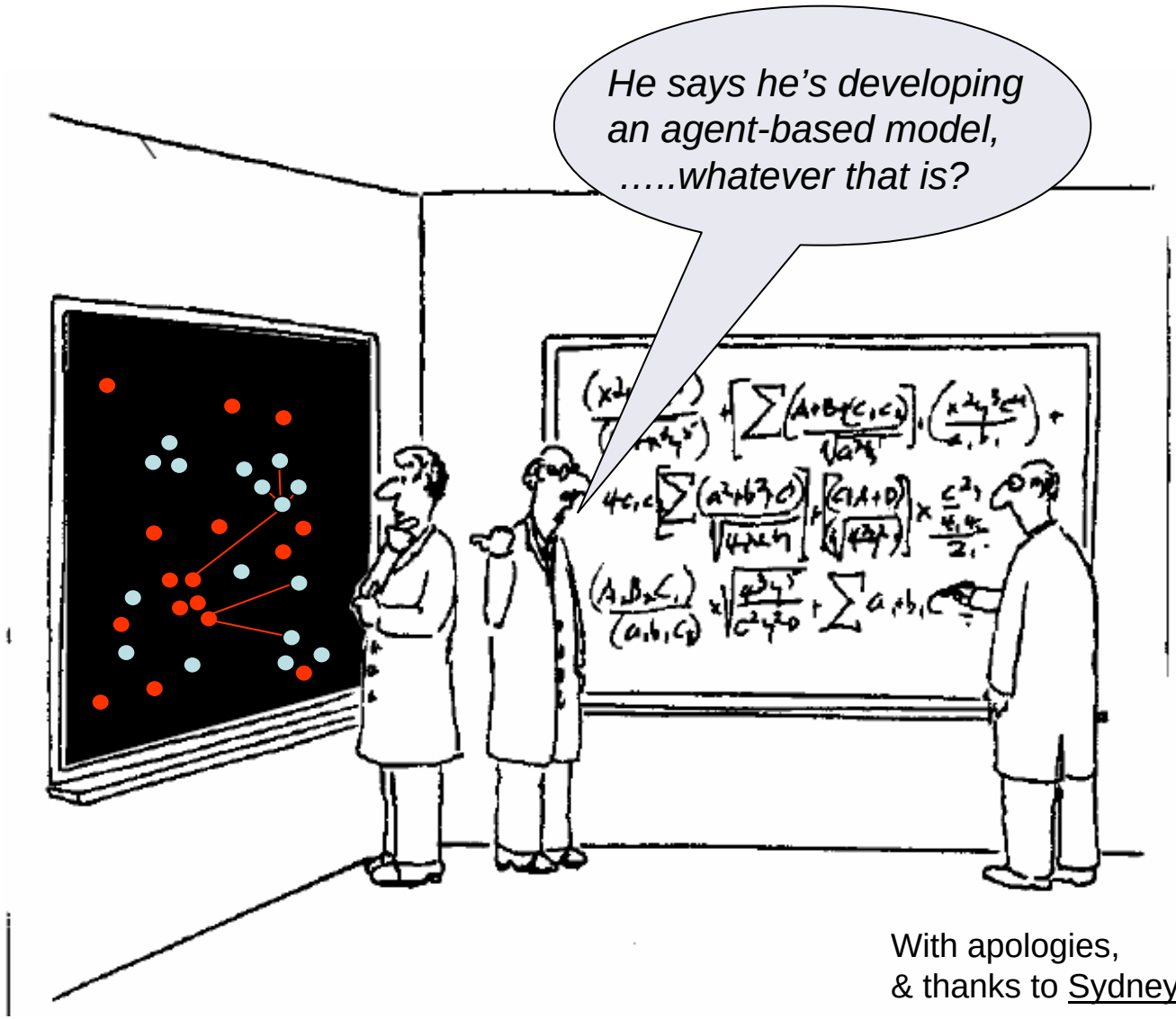
Key Challenges in Agent-Based Modelling for Geo-Spatial Simulation

Andrew Crooks (AC), Christian Castle (CC)
& Michael Batty (MB)

University College London



With apologies,
& thanks to Sydney Harris

Outline of the Talk

- What are Agent-Based Models?
- Seven Challenges, Three Examples

  1 *Purpose, 2 Theory, 3 Replication,*

  4 Calibration/Validation, 5 Representation-Dynamics,

  6 Operation(ality), 7 Sharing/Communication

- a Emergency Evacuation (CC)
- b Residential Segregation (AC)
- c Land Use/Transportation (MB)
- Conclusions and Next Steps
- Questions

MB

AC

MB

What are Agent-Based Models? Simplification & Abstraction

A model is a simplification of reality: but agent-based models are less simple than models used to be.

They are highly disaggregate, temporally dynamic, purposive, bottom-up, decentralised, non-equilibrium ….

…. and contain many more assumptions than can ever be validated against available data.

They have been borne of the view that the world works as much from the bottom up as the top down and that the traditional goals of explanation in science are not rich enough to enable good theory to be produced.

1 Purpose of the Model

Theory and Practice, Theory and Application

Hypothesis to Policy Analysis

Generic Models v Specific Models

2 Theory and Model

Theory Separate from Model, Independent from Model

Blurring of Theory & Model, Generic Models ‘Any’ Theory

How Does Domain Knowledge Count?

3 Replication and Experiment

The Idea of an Experiment, Controlled Conditions

Confirmation versus Falsification, The Inductive Fallacy

Lowrys'(1965) Principle:
"the only true test of a model is when it is fitted for one situation and then is tested in a different situation"

One Model on Many Different DataSets

Many Models Tested on One Single DataSet

4 Verification, Calibration, Validation

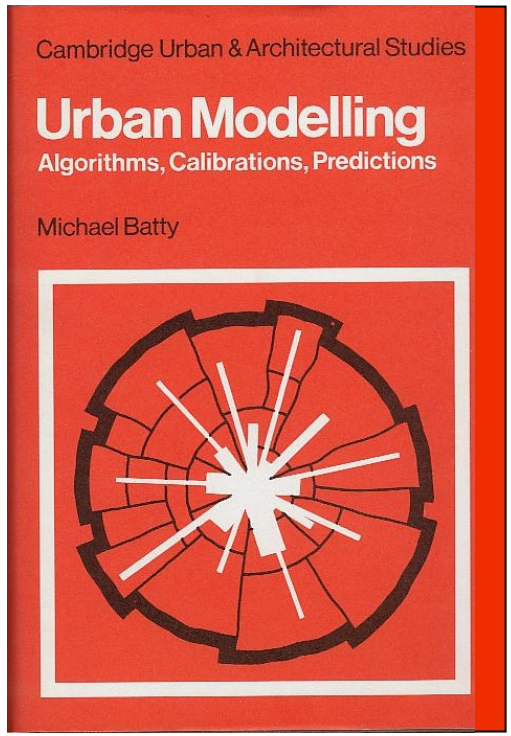
30 or more years ago, calibration was the term used for testing the goodness of fit.

Now Verification is testing the logic of the model structure, seeing if the models works in different software, for example

Calibration is fine tuning the model to some dataset

Validation is measuring the goodness of fit

Occam's Razor – ABM breaks with the notion of parsimony



5 Representation, Aggregation and Dynamics

Defining Agents – Individuals – Ambiguities,

The Question of Scale – Agents and Agencies

Mobility and Agents, Dynamics, Agent Processes

Numbers of Agents – our three examples

6 Operational Modelling

Simulation Runs, Moving the Model to Software

Generic v Specific Software e.g. Repast, Policy Apps

7 Sharing and Dissemination of the Model

Communicating the Model to Other Interested Parties

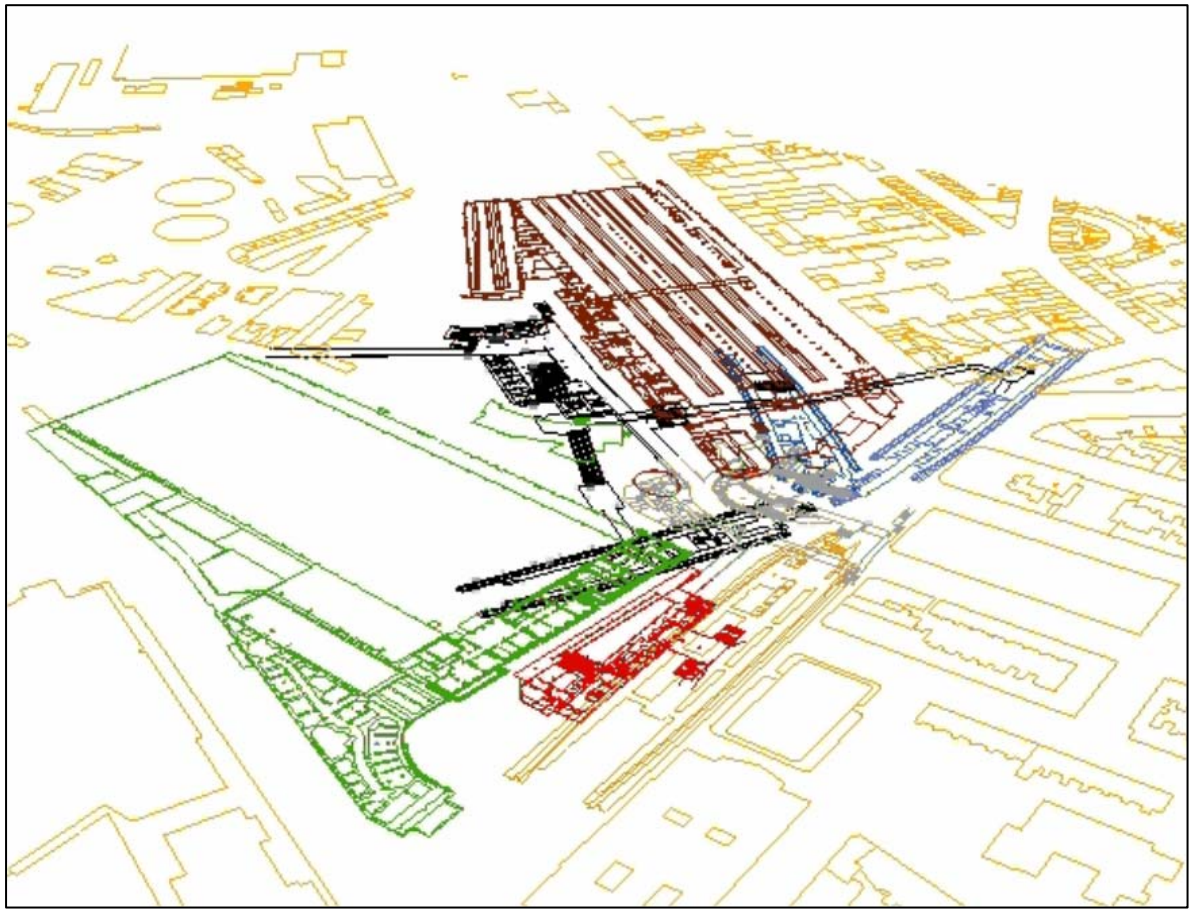
Software and Users, Generic v Specific Software

Visualization, Graphical User Interfaces

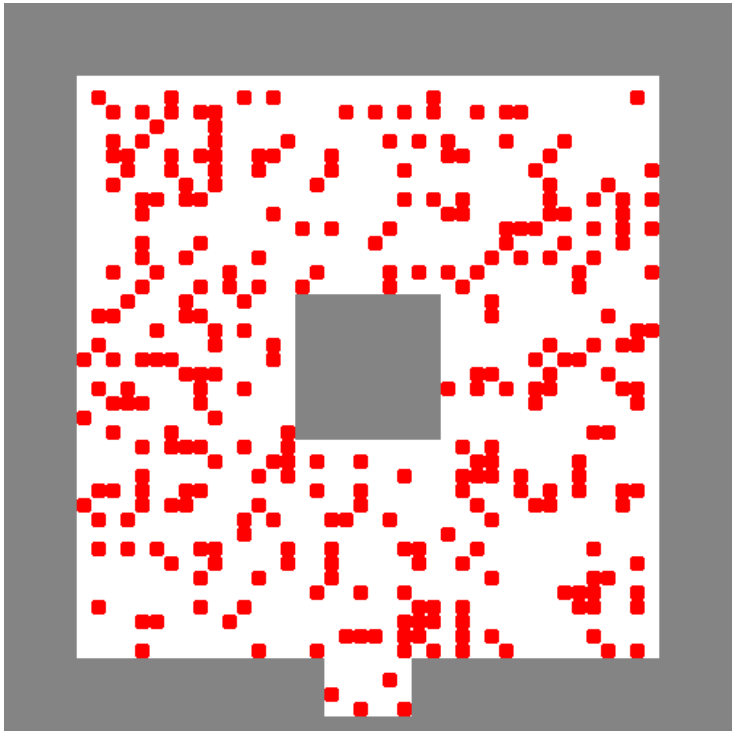
Desktop v Web, Other Media – VR Theatres etc.

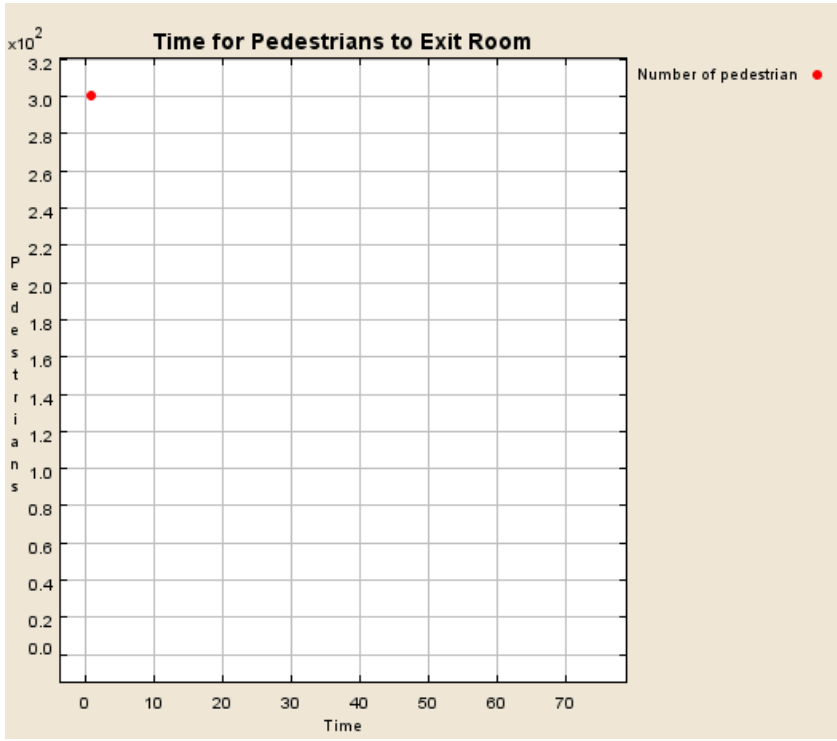
Three Examples – Andrew will now quickly demo Christian's Kings X Ped Model, his own Segregation Models and then I will return and demo the LUTM

a) A Model for Emergency Evacuation KXPEM

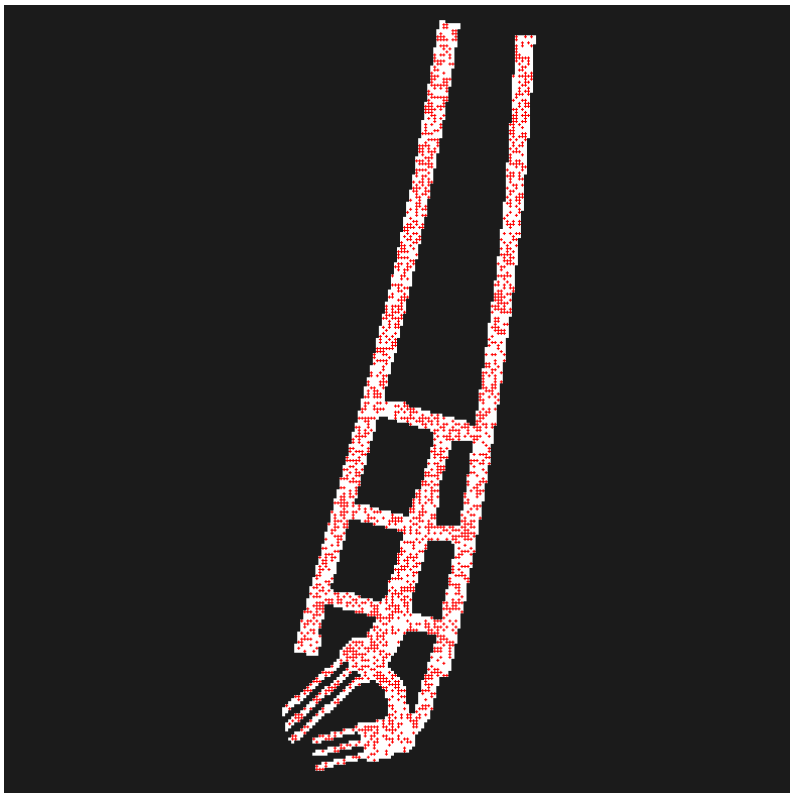


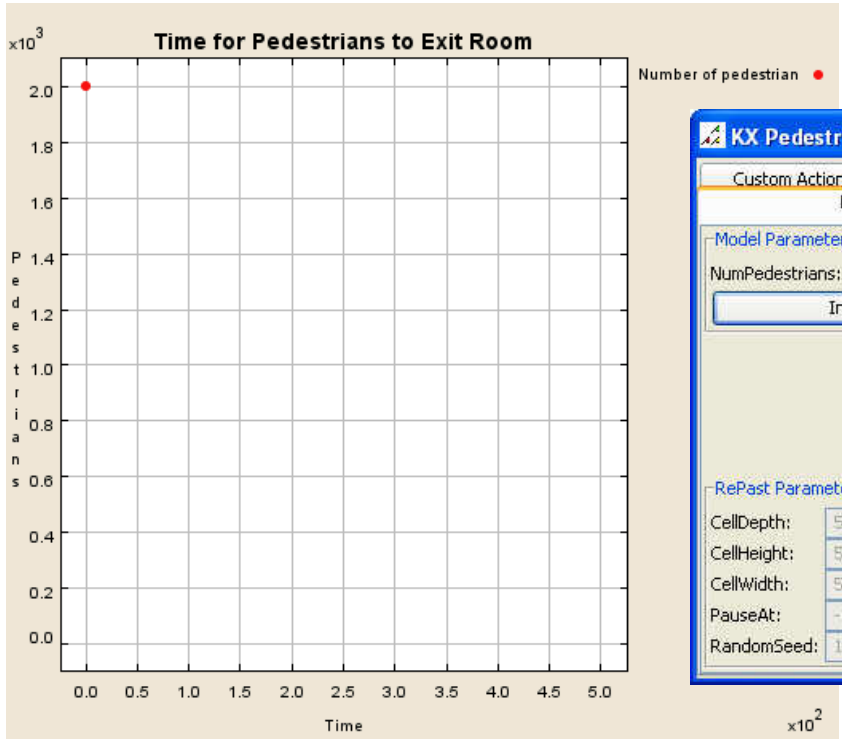
Basic Pedestrian Model

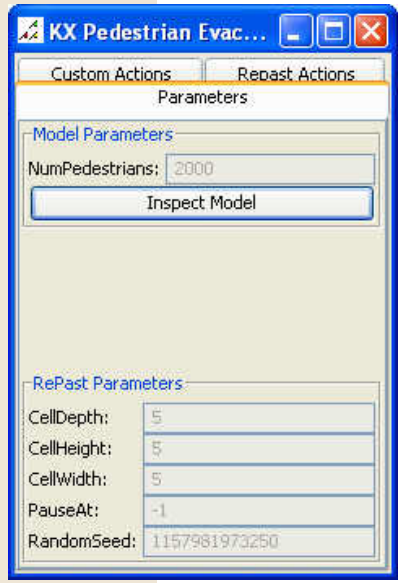




One Level

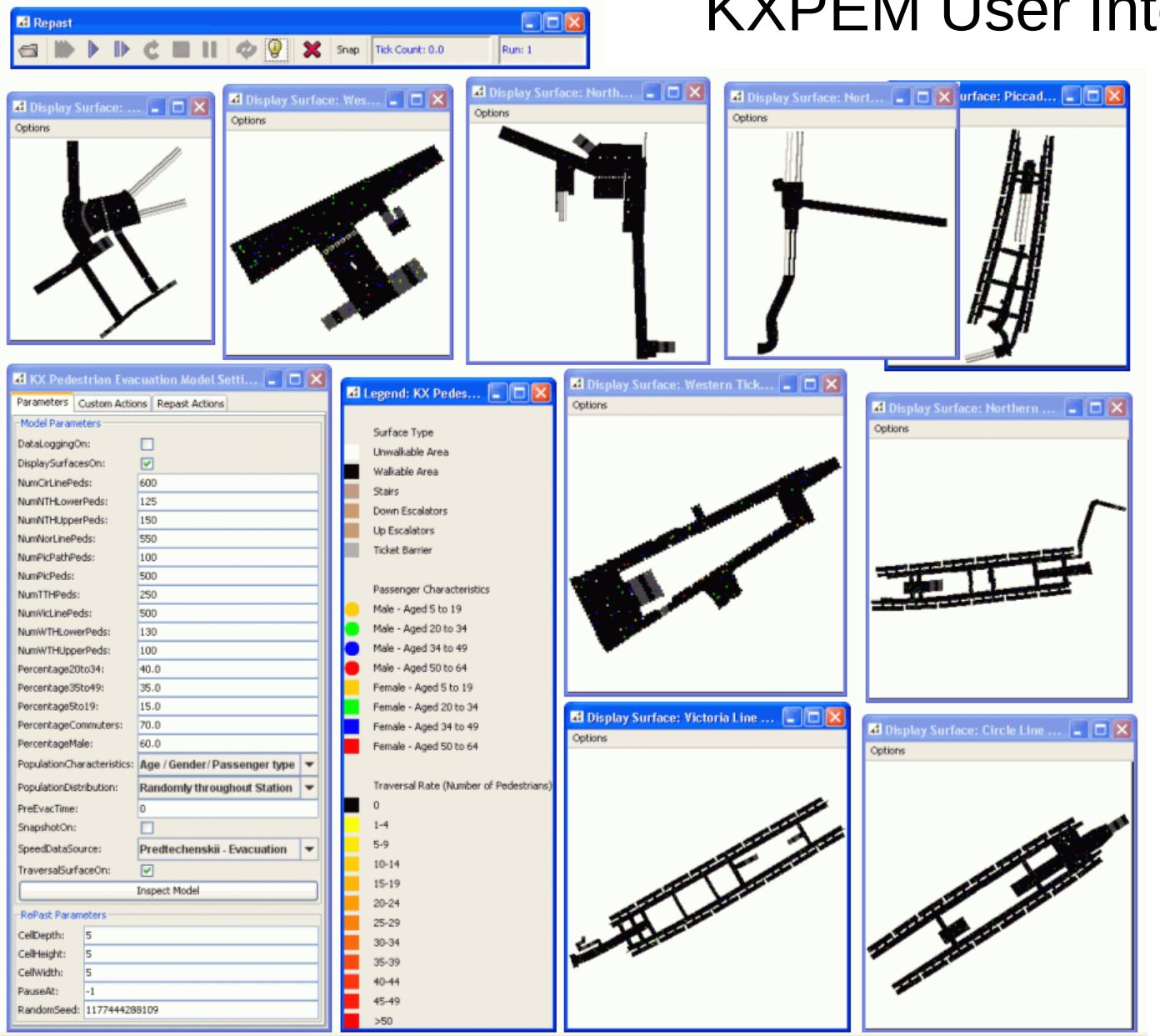



Time for Pedestrians to Exit Room
x10^3
Number of pedestrian
Pedestrians
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
Time
x10^2


KX Pedestrian Evac...
Custom Actions
Repast Actions
Parameters
Model Parameters
NumPedestrians: 2000
Inspect Model
RePast Parameters
CellDepth: 5
CellHeight: 5
CellWidth: 5
PauseAt: -1
RandomSeed: 1157981973250


Legend...
Unwalkable Area
Walkable Area
Cost Surface
Pedestrian

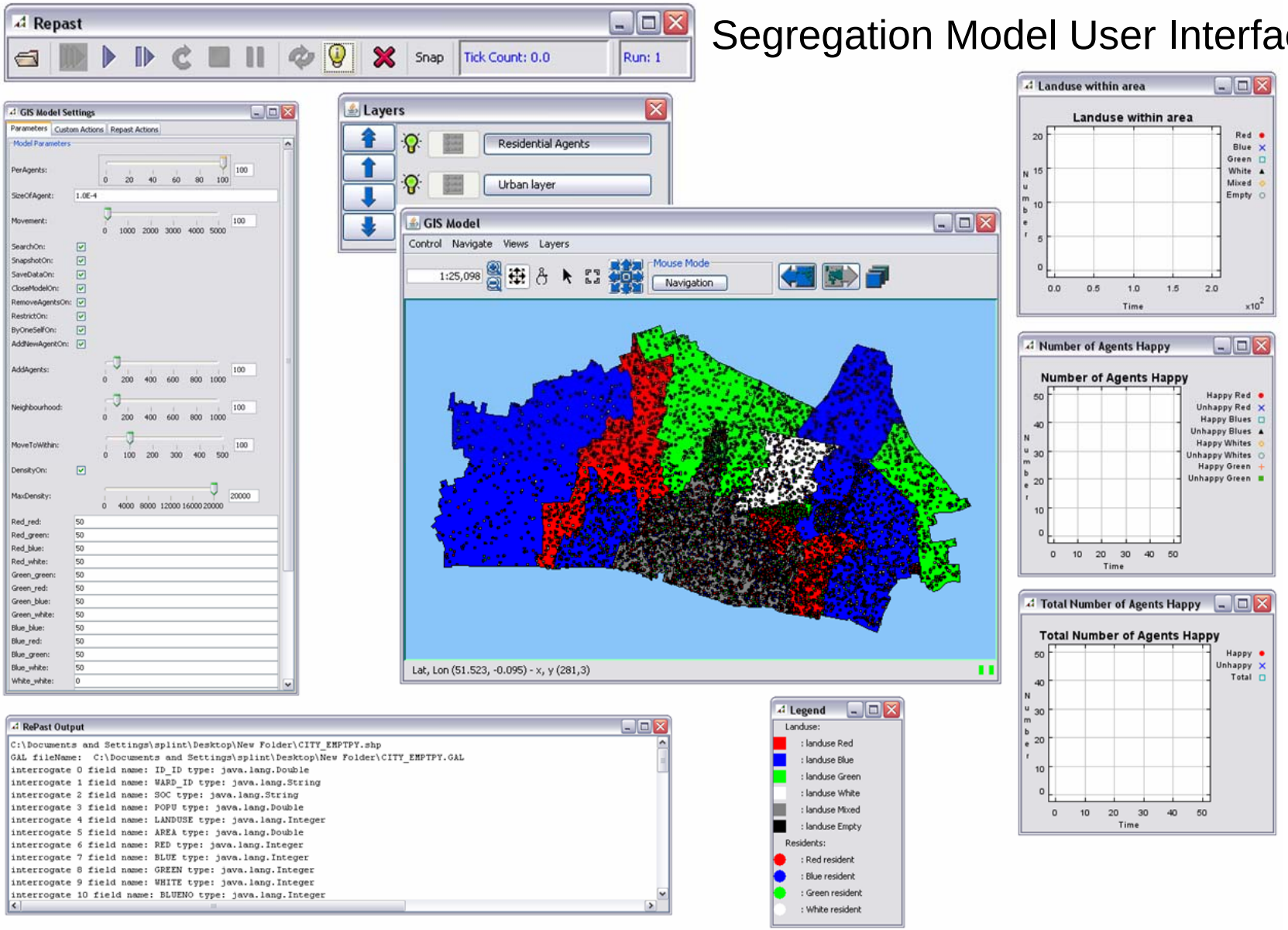
KXPEM User Interface



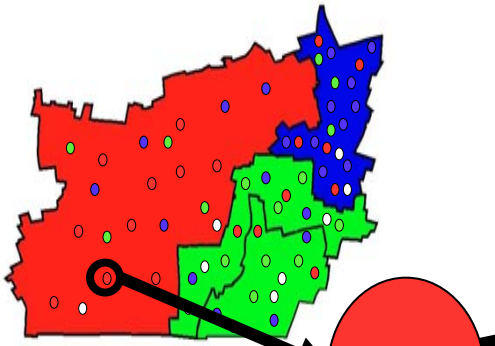
Movie

b) Residential Segregation

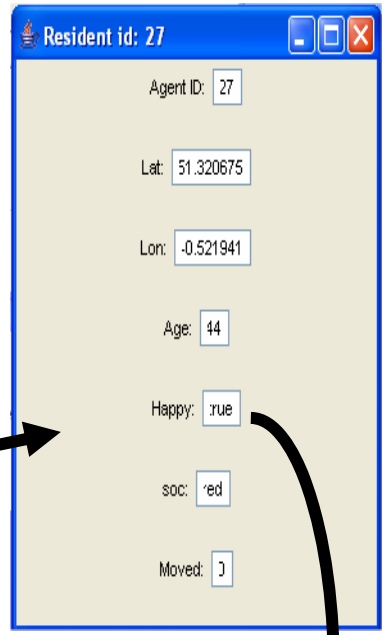
Segregation Model User Interface



Segregation Model Structure



Urban Environment

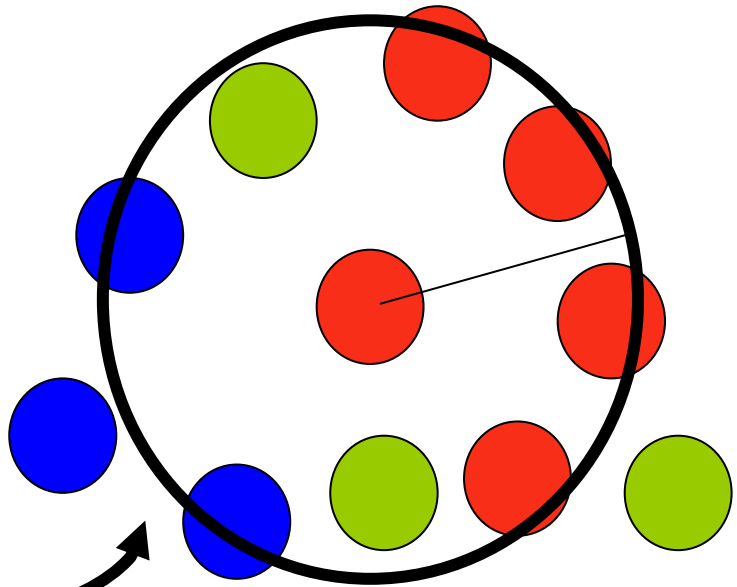


Agents Attributes

	No. of agents	Percentage
Red Agents	4	50%
Blue Agents	2	25%
Green Agents	2	25%

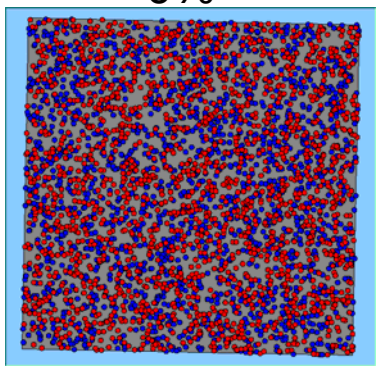
Red agent preferences	
Red with Red	>= 50% Red
Red with Blue	< 30%
Red with Green	< 50%
Red with White	< 10%

Example of Agent preferences

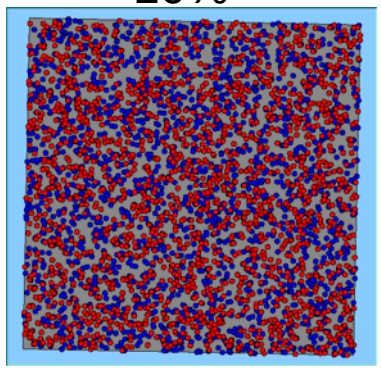


Calculating neighbourhoods

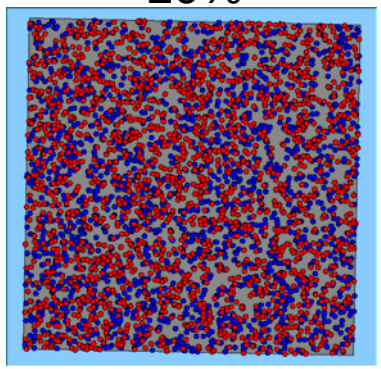
0%



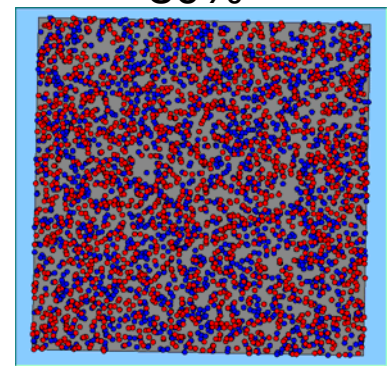
10%



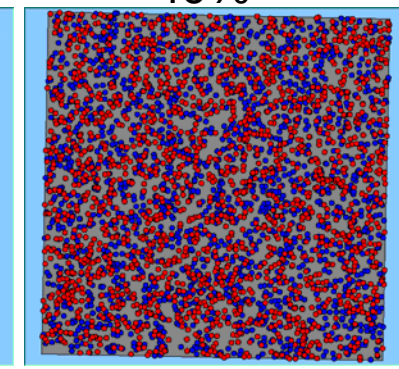
20%



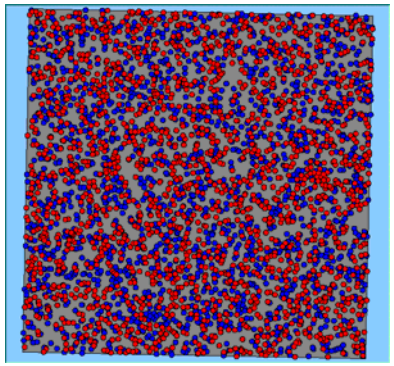
30%



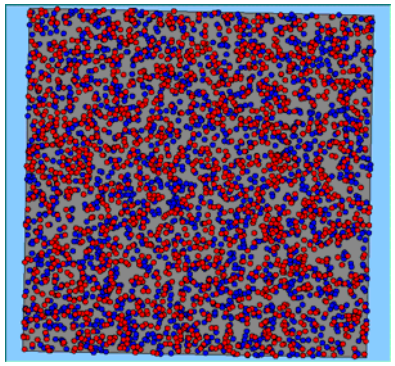
40%



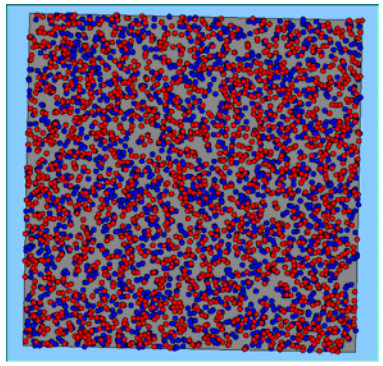
50%



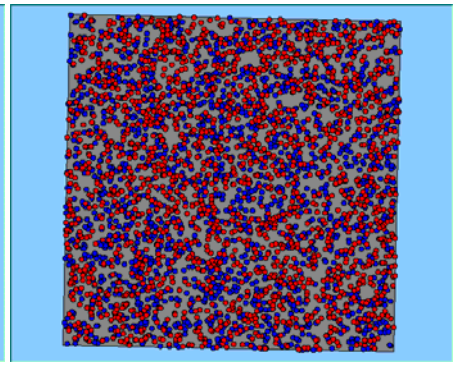
60%



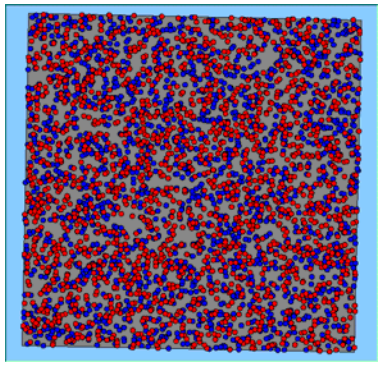
70%



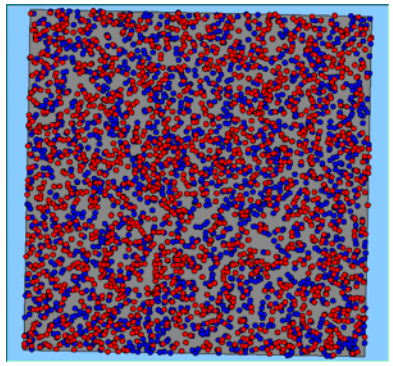
80%



90%



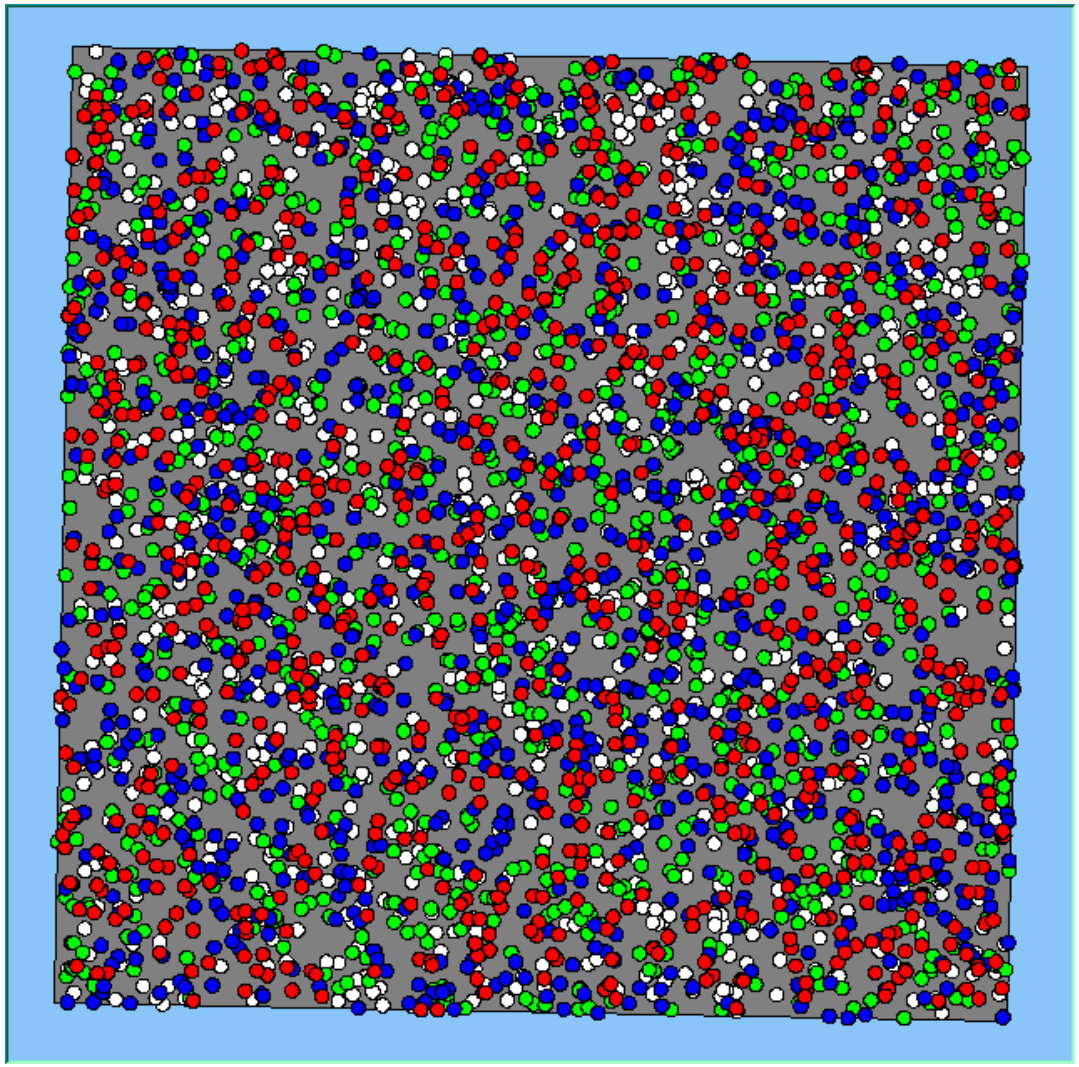
100%



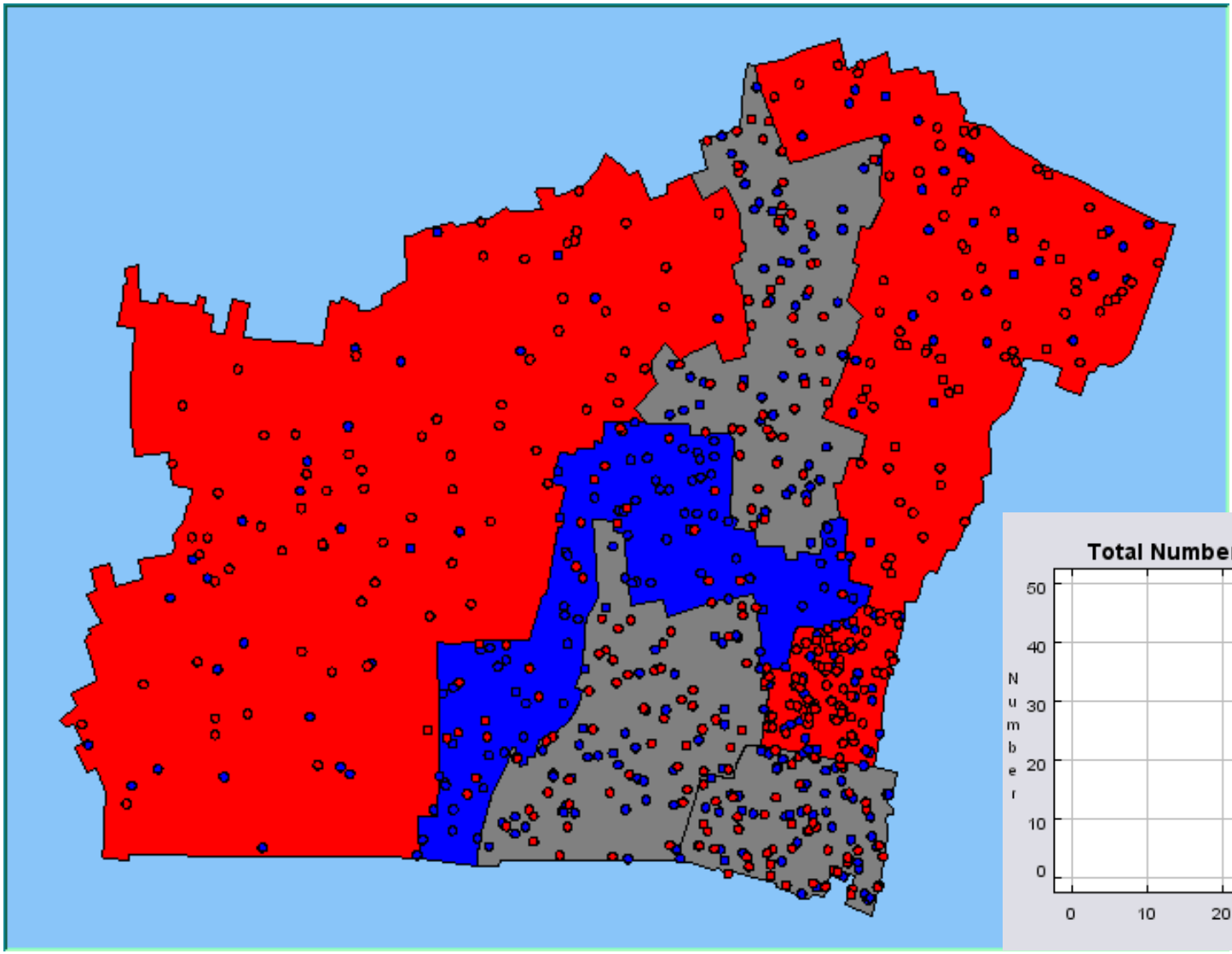
Red Agent is satisfied if:
Red Population % of neighbourhood >=40%

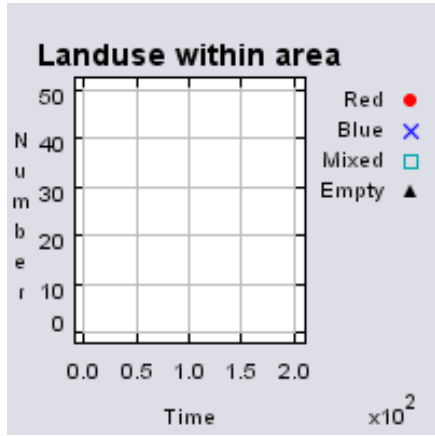
Blue Agent is satisfied if:
Blue Population % of neighbourhood >=40%

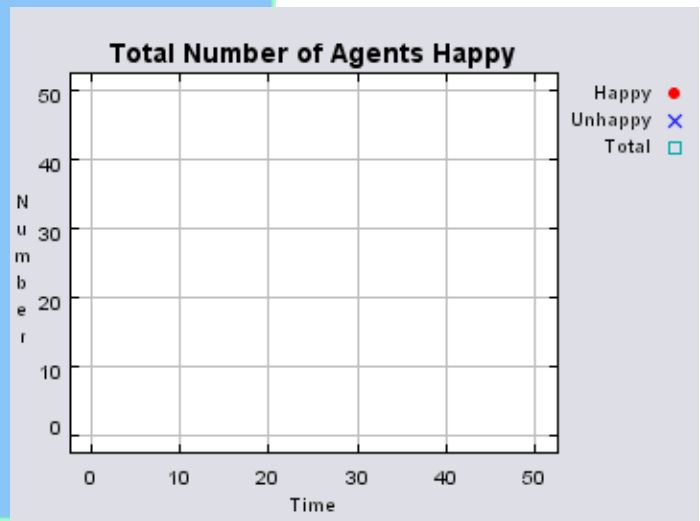
The addition and removal of agents



The addition and removal of agents



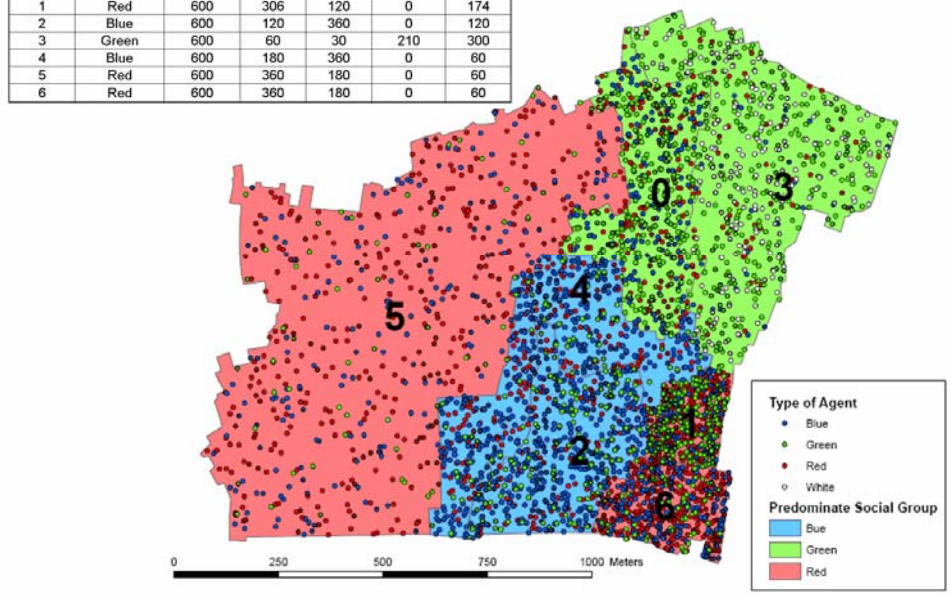




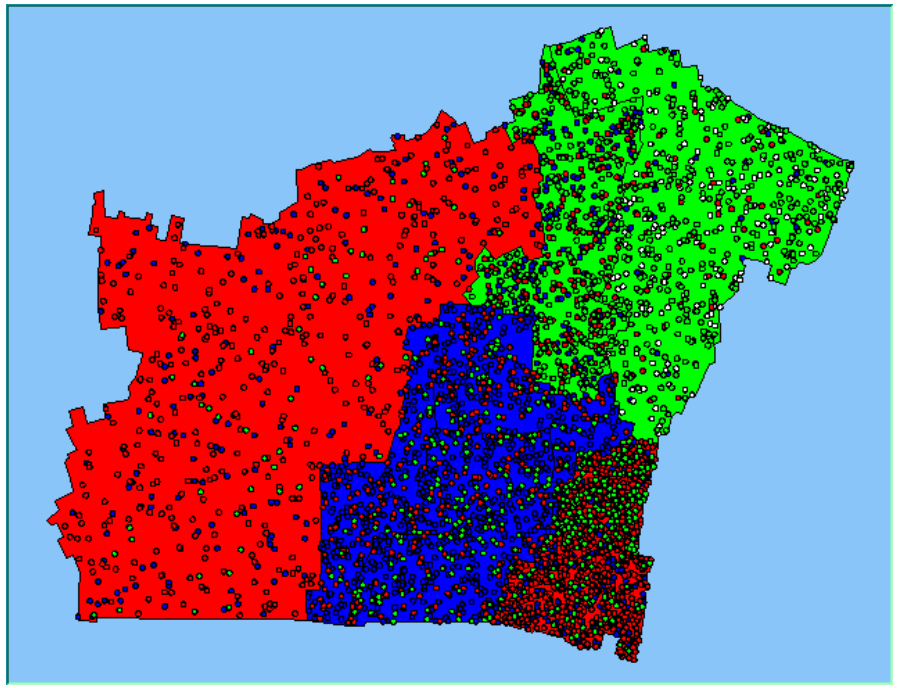
5% of the population are White at the start

Initial Conditions

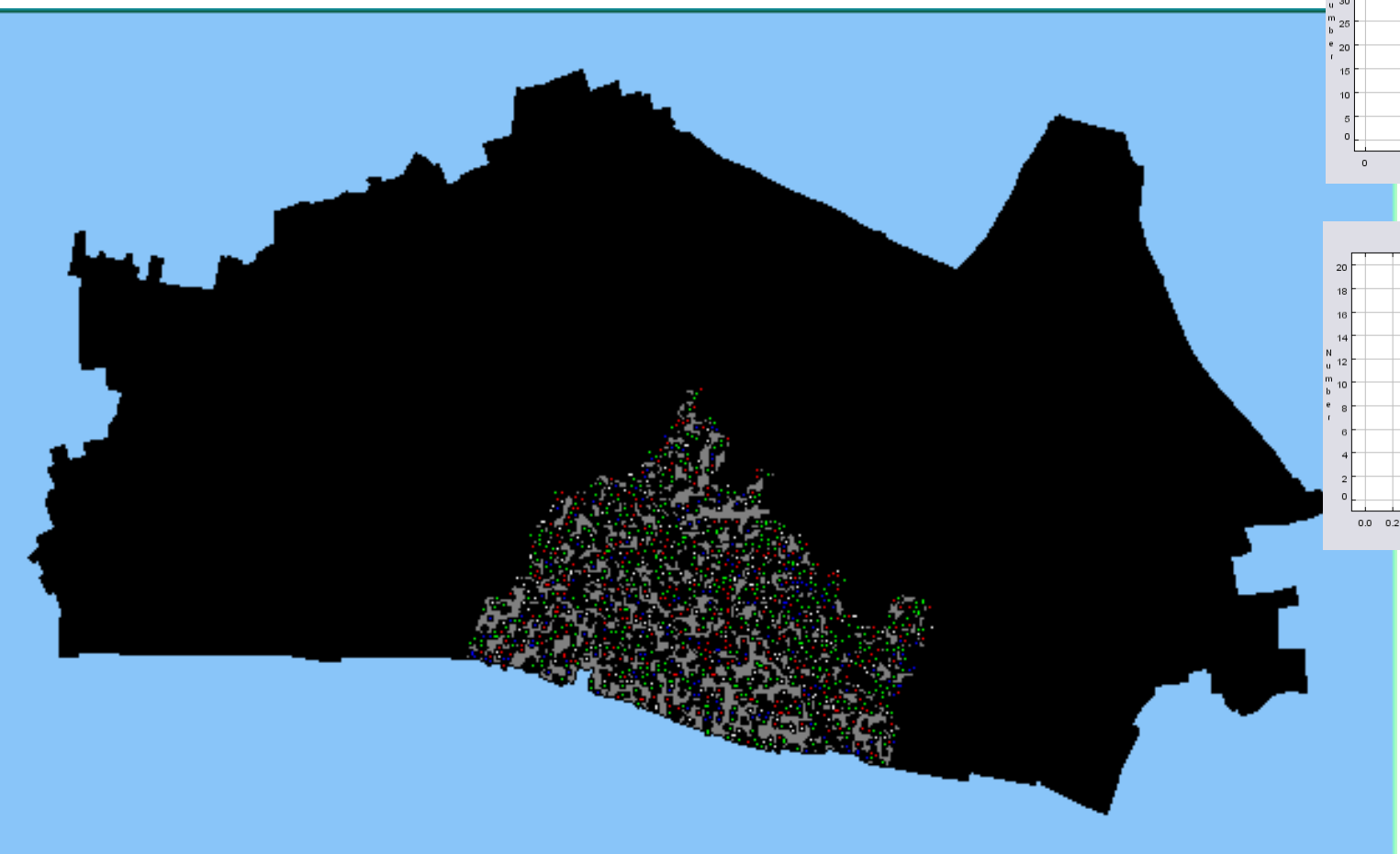
ID	Predominate Social Group	Total Population	No of Red Agents	No. of Blue Agents	No of White Agents	No. of Green Agents
0	Green	600	180	180	0	240
1	Red	600	306	120	0	174
2	Blue	600	120	360	0	120
3	Green	600	60	30	210	300
4	Blue	600	180	360	0	60
5	Red	600	360	180	0	60
6	Red	600	360	180	0	60

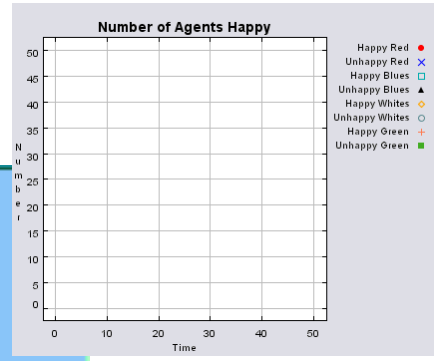


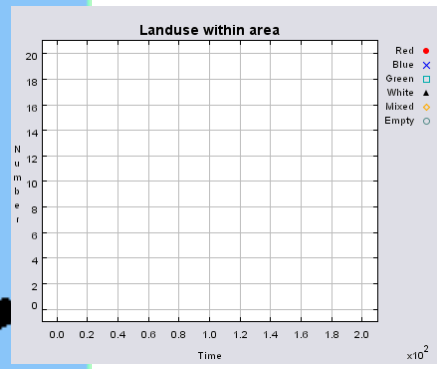
Simulation Run



Addition of agents: Density and living constraints







c) A Land Use Transportation Model

633 small zones, an aggregate style spatial interaction model with modal split, distributing employment on four modes – road, bus, tube, heavy rail – to residential locations

The model is singly constrained to conserve employment totals thus predicting employment at residential zones (population)

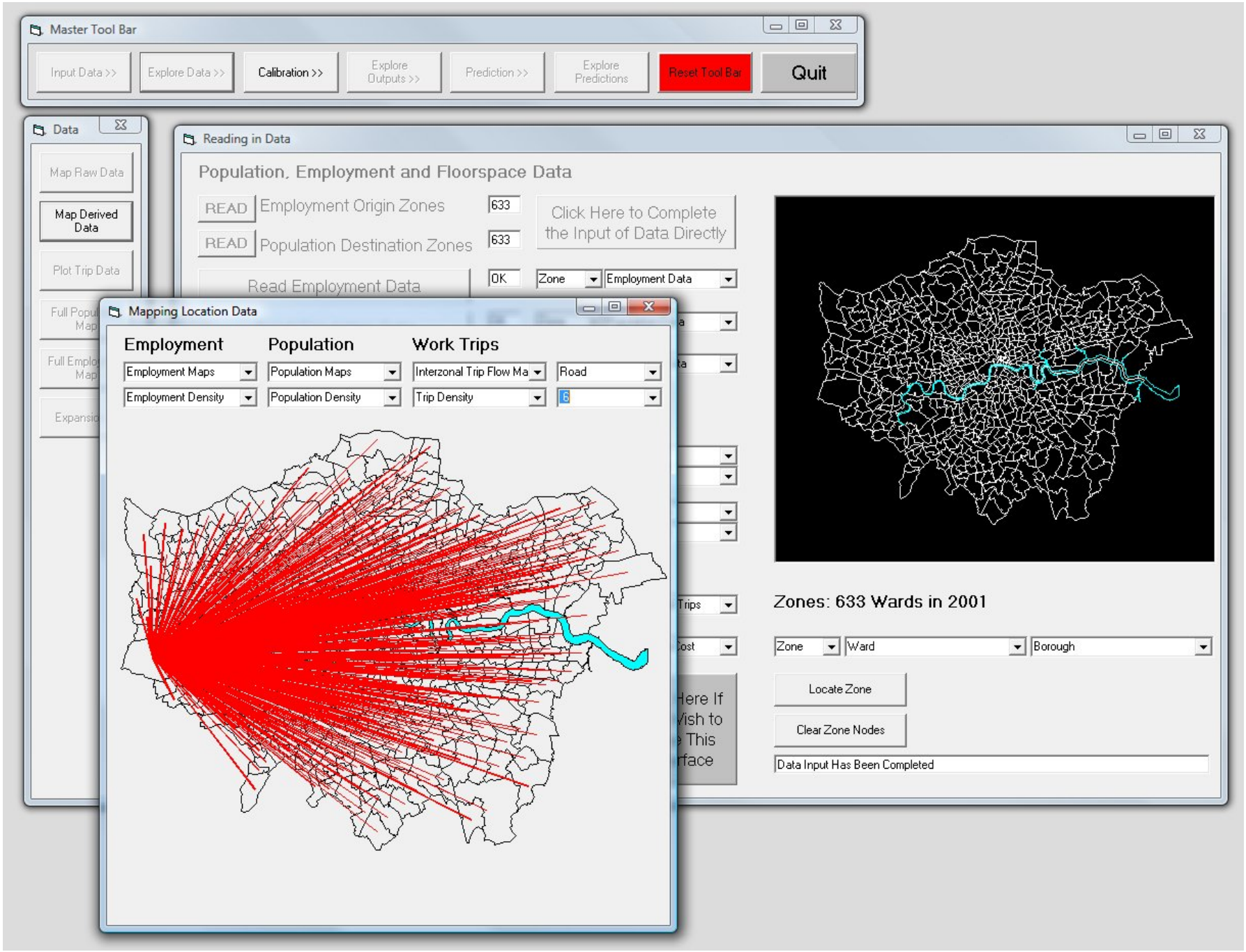
Part of an integrated assessment of climate change scenarios up to 2050 and 2100 in London and the Thames Gateway, funded as part of the Cities Theme in the Tyndall Centre for Climate Change

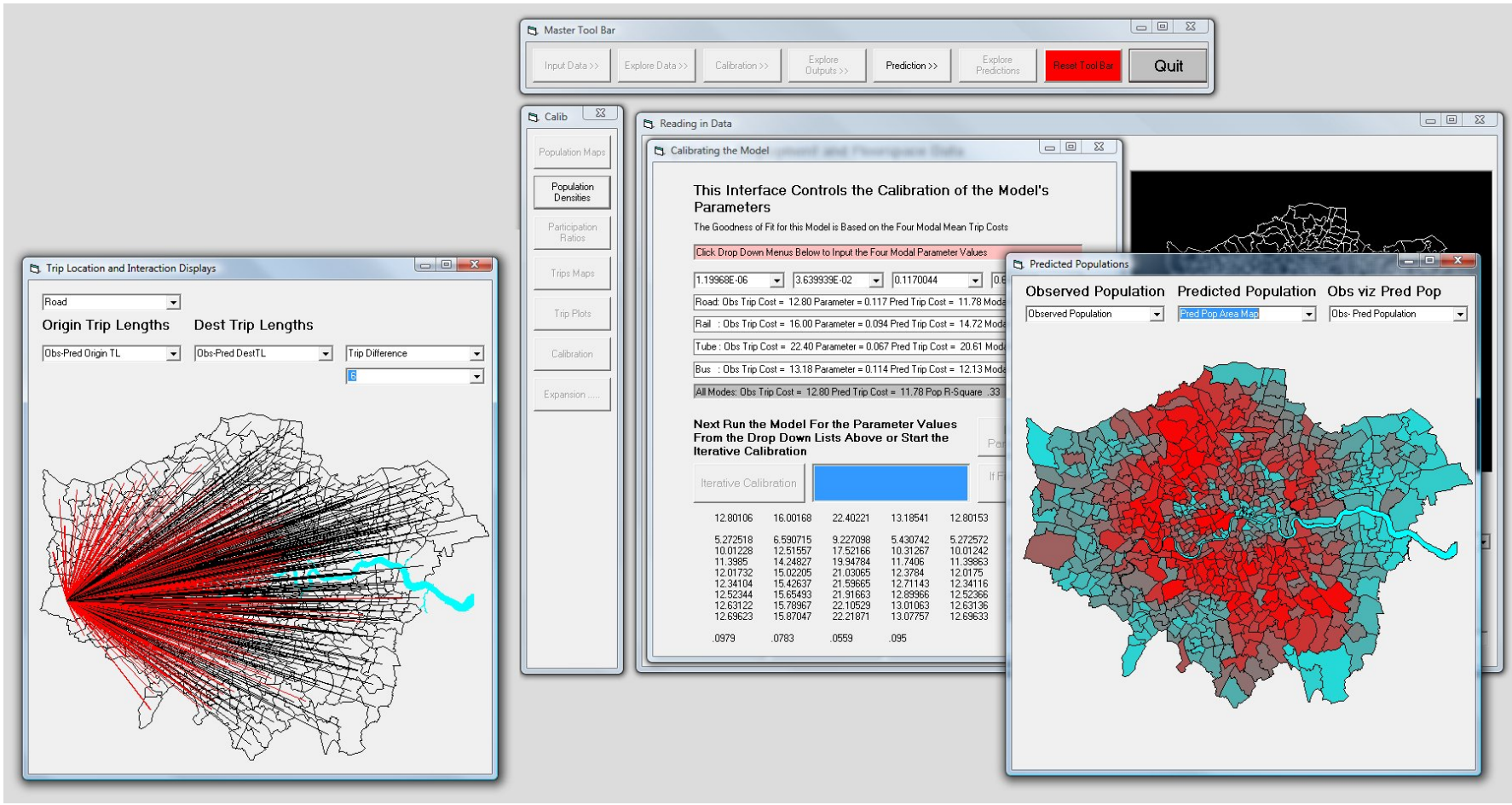
Employment and population are randomly distributed to cells within small zones and currently each one of the 4 million employment trips is predicted using crow-fly distance which can be computed on the fly.

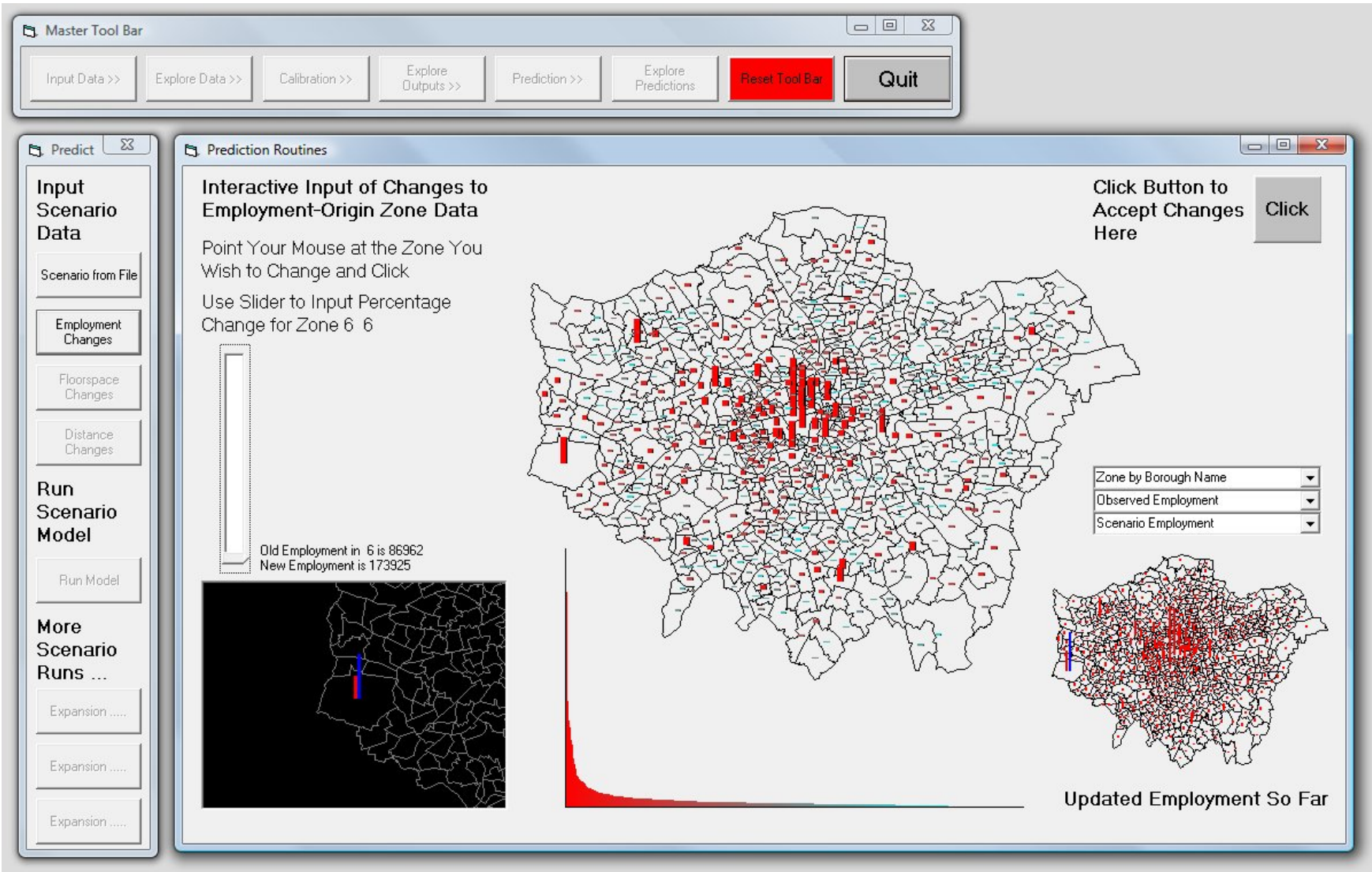
The random distribution is within zones to cell locations where employment and population is located from the land use data

The model is part of an integrated assessment of climate change scenarios up to 2050 and 2100 in London and the Thames Gateway, funded as part of the Cities Theme in the Tyndall Centre for Climate Change

Let us run the model to see what it does


Master Tool Bar
Input Data >>
Explore Data >>
Calibration >>
Explore Outputs >>
Prediction >>
Explore Predictions
Reset Tool Bar
Quit
Data
Map Raw Data
Map Derived Data
Plot Trip Data
Reading in Data
Population, Employment and Floorspace Data
READ
Employment Origin Zones
633
READ
Population Destination Zones
633
Click Here to Complete the Input of Data Directly
Read Employment Data
OK
Zone
Employment Data
Mapping Location Data
Employment
Population
Work Trips
Employment Maps
Population Maps
Interzonal Trip Flow Ma
Road
Employment Density
Population Density
Trip Density
6
Zones: 633 Wards in 2001
Zone
Ward
Borough
Locate Zone
Clear Zone Nodes
Data Input Has Been Completed


Master Tool Bar
Input Data >>
Explore Data >>
Calibration >>
Explore Outputs >>
Prediction >>
Explore Predictions
Reset Tool Bar
Quit
Calib
Population Maps
Population Densities
Participation Ratios
Trips Maps
Trip Plots
Calibration
Expansion .....
Reading in Data
Calibrating the Model
This Interface Controls the Calibration of the Model's Parameters
The Goodness of Fit for this Model is Based on the Four Modal Mean Trip Costs
Click Drop Down Menus Below to Input the Four Modal Parameter Values
1.19968E-06
3.639939E-02
0.1170044
Road: Obs Trip Cost = 12.80 Parameter = 0.117 Pred Trip Cost = 11.78 Mode
Rail : Obs Trip Cost = 16.00 Parameter = 0.094 Pred Trip Cost = 14.72 Mod
Tube : Obs Trip Cost = 22.40 Parameter = 0.067 Pred Trip Cost = 20.61 Mod
Bus : Obs Trip Cost = 13.18 Parameter = 0.114 Pred Trip Cost = 12.13 Mod
All Modes: Obs Trip Cost = 12.80 Pred Trip Cost = 11.78 Pop R-Square .33
Next Run the Model For the Parameter Values From the Drop Down Lists Above or Start the Iterative Calibration
Iterative Calibration
12.80106 16.00168 22.40221 13.18541 12.80153
5.272518 6.590715 9.227098 5.430742 5.272572
10.01228 12.51557 17.52166 10.31267 10.01242
11.3985 14.24827 19.94784 11.7406 11.39863
12.01732 15.02205 21.03065 12.3784 12.0175
12.34104 15.42637 21.59665 12.71143 12.34116
12.52344 15.65493 21.91663 12.89966 12.52366
12.63122 15.78967 22.10529 13.01063 12.63136
12.69623 15.87047 22.21871 13.07757 12.69633
.0979 .0783 .0559 .095
Trip Location and Interaction Displays
Road
Origin Trip Lengths
Dest Trip Lengths
Obs-Pred Origin TL
Obs-Pred DestTL
Trip Difference
6
Predicted Populations
Observed Population
Predicted Population
Obs viz Pred Pop
Observed Population
Pred Pop Area Map
Obs- Pred Population


Master Tool Bar
Input Data >>
Explore Data >>
Calibration >>
Explore Outputs >>
Prediction >>
Explore Predictions
Reset Tool Bar
Quit
Predict
Input Scenario Data
Scenario from File
Employment Changes
Floorspace Changes
Distance Changes
Run Scenario Model
Run Model
More Scenario Runs ...
Expansion .....
Expansion .....
Expansion .....
Prediction Routines
Interactive Input of Changes to Employment-Origin Zone Data
Point Your Mouse at the Zone You Wish to Change and Click
Use Slider to Input Percentage Change for Zone 6 6
Old Employment in 6 is 86962
New Employment is 173925
Click Button to Accept Changes Here
Click
Zone by Borough Name
Observed Employment
Scenario Employment
Updated Employment So Far

Conclusions and Next Steps

Parsimony and Models

New Ways of Validation

Replication – different places

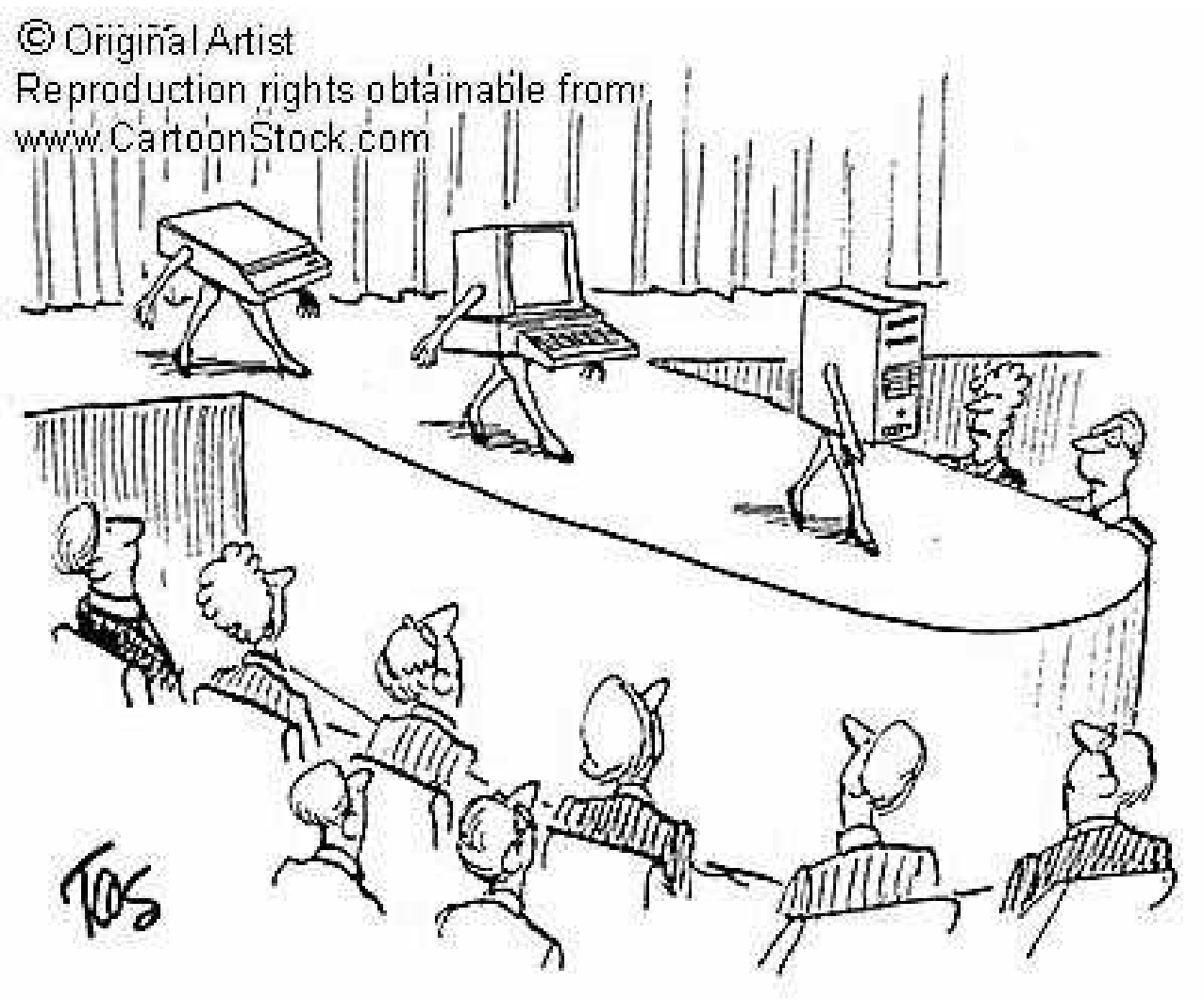
New Styles of Exploration …….

Questions?

I don’t know if there is time for any but please ask us later. Look at our websites and blogs

www.casa.ucl.ac.uk
www.genesis.ucl.ac.uk
www.gisagents.blogspot.com

We will put the paper up on Thursday as a Working Paper on our web site



The new catwalk