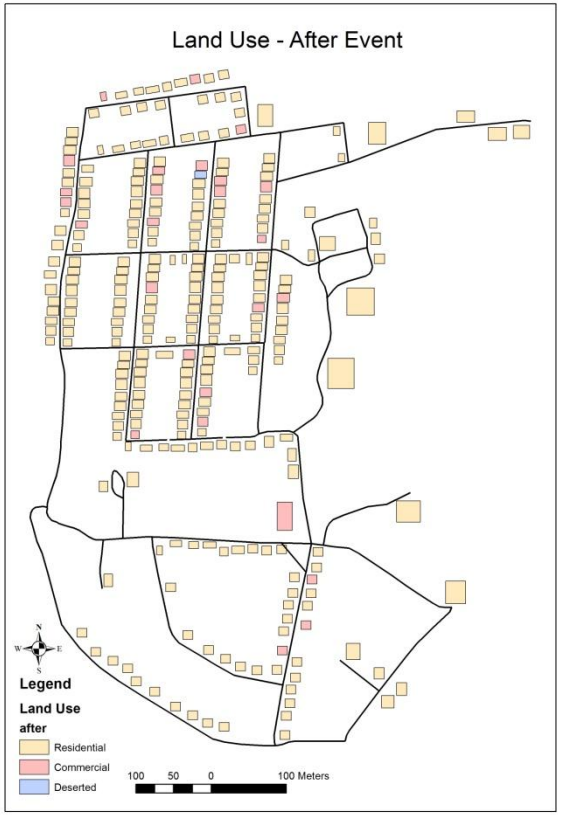
Number of runs = 50

Scenario 1
Average Difference in Number of Visits



Number of runs = 50

Scenario 2 –Static Long Duration Event
Change in Land Use



Number of runs = 50

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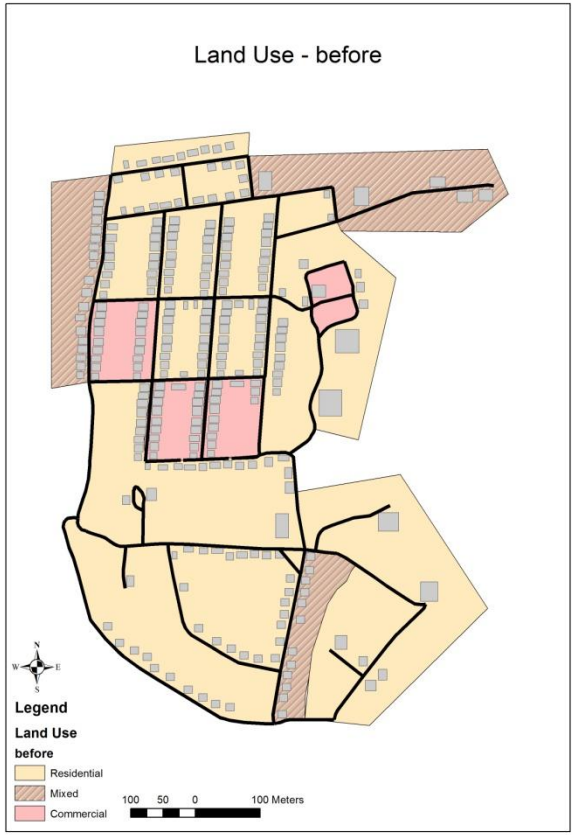
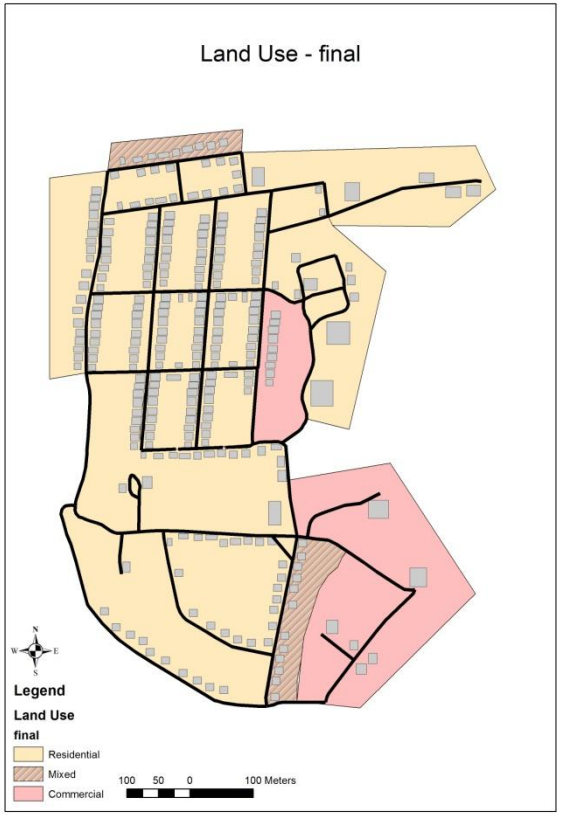
Change in Land Use



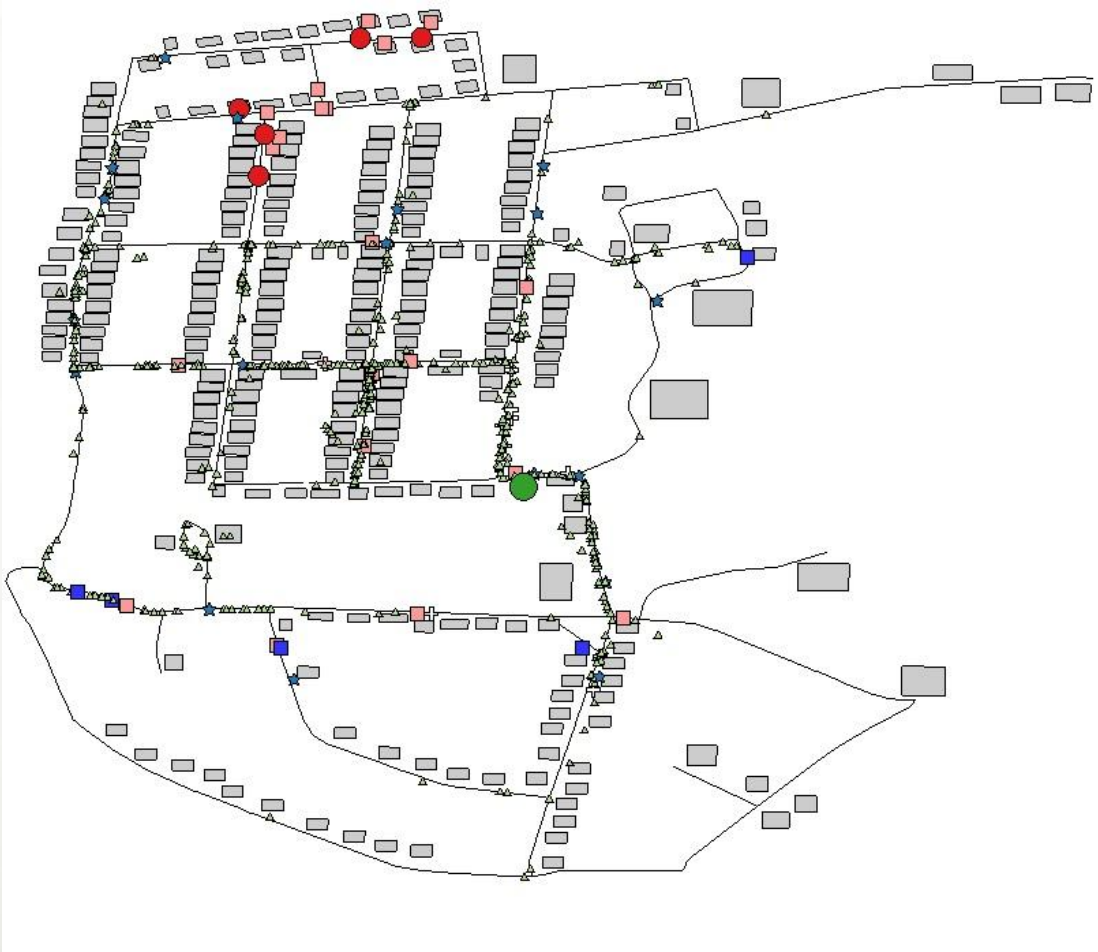


Number of runs = 50

Scenario3 – Dynamic Short Duration Event Shooting Spree

- 5 terrorists moving randomly and shooting on sight.
- Choice between 2 responses regarding non-mobile population (the elderly, children and toddlers):
  - Allocation of a police unit to each relevant institute.
  - Evacuation of population to a designated shelter.
- 60 runs for each alternative.

Scenario3 – Dynamic Short Duration Event Shooting Spree



Scenario3 – Dynamic Short Duration Event Shooting Spree

- Results:
  - No significant difference in the number of runs in which non-mobile population was hurt (16.67%, 23.33%).
  - No significant difference in the percent of non mobile population that was hurt (16.27%, 15.68%).
  - Significant difference in the average number of total casualties (199.6, 301.02 p Value < 0.001).

Conclusions

- The duration of the chaos phase has a major effect on the total duration of the event.
- Roads prone to overloads are inner city roads and connecting roads.
- A dispersal of activity can be seen during an event.
- There's a slow return towards a similar equilibrium.
- Commercial uses tend to disperse and there is a chance of a shift in CBD location.
- Response alternatives may have considerable side effects.