The analysis/prediction of burglaries and use of agent based simulation for crime reduction

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Outline

Project Background

Agent-based modelling

Burglary simulation

Results

Future work

Project Background

- Started as a PhD/MSc Project
  - "Build and agent-based model which we can use to predict rates of residential burglary"
- Individual-level (person, household).
- Predict effects of physical/social changes on burglary.
- Ongoing relationship with Safer Leeds CDRP
  - Provide essential data.
  - Expert knowledge supplement criminology theory.

Why Model?

Exploring theory

Simulation as a *virtual laboratory:*

Linking theory with crime patterns to test it.

Making predictions

Forecasting social / environmental change.

Exploring aspects of current data patterns through prediction.

Why burglary?

Spatially patterned therefore predictable(?)

Spatio-temporal variations key to understanding system.

System with history of qualitative theorisation that needs testing.

Good data (geocoding, reporting).

Geography / environment is important

Static targets

Relatively high levels in Leeds (historically)

Why difficult?

Extremely complex system:

- Attributes of the individual houses.
- Personal characteristics of the potential offender.
- Features of the local community.
- Physical layout of the neighbourhood.
- Potential offender's knowledge of the environment.

Traditional approaches often work at large scales, struggle to predict local effects

- "Computationally convenient".
- But cannot capture non-linear, complex systems.

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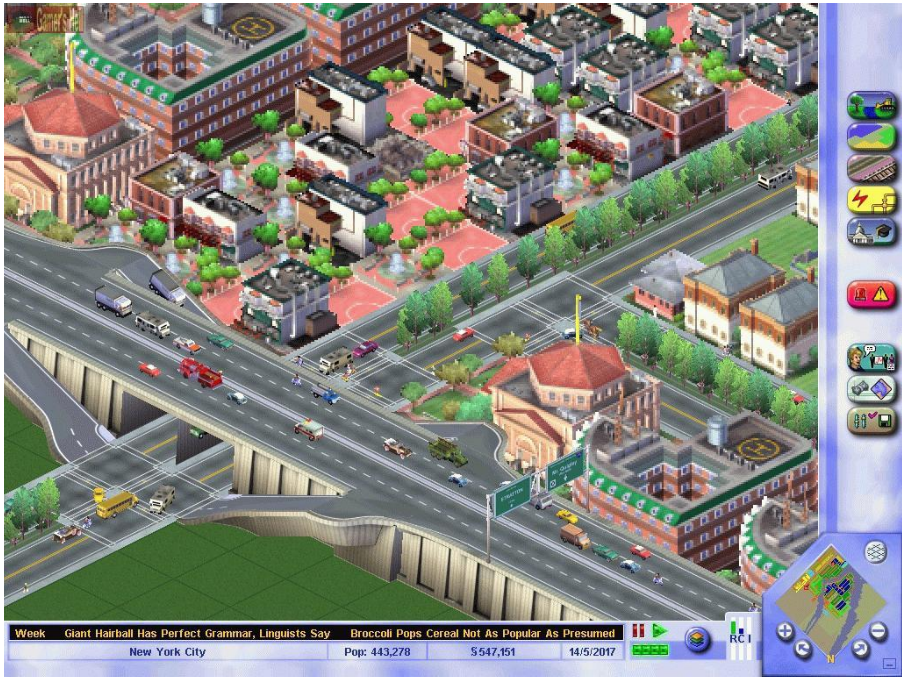
Individual-level Crime Modelling: Agent-Based Models (ABM)

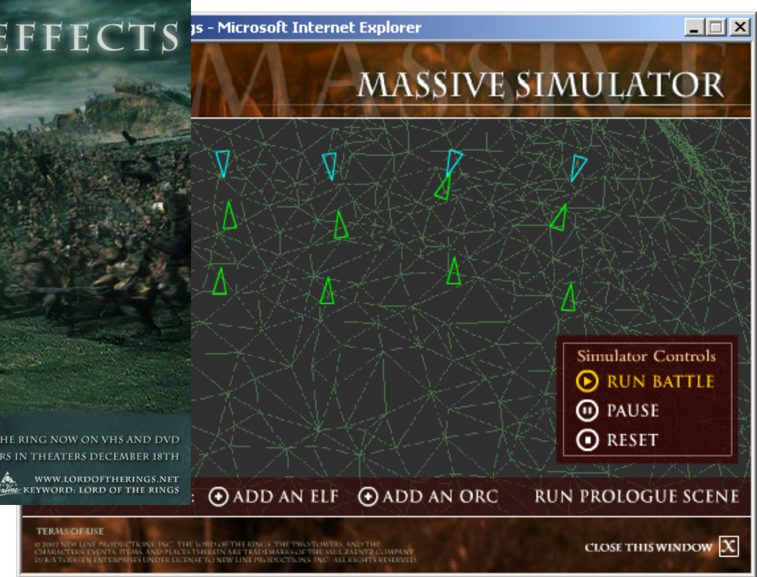
Autonomous, interacting agents

Represent individuals or groups

Situated in a virtual environment

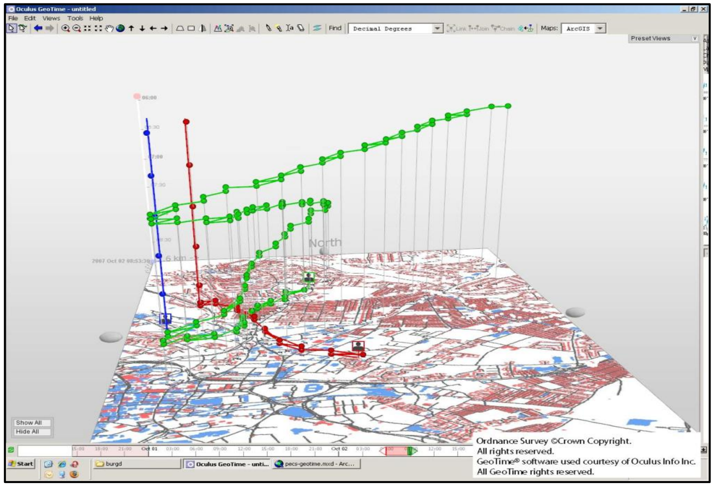
… example ABMs …





ABM Process

1. Create an urban (or other) environment in a computer model.
2. Stock it with buildings, roads, houses, etc.
3. Create individuals to represent offenders, victims, guardians.
4. Give them backgrounds and drivers.
5. See what happens.

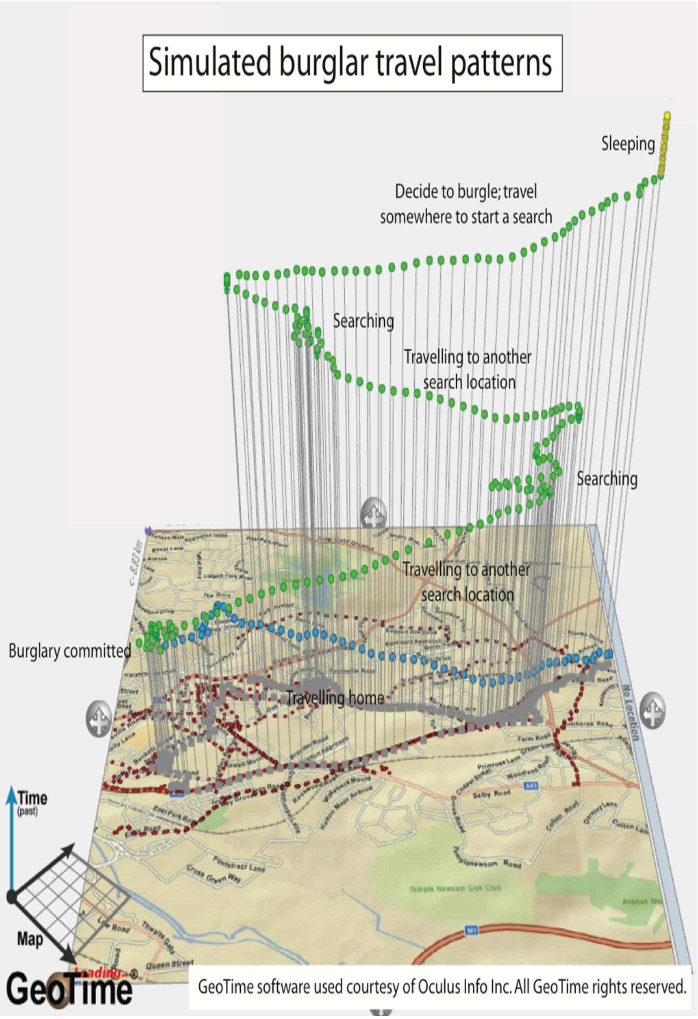


Much better understanding of relationship between:

- Individuals (offenders, victims, and guardians).
- Their routines.
- Street-level environment.
- Perceptions of urban areas.

Inherently spatial and dynamic.

Appeal of ABM



More "natural" for social systems than statistical approaches

Individual decision making is the fundamental driver of social systems

Can include physical space / social processes in models of social systems

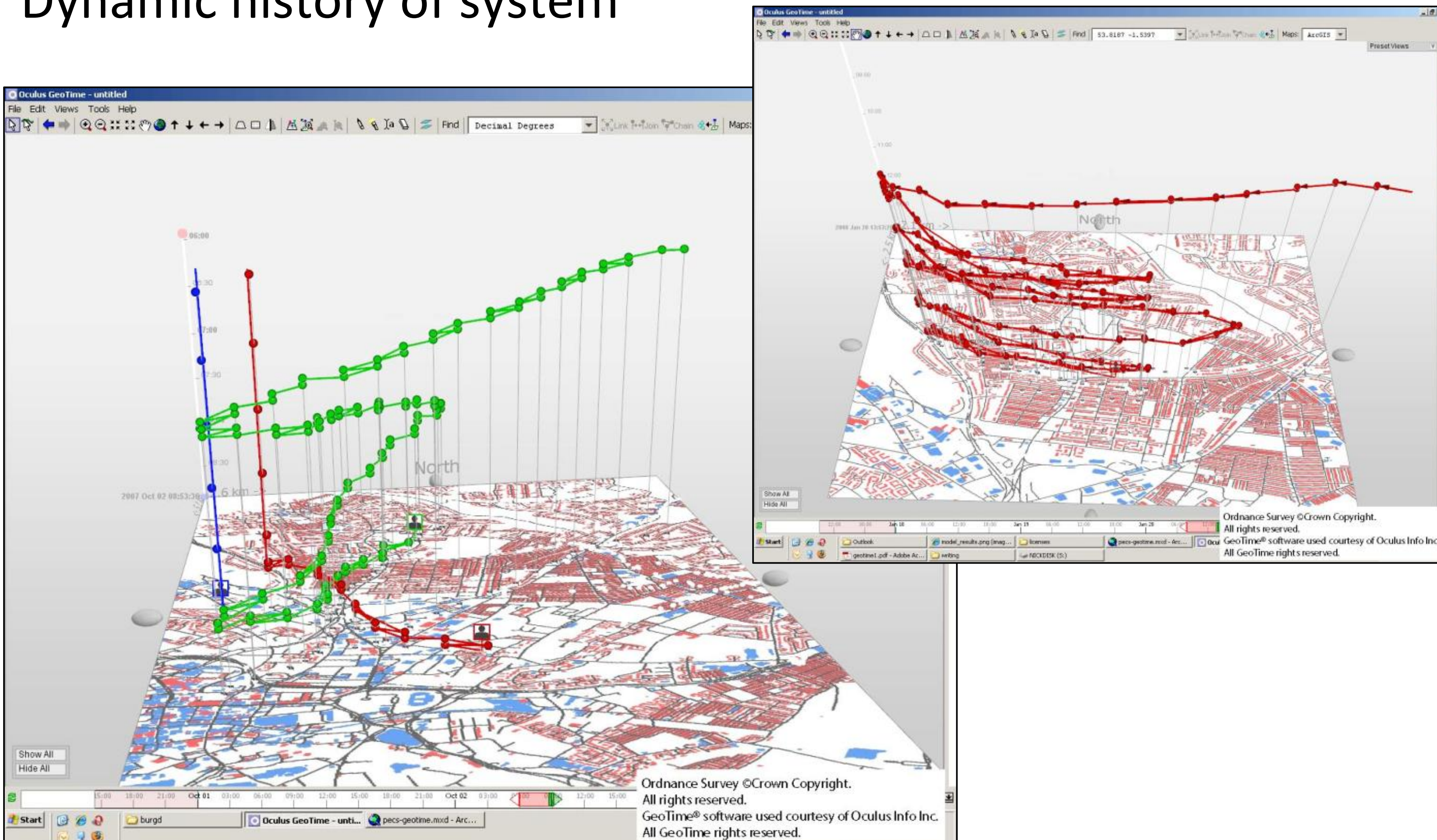
Designed at abstract level: easy to change scale

Bridge between verbal theories and mathematical models

Dynamic history of system

Appeal of ABM (ii)

Dynamic history of system



Disadvantages of ABM

Single model run reveals a theorem, but no information about robustness.

Sensitivity analysis and many runs required.

Computationally expensive.

Small errors can be replicated in many agents.

Modelling “soft” human factors.

Equifinality

Over-complication / complexity (?)

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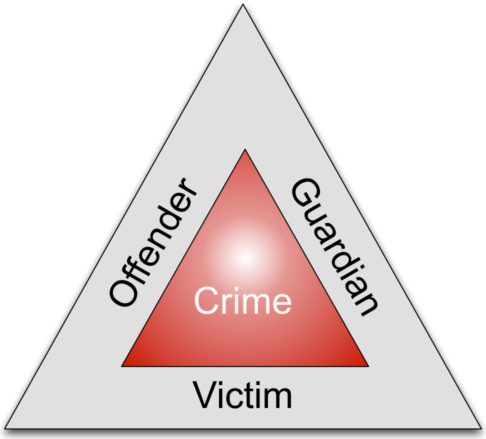
Theoretical Background

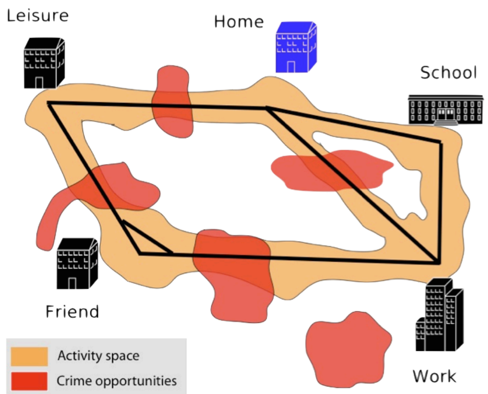
Crime are local in nature

Environmental Criminology theories emphasise importance of:

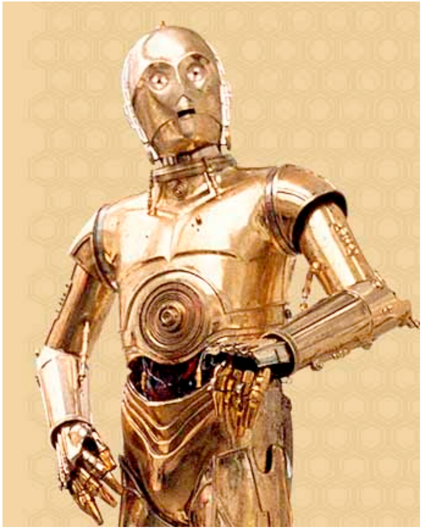
- Individual behaviour (offenders, victims guardians
- Individual geographical awareness
- Environmental backcloth



Routine Activity Theory



Geometric Theory of Crime



Rational Choice Perspective

Basic model

Real geographical environment (most recently S.E. Leeds)

Offenders allocated homes and daily routines.

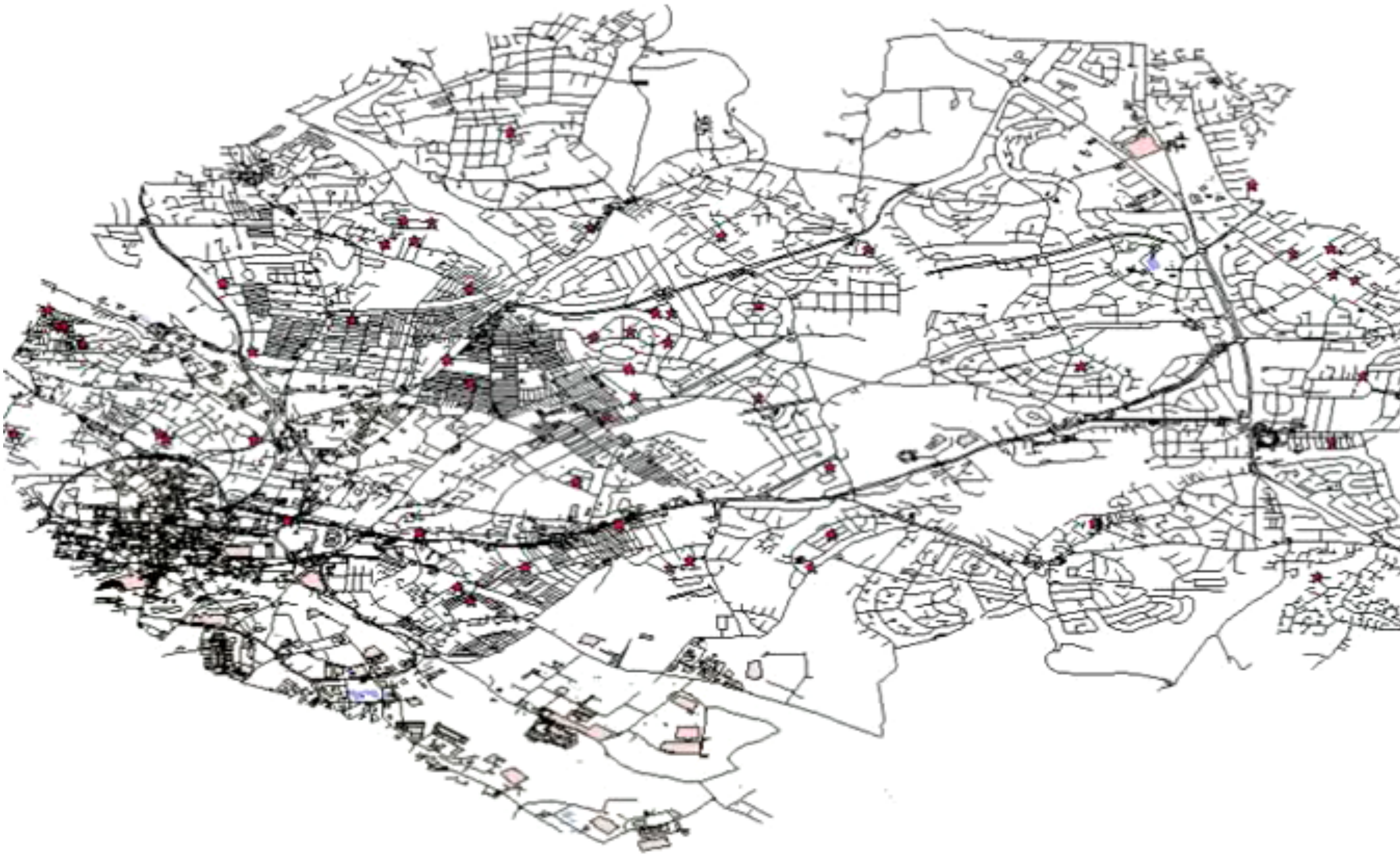
Victims communities allocated from census.

Offenders have drives including income generation.

One way to raise income is burglary.

They identify target locations, then search for appropriate and appealing houses.

Basic model



Environment

Roads and public transport

Ordnance Survey data

House/garden geometry

Ordnance Survey data

Community strength and demographics

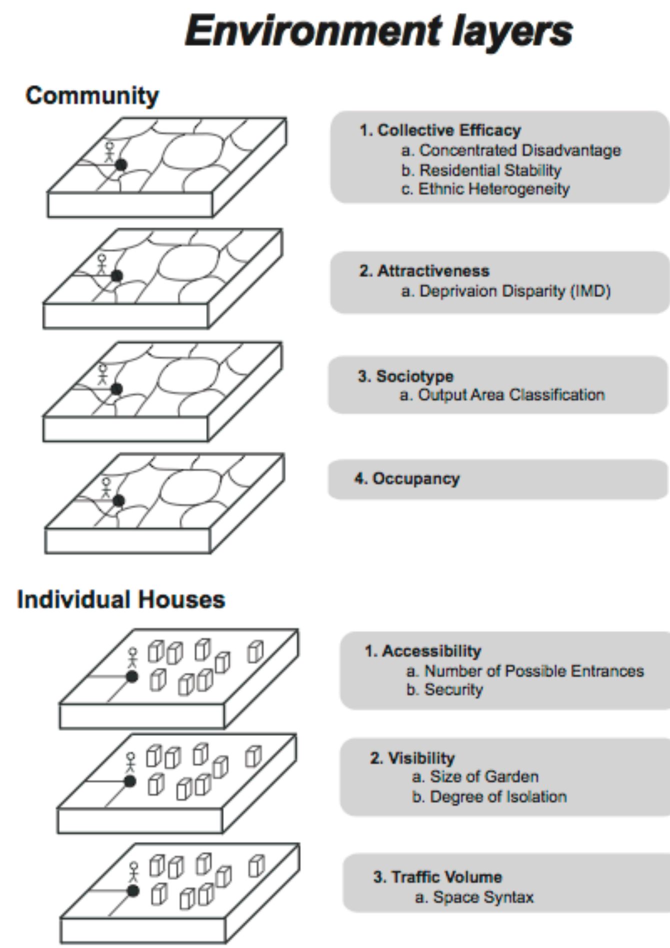
Indices of deprivation / census data

Building type

National Land Use Database division into broad types, including commercial / social locations

Drug dealer locations

Real, but randomised within postcode area

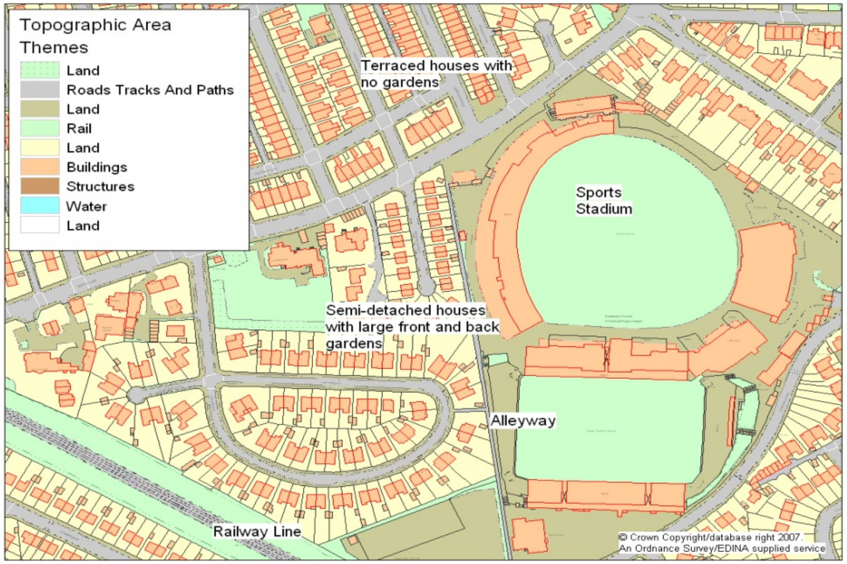


Victims – Houses

Physical attributes:

- Garden size
- Visibility to neighbours
- Road traffic volume
- Number of neighbours

Aim to build realistic picture of physical environment



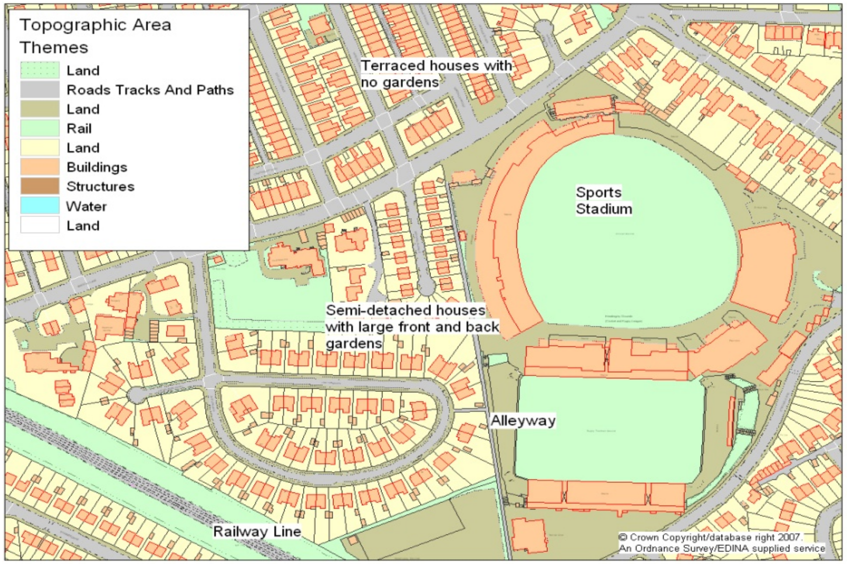
MasterMap Topographic Area Layer

Victims – People

Social attributes:

Houses take on demographic characteristics from their census Output Areas (~100 households in each area).

Community demographics include economic variables like careers, levels of unemployment, retirement, etc.



MasterMap Topographic Area Layer

Also include probabilistic assessments of occupancy for houses in the area at different times of day (based on numbers of employed, unemployed, retired, and students and lifestyle of these groups over the course of a day).

Offenders

Locations

Real offender numbers allocated randomly to households in their real postcodes.

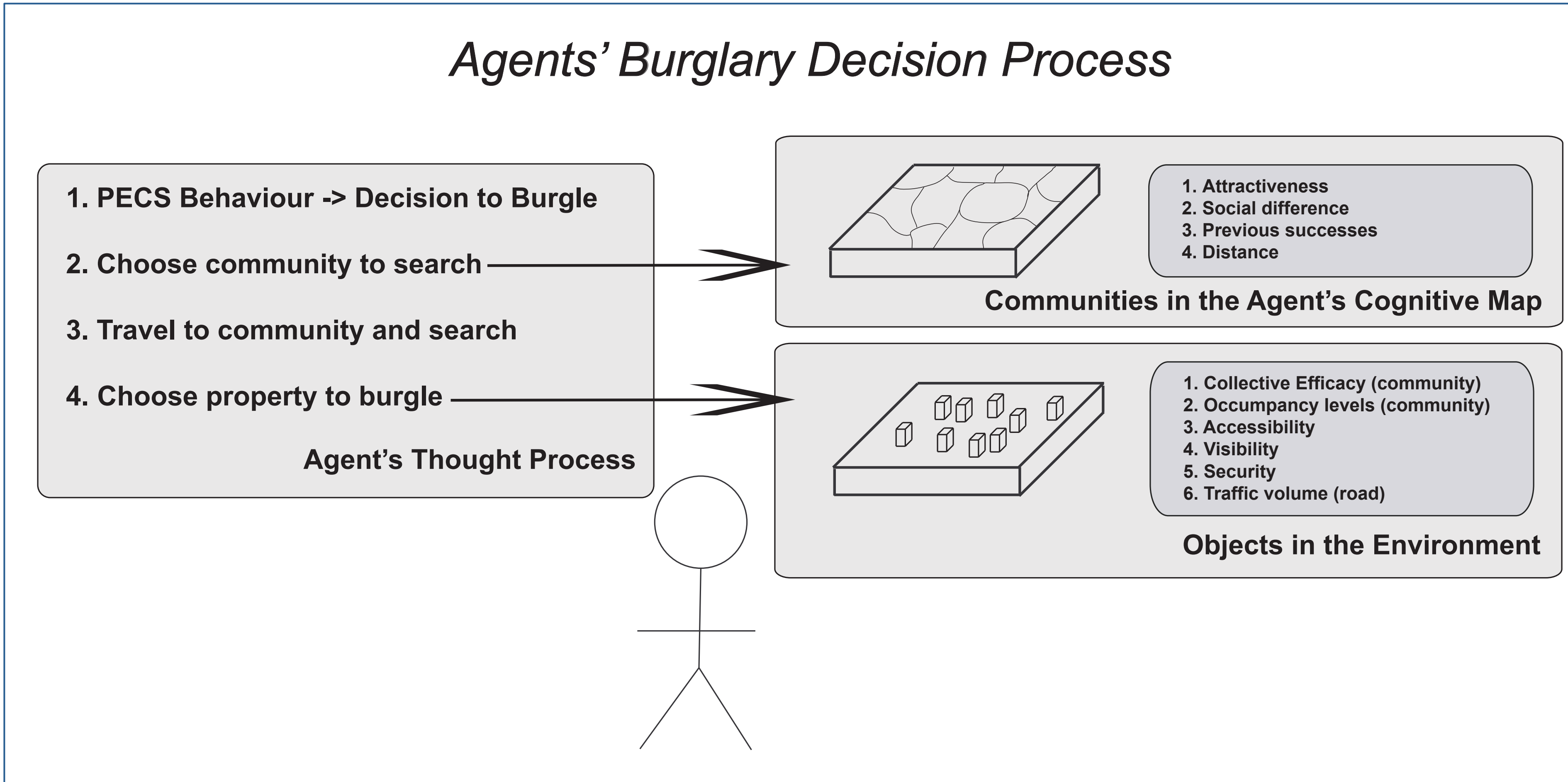
Characteristics

Drug supplier and socialisation space allocated randomly (socialisation biased on distance from home and demographic similarity).

Behaviour

Possible to vary the perception of different environment variables – *bring out more advanced behavioural traits*

Offender behaviour



Target community area

Act as “optimal foragers”.

Pick a community areas to visit.

Attraction:

- Wealth disparity
- Nearness to home
- Comfort (closeness in socio-economic variable space).
- Number of previously successful burglaries in area.

Weights of these are calibrated.

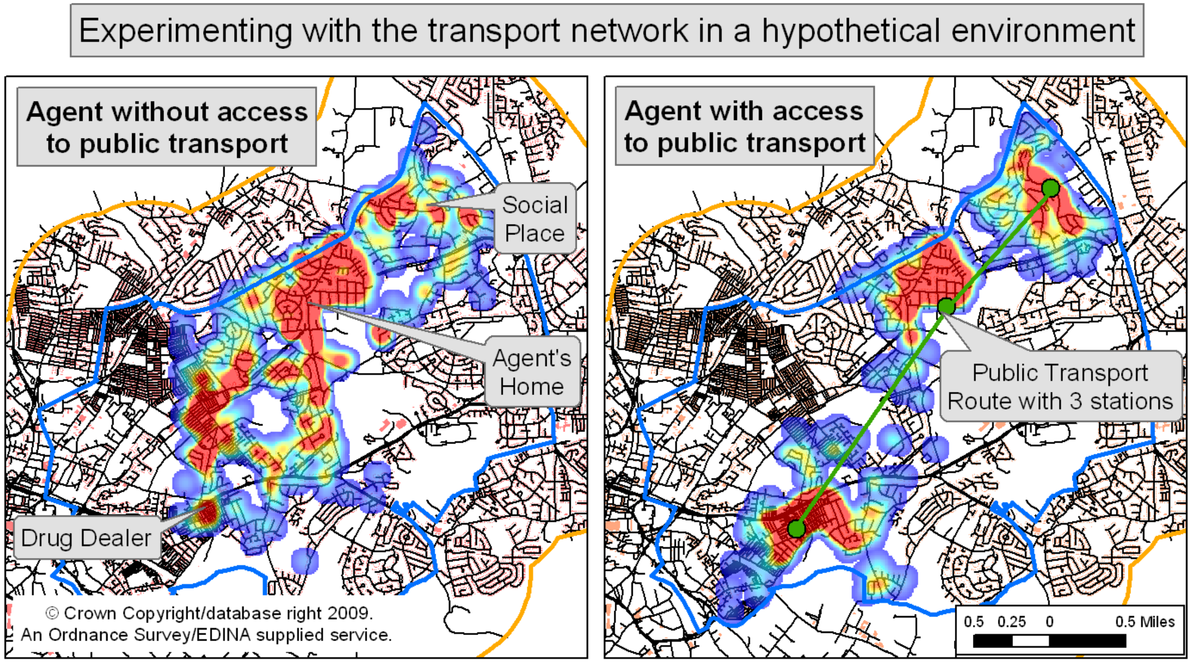
Route to area

Shortest on weighted vector network constructed from road map.

Different travel options assigned (walk, public, car).

Search on way, then bullseye out from a house picked in the community area.

Search shape tear-drop if away from home, bulls-eye around home.



Target ease

Collective efficacy:

Calculated from deprivation and demographic variation.

Traffic volume:

Calculated using traffic estimates and space syntax.

Accessibility:

Calculated using property free walls (window/door proxy).

Occupancy likelihood:

Estimated from community demographics.

Visibility:

Estimated from garden dimensions and house arrangement.

Security:

Applied manually from stakeholder discussions.

Target choice

Occupied properties are not usually burgled.

Targets probabilistically picked weighted on ease, area attractiveness, and desperation (more desperate burglars worry less about being recognised close to home). Some weights calibrated.

All burglaries are successful.

Burgled properties and their neighbours increase in attractiveness for some period, however, security also rises for some (usually lesser) period (reflects recent findings on repeat victimisation).

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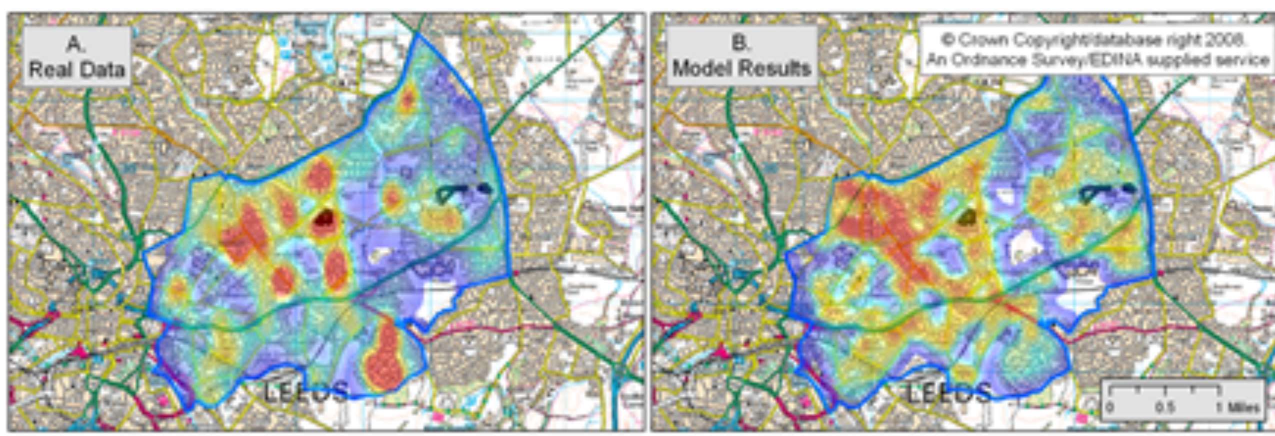
Model calibration

We have an intelligent idea of many variables from literature and stakeholders.

Calibration of rest by hand to 2001 data, checking against known 2001 crimes.

Did try Genetic Algorithm calibration early on, but impractical for full model.

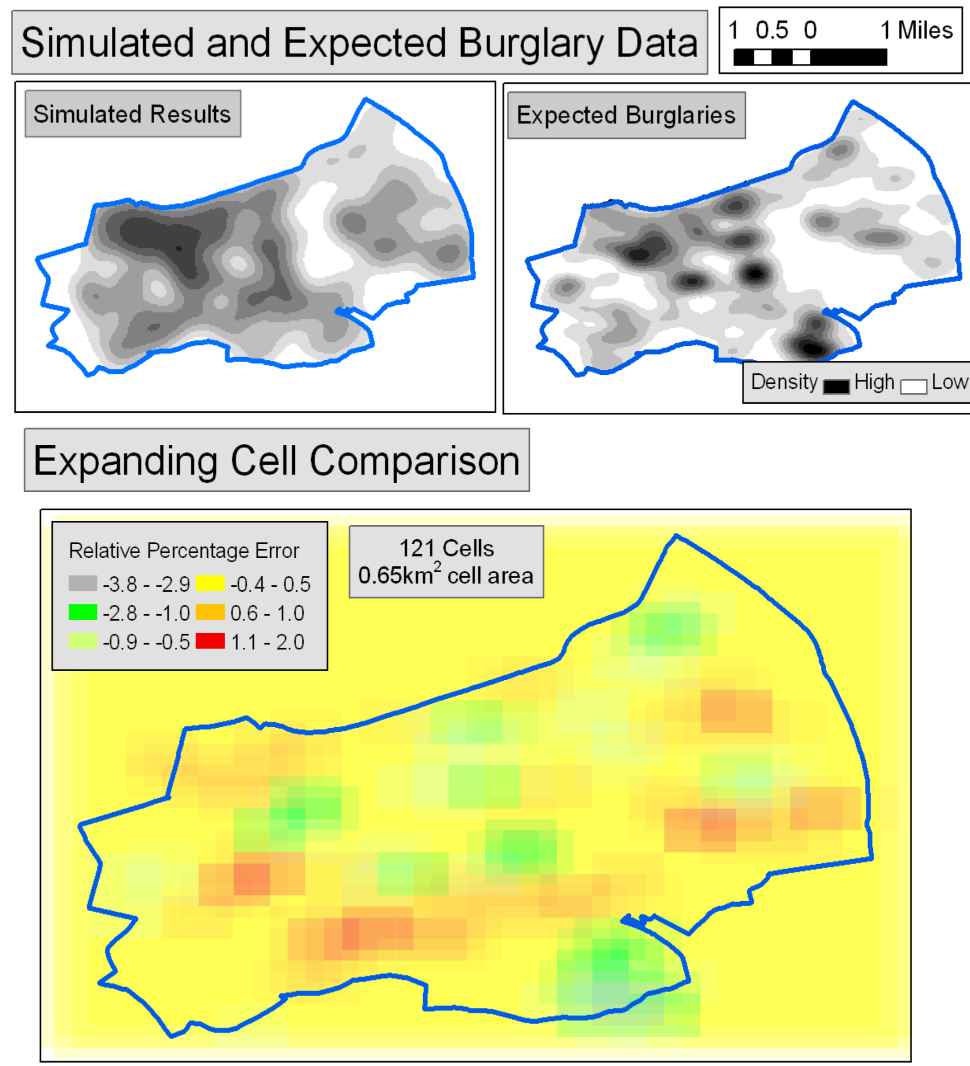


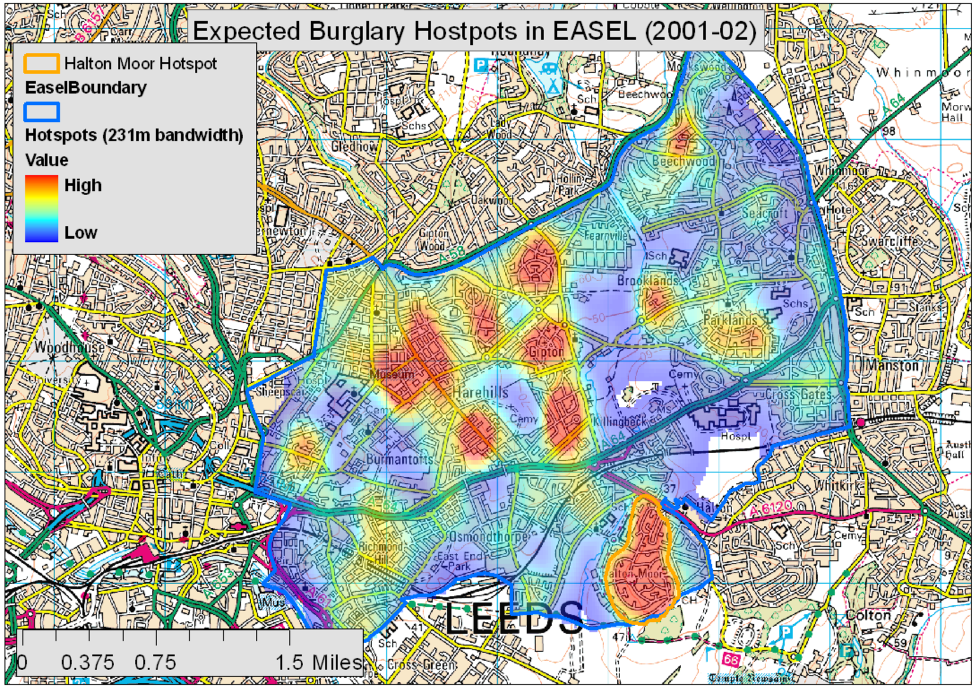
Model validation

Results validated against 2004 crime data.

Utilised multi-scale error statistics to look at both match and change of predictability with scale.

Better than equivalent non-local regression models.





Halton Moor

Result

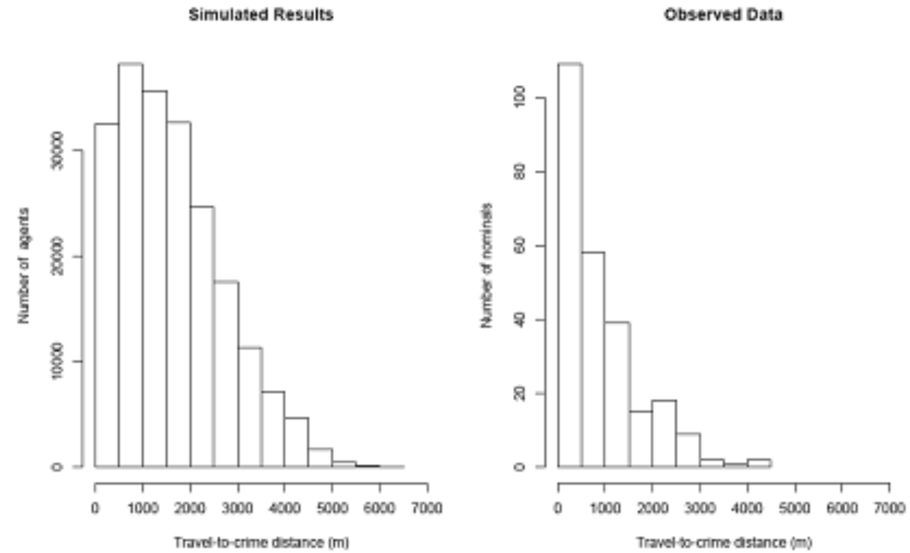
– Halton Moor area significantly under predicted by model

Explanation

– Motivations of burglars in Halton Moor

Model failures can help to indicate where we misunderstand the real world

Model validation II



Generally, agents travel further than real criminals.

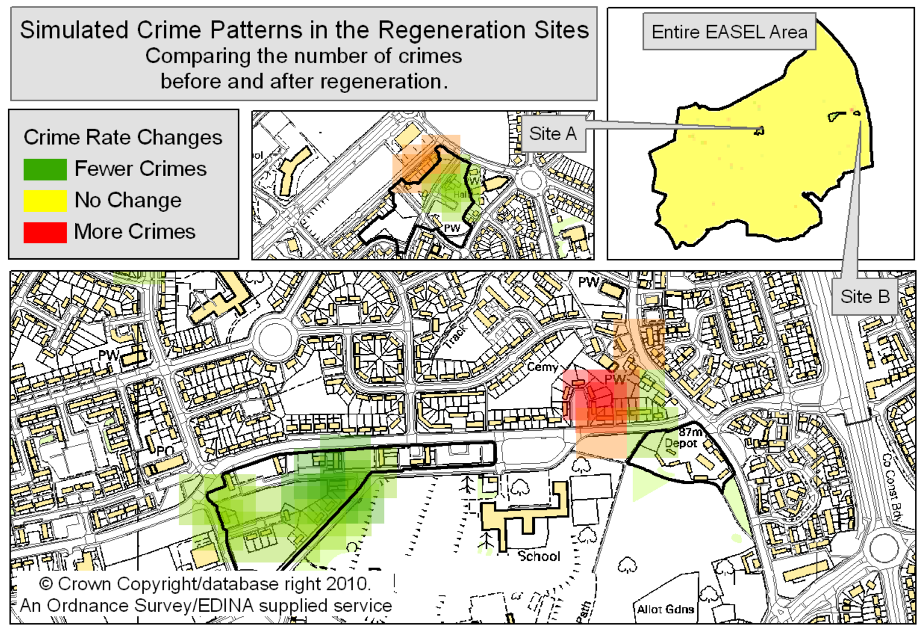
The good match to aggregate crime levels, but poorer individual links suggests area attraction important, but with equifinality/identifiability issues for detailed understanding.

Indicates that individual-level models and statistics of individual actions are important for exploring causes.

Results: Simulating Urban Regeneration

Simulation

- Test the effects of a large urban regeneration scheme
- A small number of individual houses were identified as having substantially raised risk



Why?

- Location on main road
- In the awareness space of offenders
- Slightly more physically vulnerable

Need for a realistic, individual-level model to predict crime

Other issues

No prediction of crime numbers.

Socialisation and drug dealers randomly allocated.

Wealth elements educated guesses, especially returns from burglary.

No social interaction/knowledge transfer or collaboration.

No reaction to opportunities if not searching for a target already.

Data can be critical (e.g. drug dealers Vancouver).

Who else is doing this?

Researchers:

Elizabeth Groff: street robbery

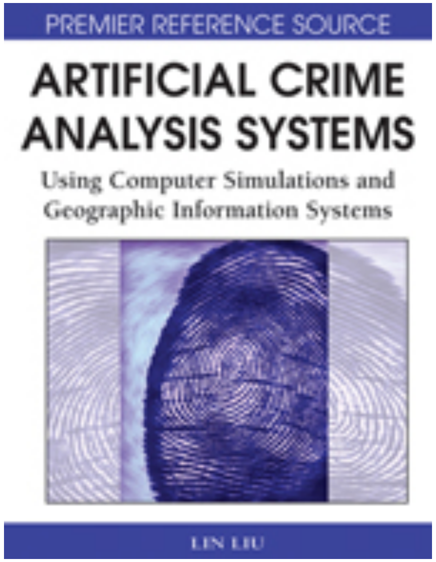
Daniel Birks: burglary

Patricia Brantingham *et al.*: Mastermind (exploring theory)

Lin Liu, John Eck, J Liang, Xuguang Wang: cellular automata

Books / Journals:

- *Artificial Crime Analysis Systems* (Liu and Eck, 2008)
- Special issue of the *Journal of Experimental Criminology* (2008)*:*``Simulated Experiments in Criminology and Criminal Justice'



An abstract burglary model

Theory	Enabled	Disabled
Routine activities	Agents assigned a ‘home’ and routine paths	Random movements
Rational choice	Victim attractiveness (based on risk, reward, effort)	Homogenous target attractiveness
Awareness space	Dynamic awareness – alters offender decision-making	Uniform environment awareness

Birks at al. (2012)

Randomly generated environments

Theoretical ‘switches’

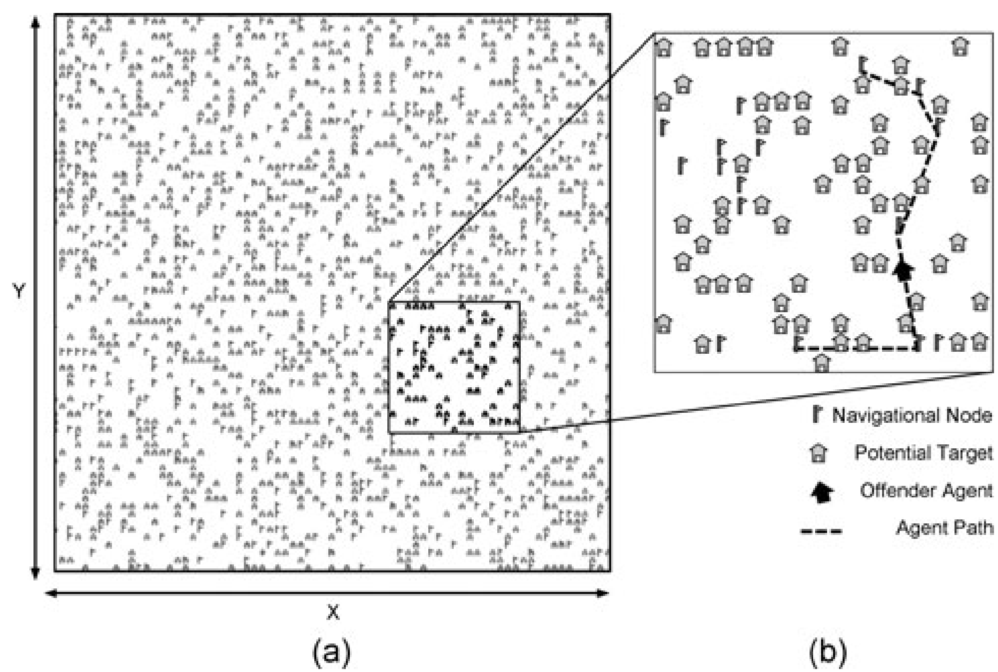
Compare results to expected outcomes:

- Spatial crime concentration
- Repeat victimisation
- Journey to crime curve

Results:

- All hypotheses are supported
- Rational choice has lower influence

Figure 1. Example Model Environment



Taken from Birks et *al.* (2012)

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Future work in this area

Project Background – PhD project

Collaboration with West Yorkshire Police and Safer Leeds Partnership

Until now, Models have largely been based upon existing Criminological theory.

Model development represents continual evolutionary process.

How else can we take this further?

Integration of Real-life Offender Data

Integrating theory and real-world knowledge.
Use of Police data for analysis of offence behaviours/ environmental features of offence locations.
Model validation using Police data.
Explore the impact of offender heterogeneity on levels of burglary and burglary patterns within Leeds.

Why Agent-Based Models?

Helps understand the relationship between Micro and Macro-level behaviours.

Model may be comprised of many different 'agents', whose behaviour can be informed to interact with other agents, as well as their environment.

Model environment may consist of an 'abstract space', or a replicated environment.

May be used a 'test bed' for future Crime Reduction Initiatives – different offenders, areas, Policing approaches.

Proposed Methodology

Undertake ~ 50 Semi-structured interviews with burglars from Leeds area.

Conduct a Cluster-based analysis to derive offender groups based on offenders' behavioural features/ selection criteria.

Develop an 'Agent-Based' simulation model of burglary for area within Leeds, integrating the derived offender groups.

Analyse the movements and crime patterns of offender groups within the simulation model.

Model validation with real-world observed data.

Gathering data through interviews

Series of semi-structured interviews, exploring behavioural features/ target selection criteria.

Guided by literature and expert knowledge.

Aim to gather data on presence of range of offence/ offending-related variables.

Require variables that can be modelled

- *i.e. distance of journeys to crime, whether someone takes a tool (and uses it), how far in advance familiar with a target*

Transcription and Coding process.

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Latent Class Analysis Approach…

'Person-centred' approach used to identify classes within a set of individuals.
Focuses on 'person-based' probability.
Uses range of variables, grouping individuals into alike categories, 'qualitatively distinct' from other groups.
Used effectively in work on burglary within Florida, USA (Fox and Farrington 2012).

Latent Class Analysis – the ‘Road test’

Road-tested analysis to explore method/ potential variables.
Developed a questionnaire for use with students, asking to imagine ‘self’ as a burglar.
Questionnaire explored behaviours of ‘pseudo-burglars’

- i.e. *When do you typically commit burglaries? What types of item do you usually take from burglaries?*

52 questionnaires coded for presence of different variables.
Latent Class Analysis undertaken using ‘Q’ statistical Package.

Results from the Road-Test…

Most closely fitting model – 3-class solution;

Experienced Professionals (28.85%)

Intermittent Late Starters (32.69%)

Inexperienced, Chaotic Student Dwellers (38.46%)

Illustrates the 'nuances' and subtleties of potential offender groupings

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The Current Prototype…

Demographic areas

Central Business District

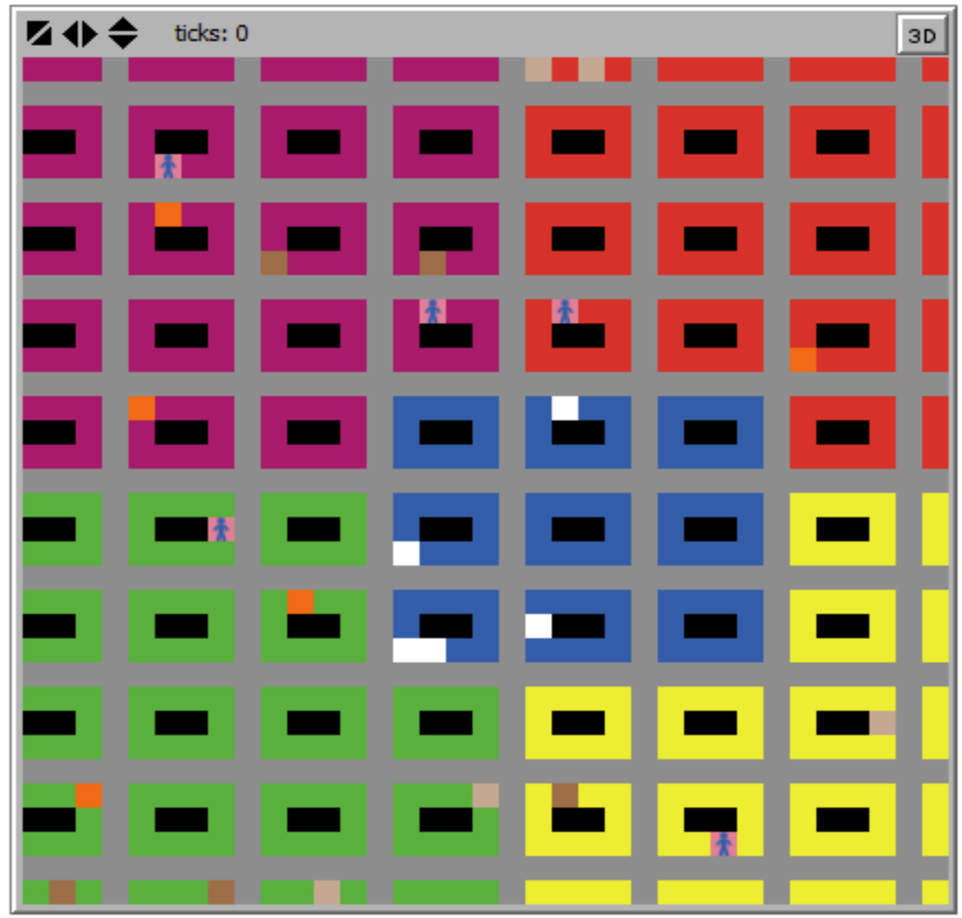
Road Network

House and Work locations

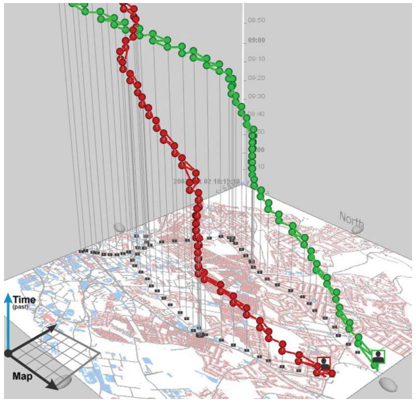
Individual Activity Spaces

Dynamic levels of wealth

and energy



Anticipated Outcomes



Taken from Malleson (2008 p. 29).

Understand patterns of offending/ journeys to crime.

Understand Micro and Macro-level dynamics of crime.

Use as a predictive tool?

Complement existing Crime Reduction Initiatives.

Act as ‘test-bed’ for future Crime Reduction Initiatives.

And finally…

Dynamic data

We are currently looking at mining social media feeds for population numbers around the city, and travel patterns for victims.

More socio-economic data coming online all the time.

Utilise this dynamically to dampen errors.

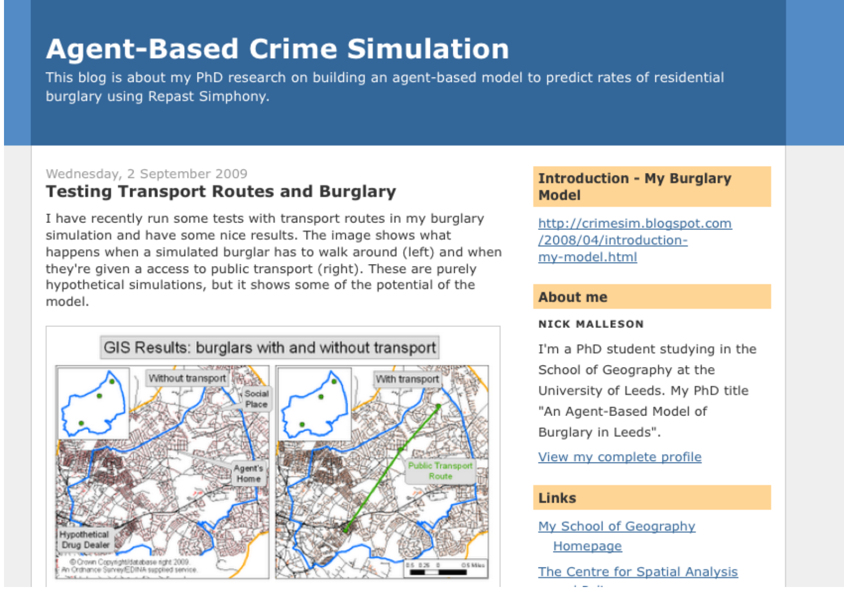
Ethical issues

Currently anonymise and randomise real offender data.

Could we imagine a day when resources were directed to predictions of real people?

Up to us to take a lead on what we do and don't find acceptable.

More information



General info:

http://crimesim.blogspot.com/

Papers etc:

http://www.geog.leeds.ac.uk/people/n.malleson

http://www.geog.leeds.ac.uk/people/a.evans

http://www.geog.leeds.ac.uk/people/n.addis

GeoCrimeData project:

http://geocrimedata.blogspot.com/