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Land Use Transportation Models: Applications to Greater London

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Outline

- LUTI Models: A Little Bit of History, Early Graphics Interfaces, and the Tyndall Model
- SIMULACRA: ARCADIA and SCALE Projects
- Requirements: The Model Design: Models Flows: Physical Movements, Money & the Residential Model
- The Visual Template: The Desktop Model: Running It
- Building a Web-Based Model Interface
- Data Bases: Location, Interactions & Networks
- Current Challenges for Immediate Developments
- The SIMULACRA Web Applications

LUTI Models: A Little Bit of History, Early Graphics Interfaces, and the Tyndall Model

Early models: CATS 1955: The 1960s Models

Largeness, remoteness from users, crude representation, limits on computation, poor links to policy

Lack of understanding of model outcomes

Statics versus dynamics – semi-dynamic models but most operational models predicated in terms of equilibrium and as we have seen, the most developed are structured in terms of a dynamic equilibrium

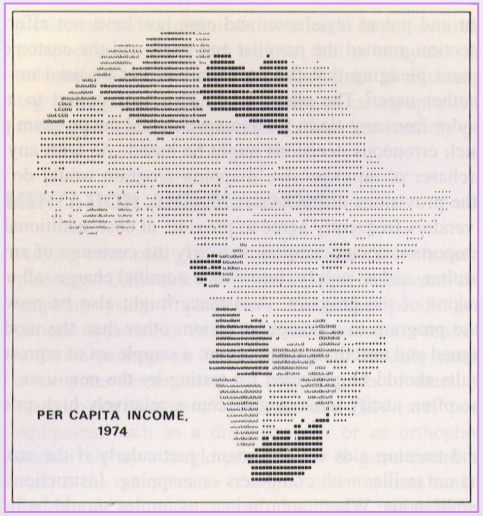
Disaggregation of sectoral activities

Early attempts at Visualisation: Traffic Flows in CATS, and Schmidt's model of the growth of East Lansing 1967

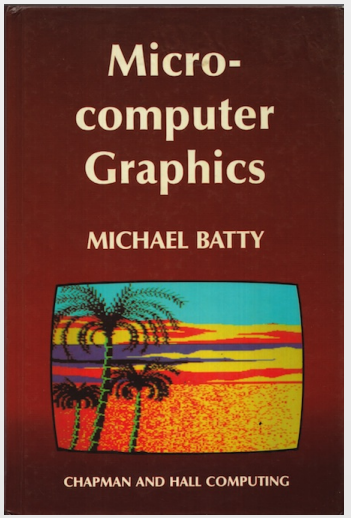
Harvard Lab: SYMAP – Symbol Mapping Systems, 1967-1970

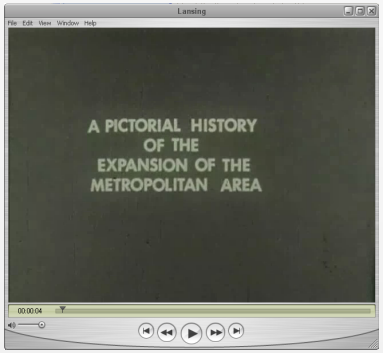
Early cathode ray displays, 1960

Apart from some SYMAP applications, my own attempts began in the early 1980s with the Melbourne Model




Program 1.1 'Mickey Mouse' line printer program-plot
© 1987 The Walt Disney Company




Lansing
File Edit View Window Help
A PICTORIAL HISTORY
OF THE
EXPANSION OF THE
METROPOLITAN AREA
00:00:04


Lansing
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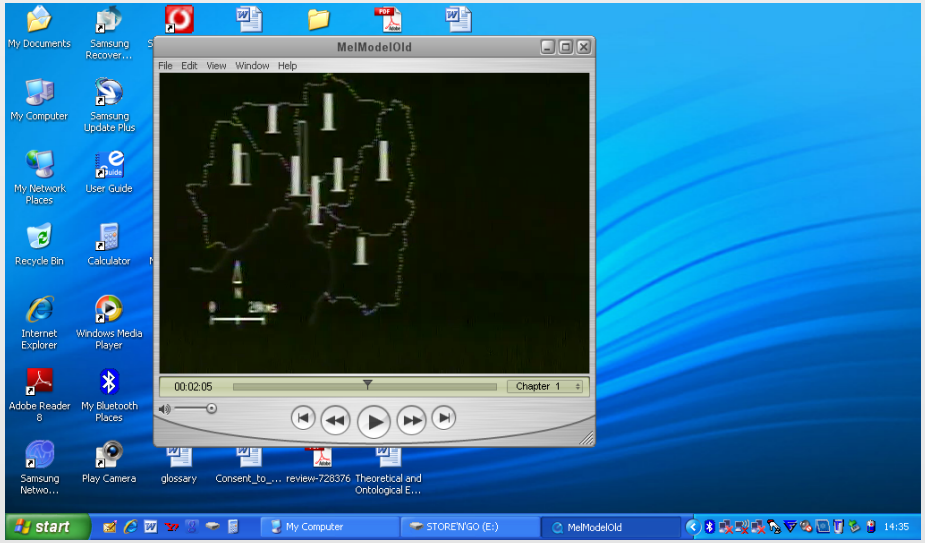
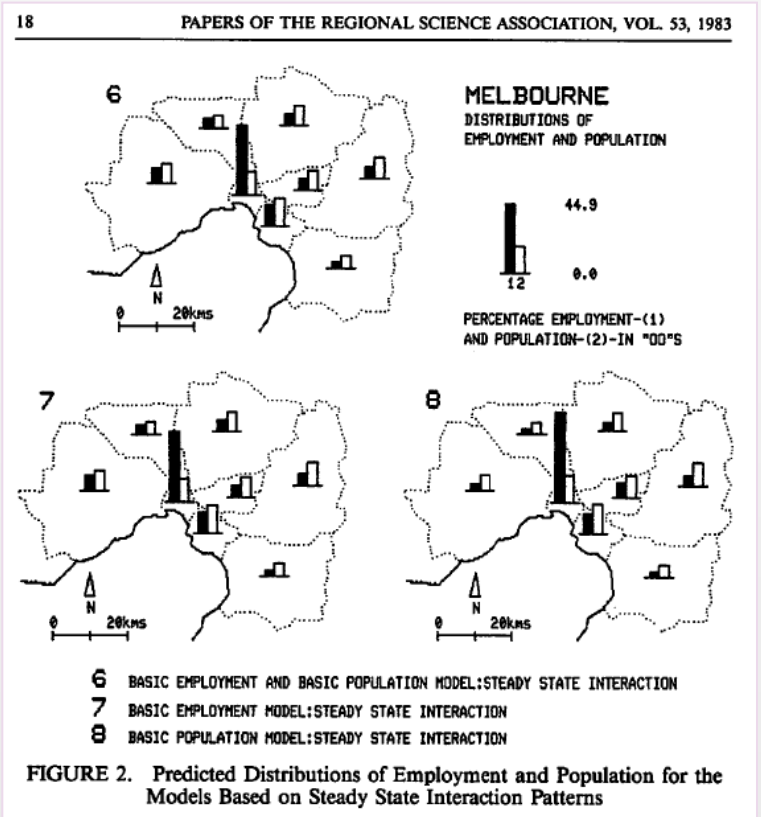
1965
00:02:58

I didn't work on these models as such from about 1982 onwards as I got into fractal type stuff with Paul (Longley) but I did develop quite a lot of visualisations really for demo and teaching purposes

Early version of Melbourne model in 1982 and then development of a WATFor77 version in 1986

The Melbourne Version is primitive and not nice to look at because we attached a video to the raster display device





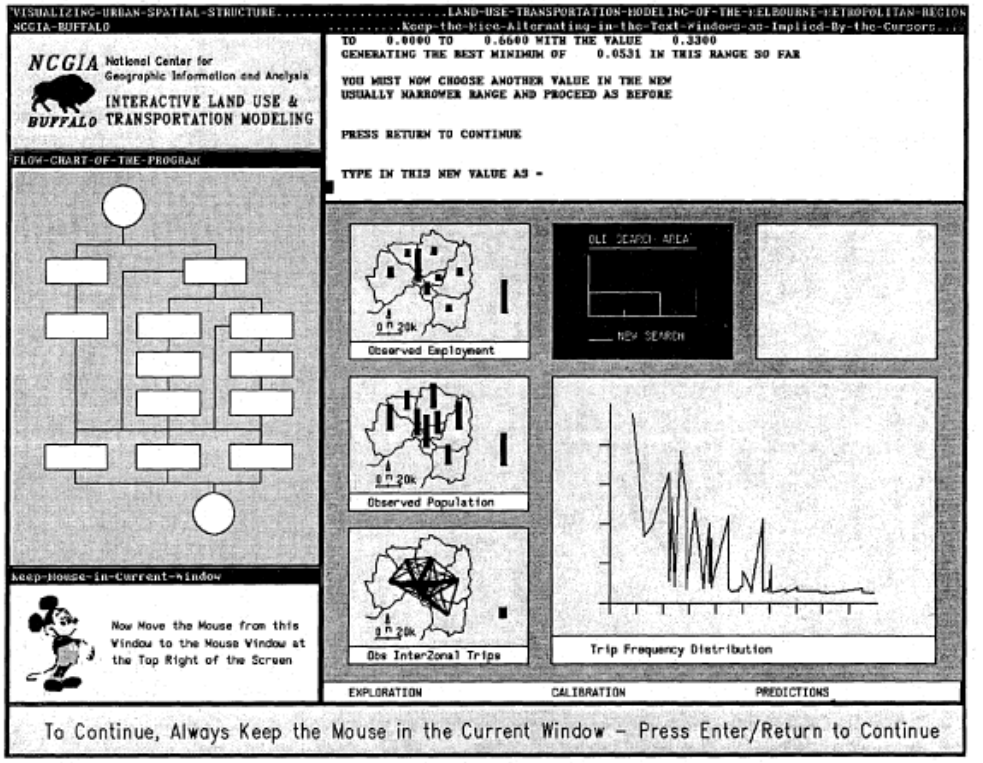


Figure 6. Progress in calibrating the model using dichotomous search.

From a VAX Terminal – A Raster 1982

From a Sun Workstation – Simple Windows - 1991

I don't have time to show the 1986 demo – but it still runs under DOS on this laptop

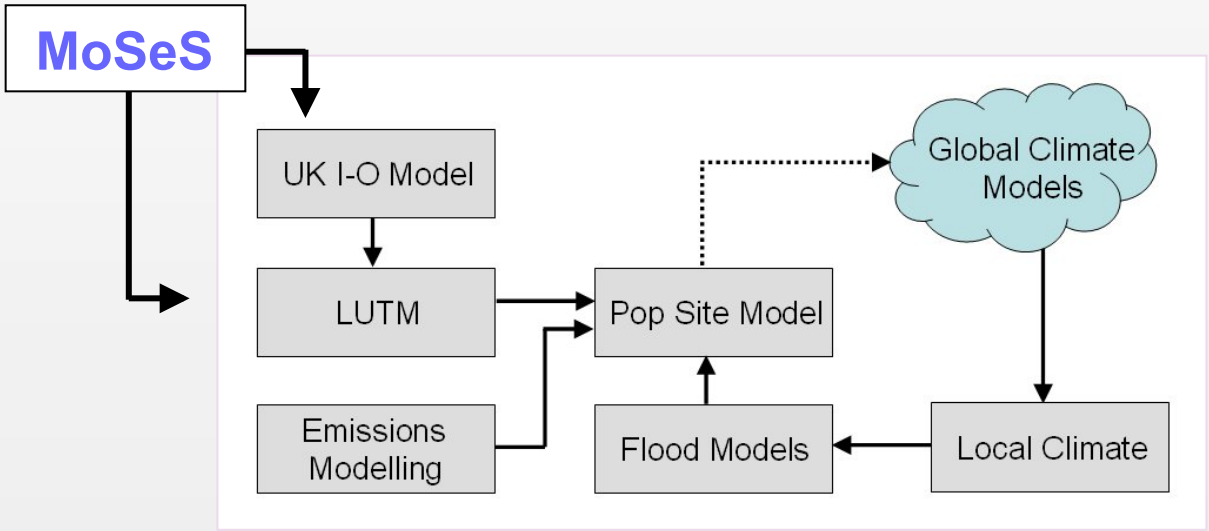
And bringing it all more up to date:

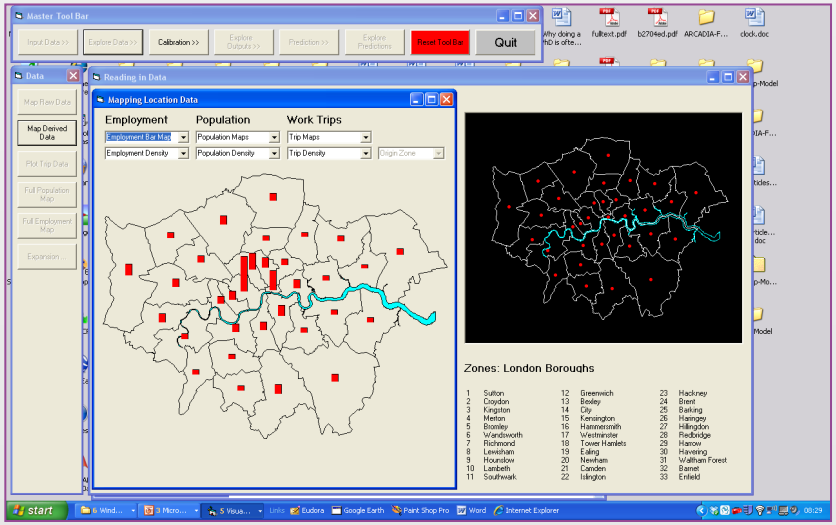
We began the current wave of urban models which led to SIMULACRA the model system I am talking about today with our application to climate change in the Tyndall Model where one of our guiding principles was to communicate the model as easily and as effectively as possible to our stakeholders

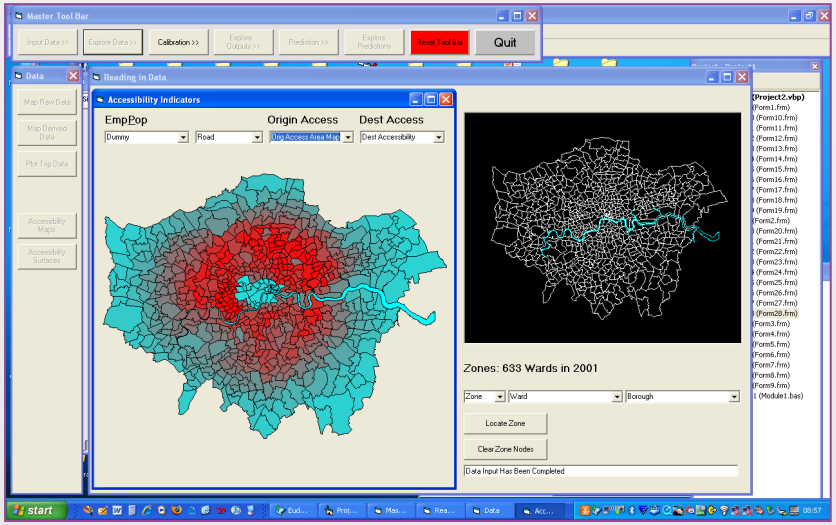
These were largely policy analysts and had some expertise in climate change problems and some knowledge of models of various kinds but not any one particular model

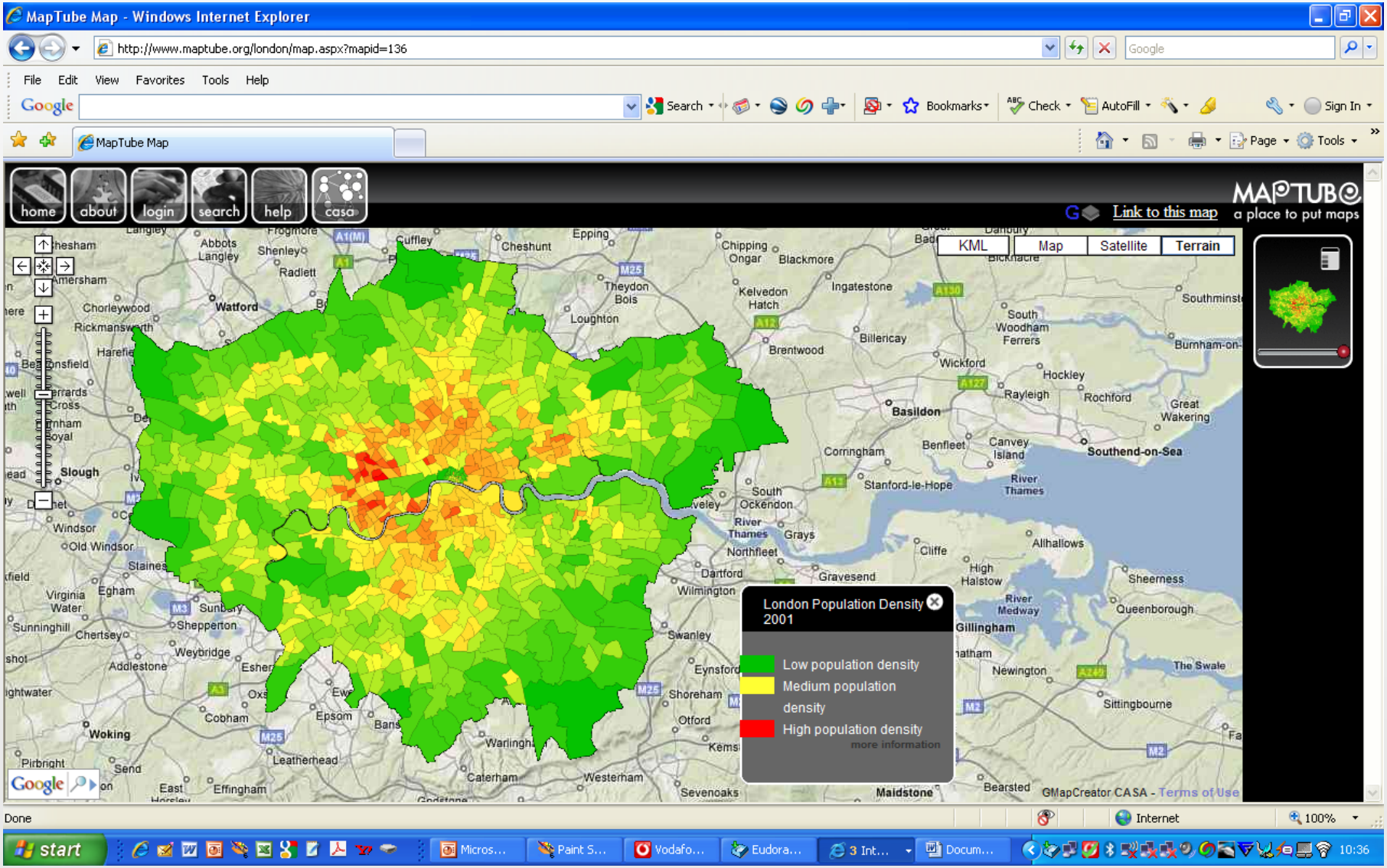
We also needed to communicate these ideas to other modellers, such as the flood modellers, input-output people and so on

Hence our focus still on visualisation, besides the sort of complexity that these ideas portrayed which we believe requires visualisation at every stage of the process.


MoSeS
UK I-O Model
LUTM
Emissions Modelling
Pop Site Model
Flood Models
Global Climate Models
Local Climate

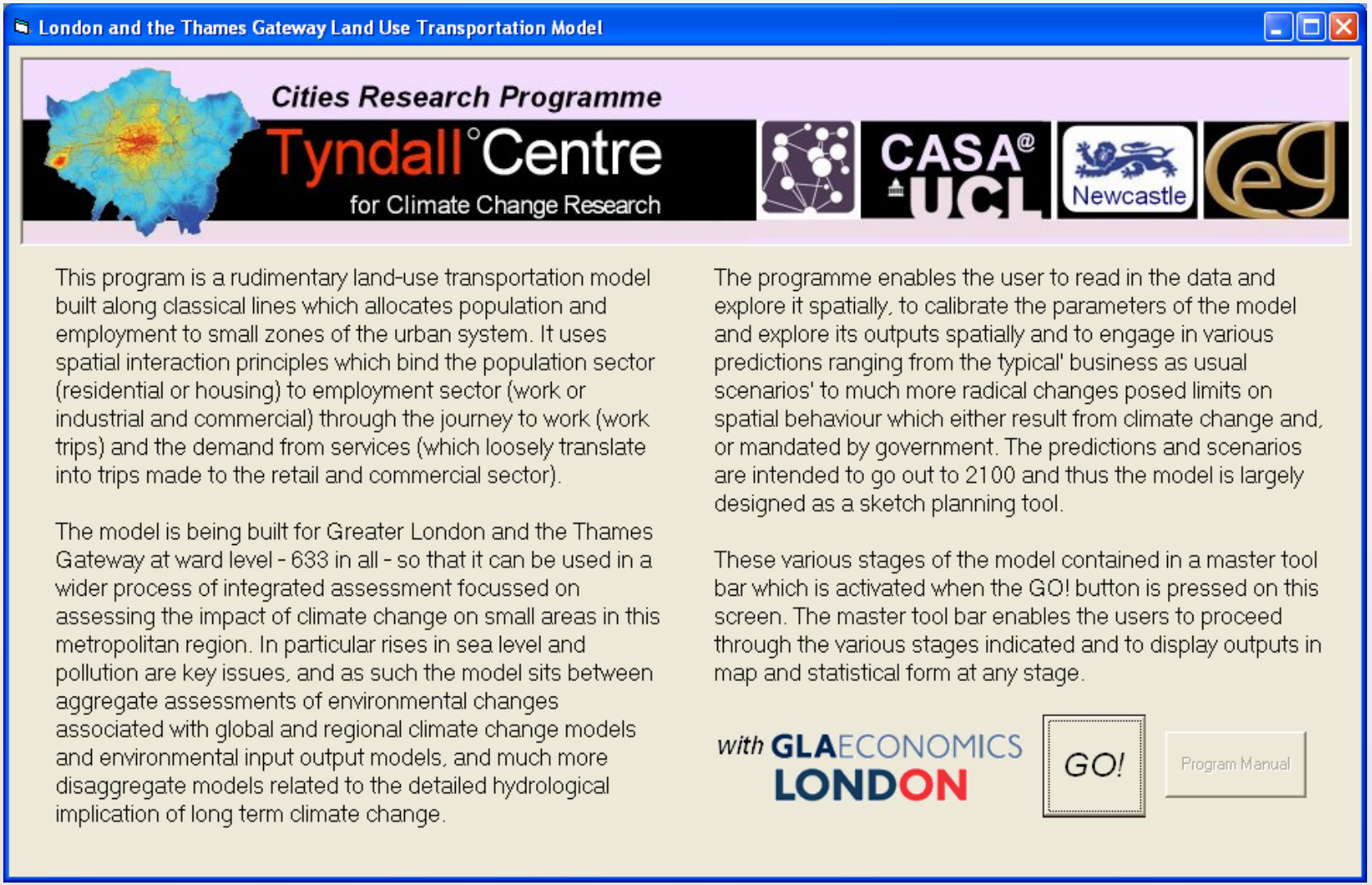

Master Tool Bar
Quit
Reading in Data
Mapping Location Data
Employment
Population
Work Trips
Zones: London Boroughs

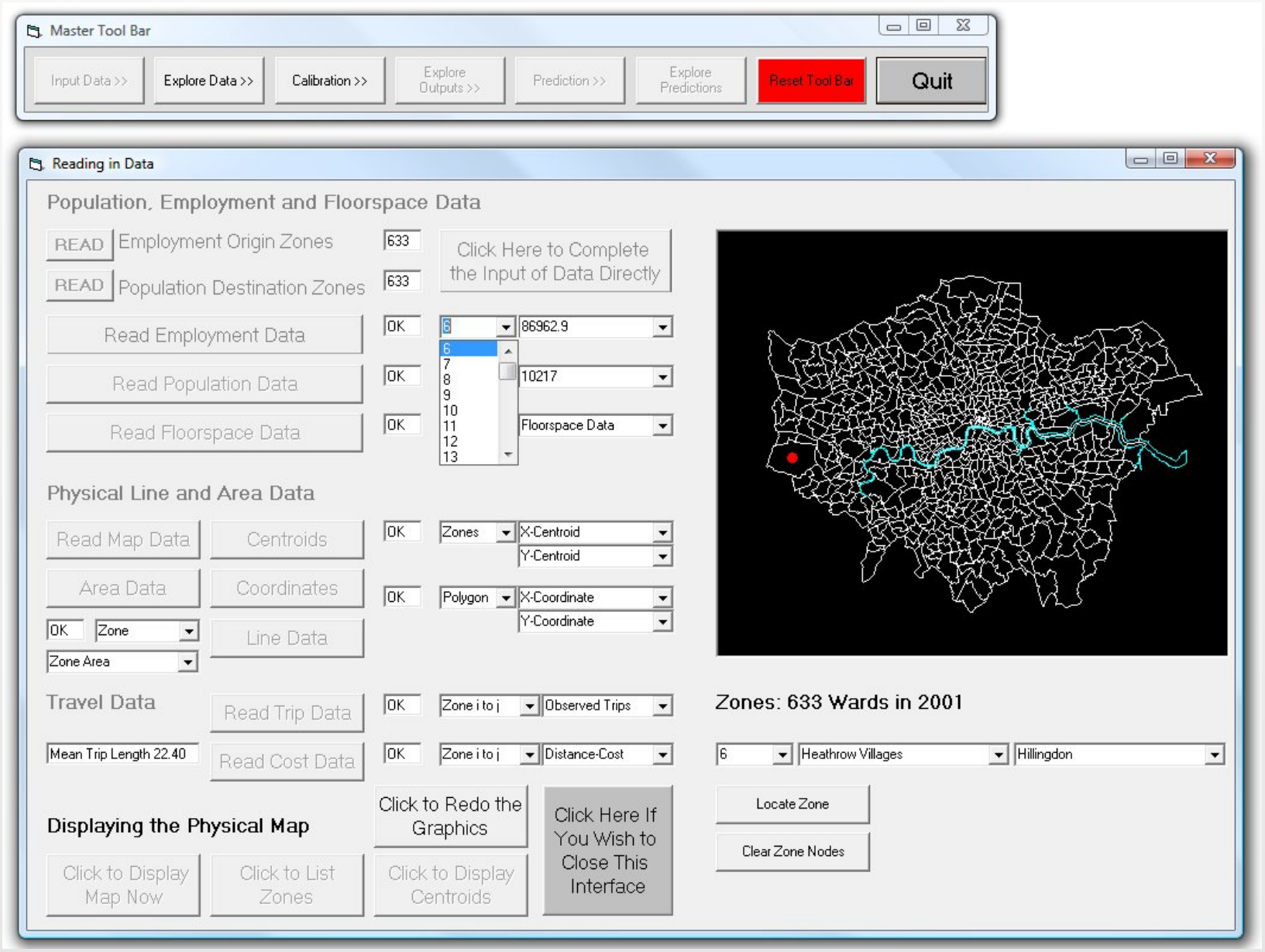

Master Tool Bar
Quit
Reading in Data
Accessibility Indicators
EmpPop
Origin Access
Dest Access
Zones: 633 Wards in 2001
Locate Zone
Clear Zone Nodes
Data Input Has Been Completed

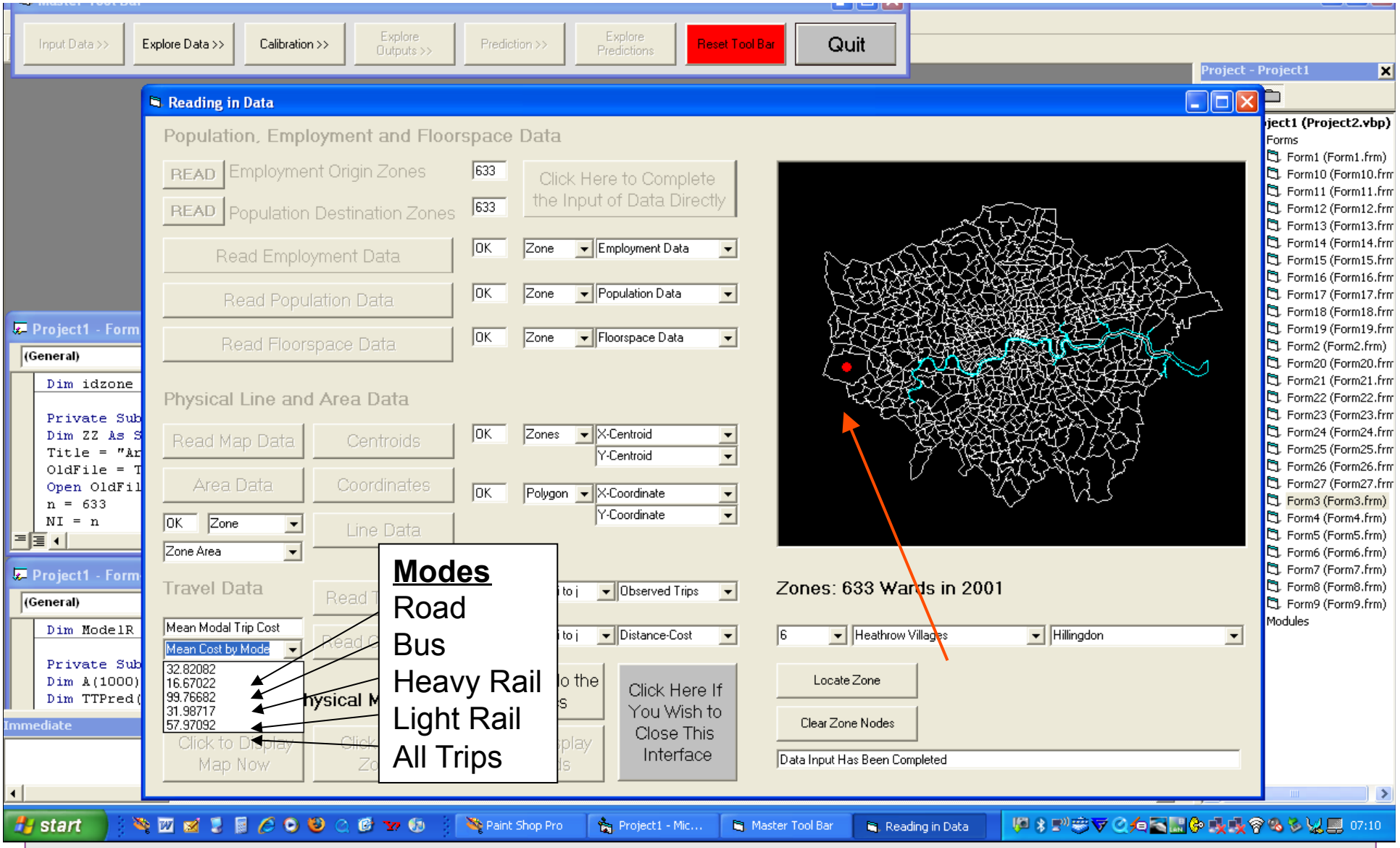


Go to www.maptube.org to see many maps of Greater London

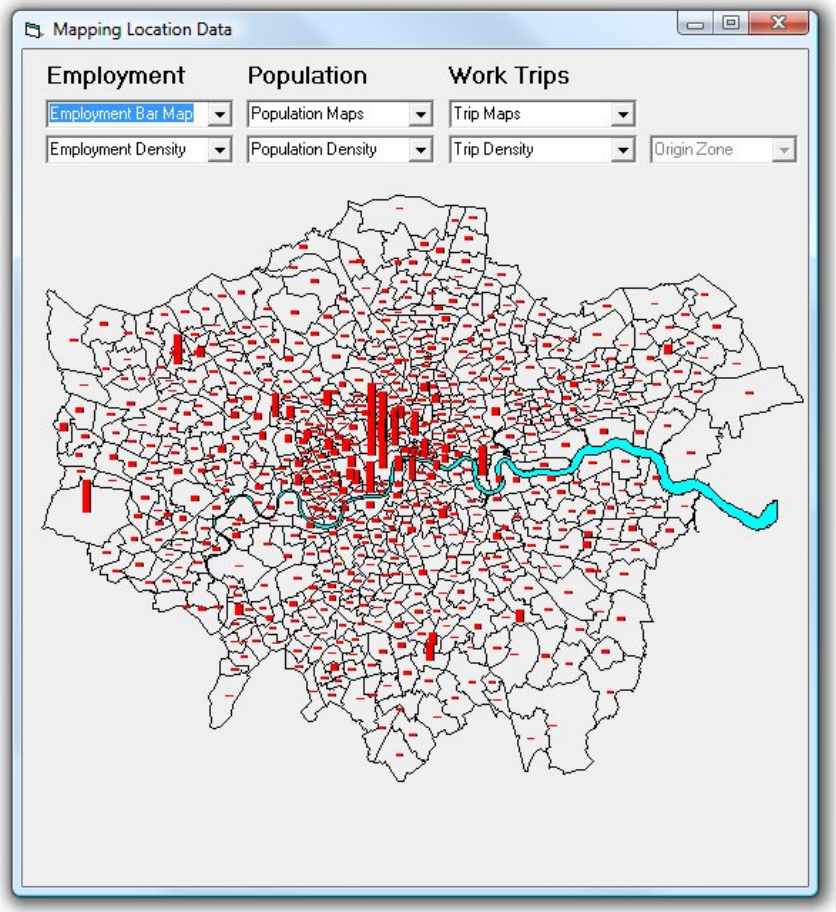
The Model Interface

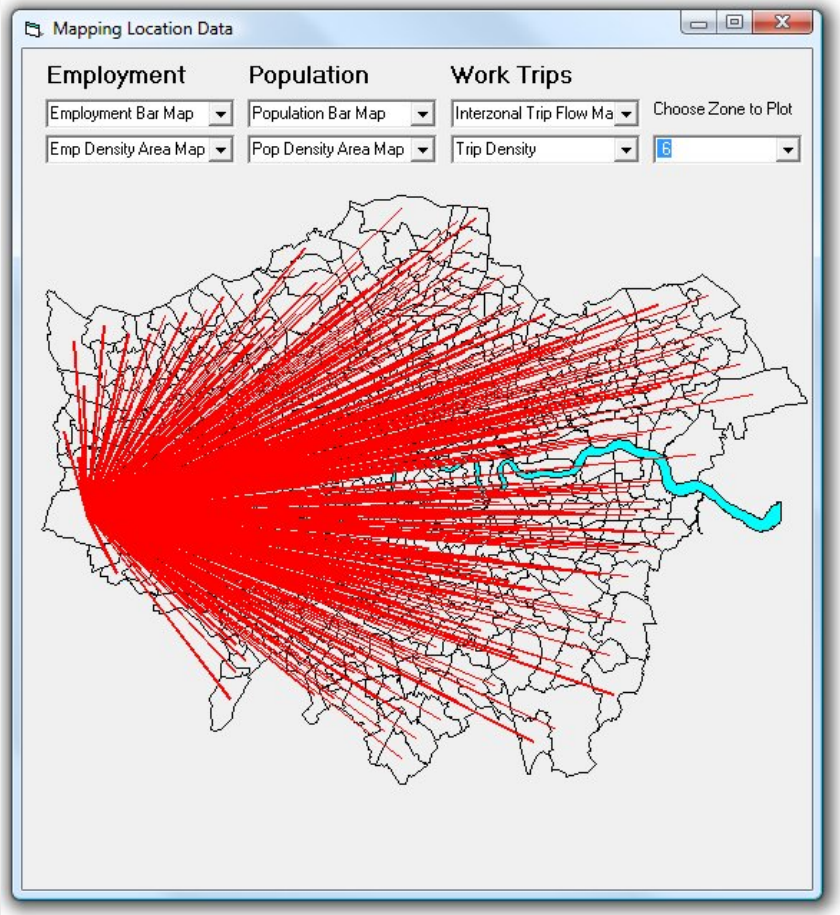


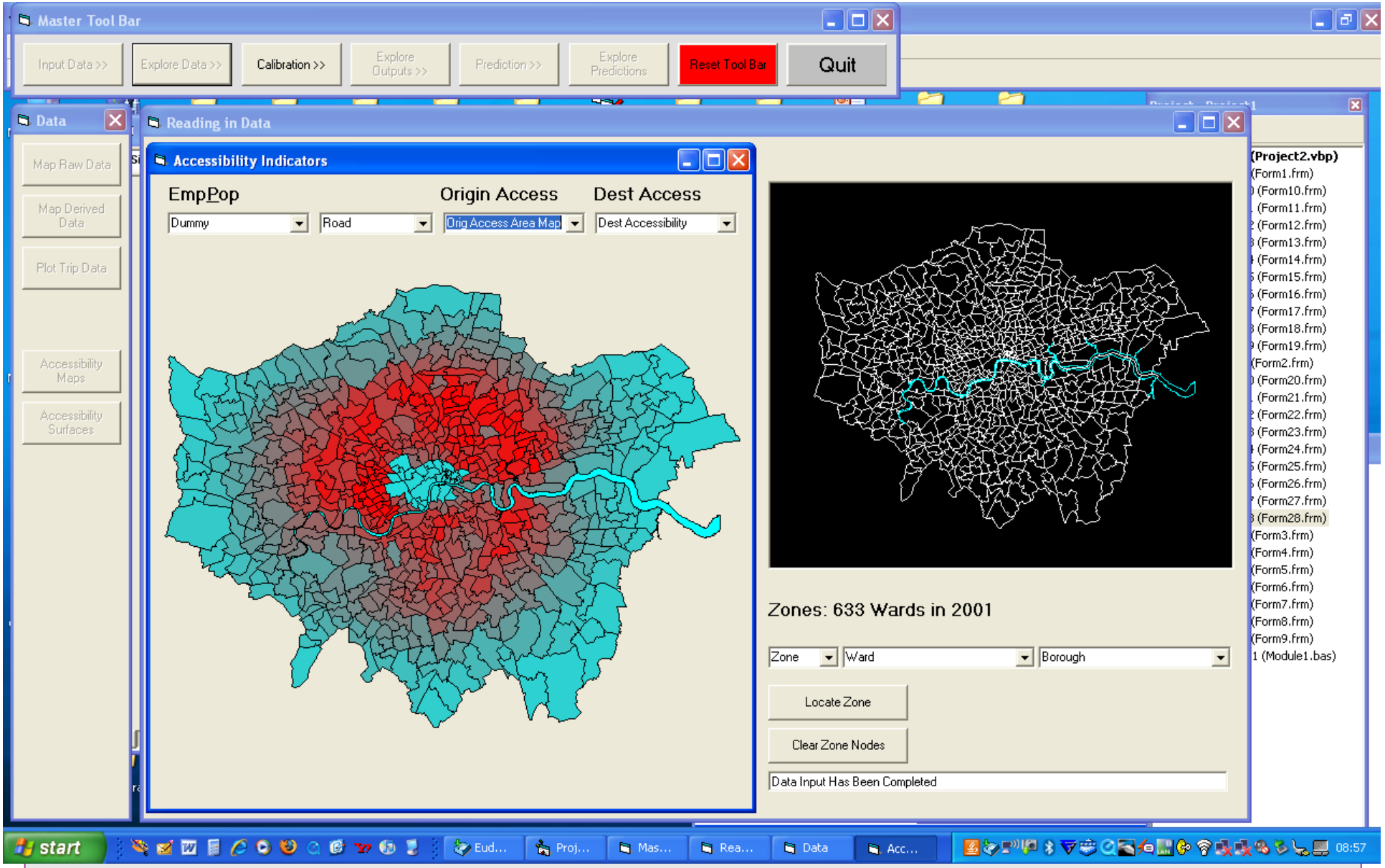

Master Tool Bar
Input Data >>
Explore Data >>
Calibration >>
Explore Outputs >>
Prediction >>
Explore Predictions
Reset Tool Bar
Quit
Reading in Data
Population, Employment and Floorspace Data
READ
Employment Origin Zones
633
READ
Population Destination Zones
633
Click Here to Complete the Input of Data Directly
Read Employment Data
OK
6
86962.9
6
7
8
9
10
11
12
13
Read Population Data
OK
10217
Read Floorspace Data
OK
Floorspace Data
Physical Line and Area Data
Read Map Data
Centroids
OK
Zones
X-Centroid
Y-Centroid
Area Data
Coordinates
OK
Polygon
X-Coordinate
Y-Coordinate
OK
Zone
Line Data
Zone Area
Travel Data
Read Trip Data
OK
Zone i to j
Observed Trips
Mean Trip Length 22.40
Read Cost Data
OK
Zone i to j
Distance-Cost
Zones: 633 Wards in 2001
6
Heathrow Villages
Hillingdon
Displaying the Physical Map
Click to Redo the Graphics
Click Here If You Wish to Close This Interface
Locate Zone
Clear Zone Nodes
Click to Display Map Now
Click to List Zones
Click to Display Centroids



Road: 38%; Bus: 12%: Heavy Rail: 12%: Light Rail 19%; Other (Walk, Bike, Fly): 19%

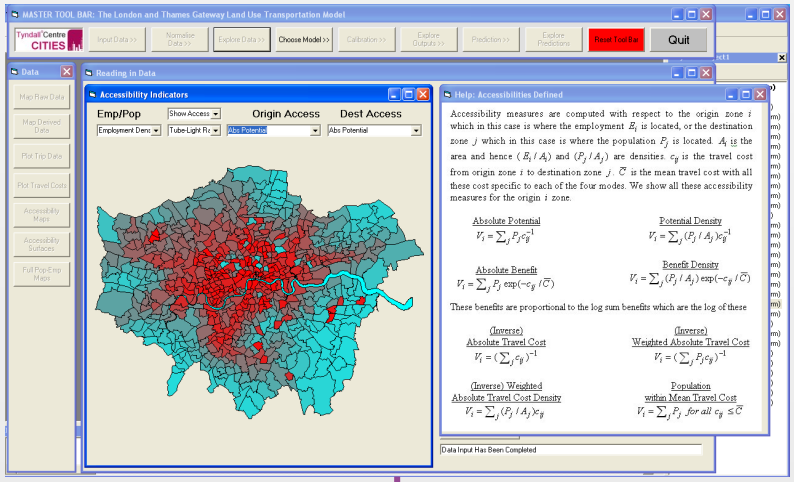

Mapping Location Data
Employment
Population
Work Trips
Employment Bar Map
Population Maps
Trip Maps
Employment Density
Population Density
Trip Density
Origin Zone


Mapping Location Data
Employment
Population
Work Trips
Employment Bar Map
Population Bar Map
Interzonal Trip Flow Ma
Choose Zone to Plot
Emp Density Area Map
Pop Density Area Map
Trip Density
6


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
Accessibility Maps
Accessibility Surfaces
Reading in Data
Accessibility Indicators
EmpPop
Origin Access
Dest Access
Dummy
Road
Orig Access Area Map
Dest Accessibility
Zones: 633 Wards in 2001
Zone
Ward
Borough
Locate Zone
Clear Zone Nodes
Data Input Has Been Completed
(Project2.vbp)
(Form1.frm)
(Form2.frm)
(Form3.frm)
(Form4.frm)
(Form5.frm)
(Form6.frm)
(Form7.frm)
(Form8.frm)
(Form9.frm)
1 (Module1.bas)
start
08:57

Accessibility from the LUTM model

Many different accessibility measures, 8 in all



Help: Accessibilities Defined

Accessibility measures are computed with respect to the origin zone i which in this case is where the employment E_i is located, or the destination zone j which in this case is where the population P_j is located. A_i is the area and hence (E_i / A_i) and (P_j / A_j) are densities. c_{ij} is the travel cost from origin zone i to destination zone j. $\overline{C}$ is the mean travel cost with all these cost specific to each of the four modes. We show all these accessibility measures for the origin i zone.

Absolute Potential
$$V_i = \sum_j P_j c_{ij}^{-1}$$

Potential Density
$$V_i = \sum_j (P_j / A_j) c_{ij}^{-1}$$

Absolute Benefit
$$V_i = \sum_j P_j \exp(-c_{ij} / \overline{C})$$

Benefit Density
$$V_i = \sum_j (P_j / A_j) \exp(-c_{ij} / \overline{C})$$

These benefits are proportional to the log sum benefits which are the log of these

(Inverse) Absolute Travel Cost
$$V_i = (\sum_j c_{ij})^{-1}$$

(Inverse) Weighted Absolute Travel Cost
$$V_i = (\sum_j P_j c_{ij})^{-1}$$

(Inverse) Weighted Absolute Travel Cost Density
$$V_i = \sum_j (P_j / A_j) c_{ij}$$

Population within Mean Travel Cost
$$V_i = \sum_j P_j \text{ for all } c_{ij} \leq \overline{C}$$

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 .....

Reading in Data

Prediction Routines

Long Term Scenarios Based on the Impact of Changes in Employment, Residential Floorspace, and Transport Costs

Predictions with the model involve forecasting the location of small area populations and the trip patterns associated with the four modes used to distribute employment as population to these small (residential) areas. This involves changing the input variables - employment and residential floorspace by small area, and the travel costs associated with each mode of transport, which in turn imply changes to the transport infrastructure. The user also has control over the parameter values on the friction of Travel Cost or travel cost associated with each mode. This can be changed in value to reflect changes in the average Travel Cost or cost travelled on each mode.

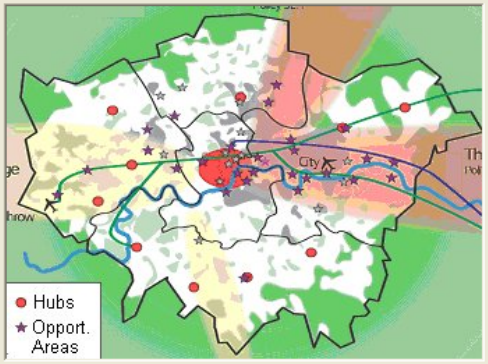
Users have a choice of inputting a preset scenario in which all these variables are changed exogenously or a process of changing these variables interactively, on screen. The interactive process can involve many thousands of changes and is probably best used to input data which reflects 'what-if' scenarios which require a small number of rather simple changes in the inputs reflecting substantial or radical change.

By clicking the 'Scenario from File' button in the toolbar to the left, a preset scenario is loaded and the user is then taken to the point where the model must be run. Alternatively if the user clicks the Employment Changes button, the user activates a screen where each employment zone can be identified by pointing the mouse at it and clicking. Then the user can use a slider bar to increase the value of employment in that zone by up to 100 percent or decrease it by up to 100 percent. As many zones as required can be changed using this method. When the user is satisfied with the employment scenario which has been developed, a button accepting these changes can be clicked. The same can then be done for floorspace activated by clicking the relevant button from the toolbar to the left.

Finally the travel cost on any link by any mode from one zone to another can be changed using the same method. An origin and then a destination zone need to be clicked and then reduced or increased travel cost (by up to 100 percent) made using the slider bar. The user must choose the mode each time and the program then recomputes all the shortest routes implied by these changes once the changes are accepted.

The user then proceeds to run the model as for the 'Scenario from File' option and once this is done, the outputs can be visualised using the same system for exploring the data and calibration results.

Key Elements of the London Plan to 2025 Shown Below.



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(Form1.frm)
(Form10.frm)
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(Form18.frm)
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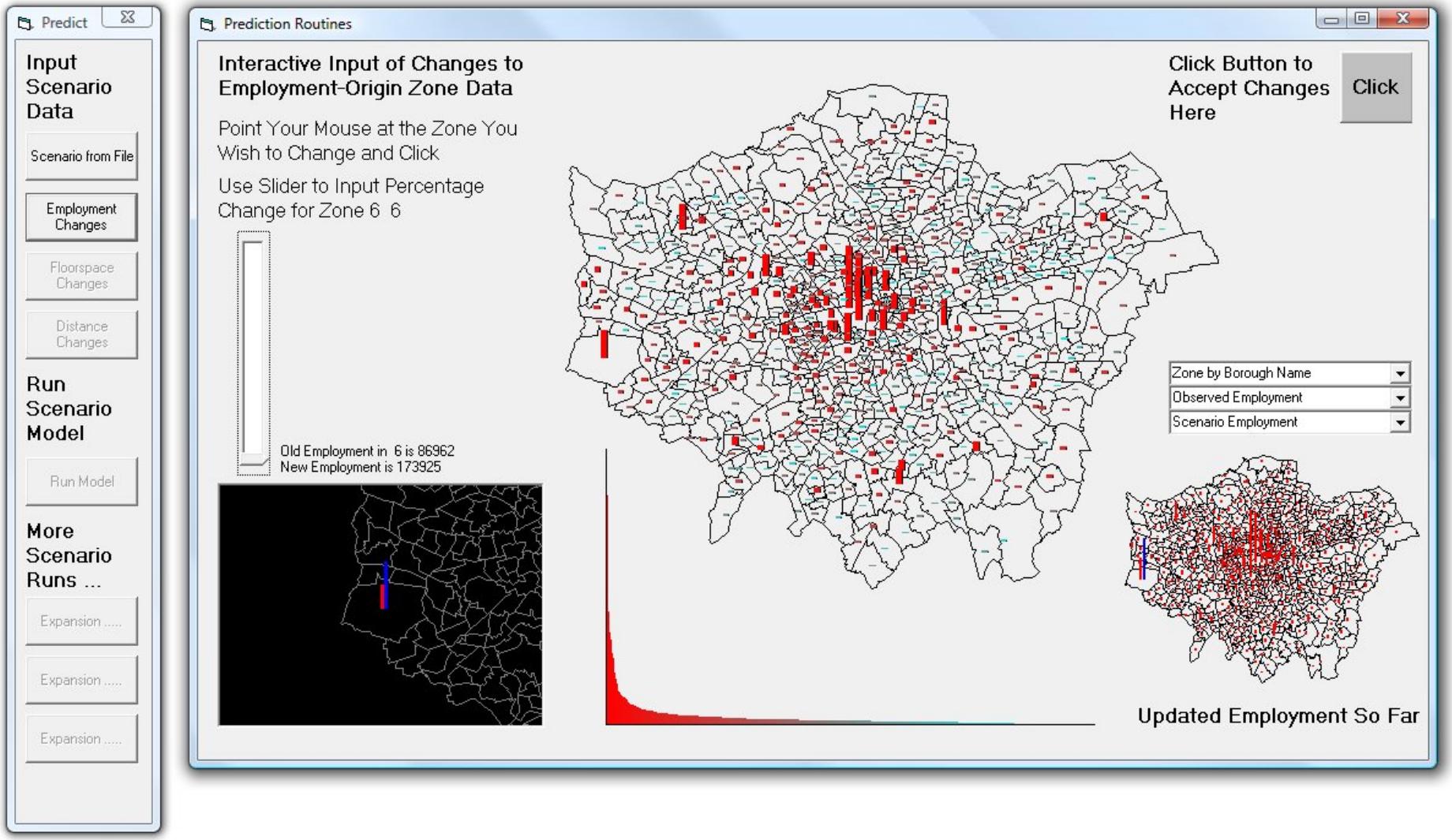
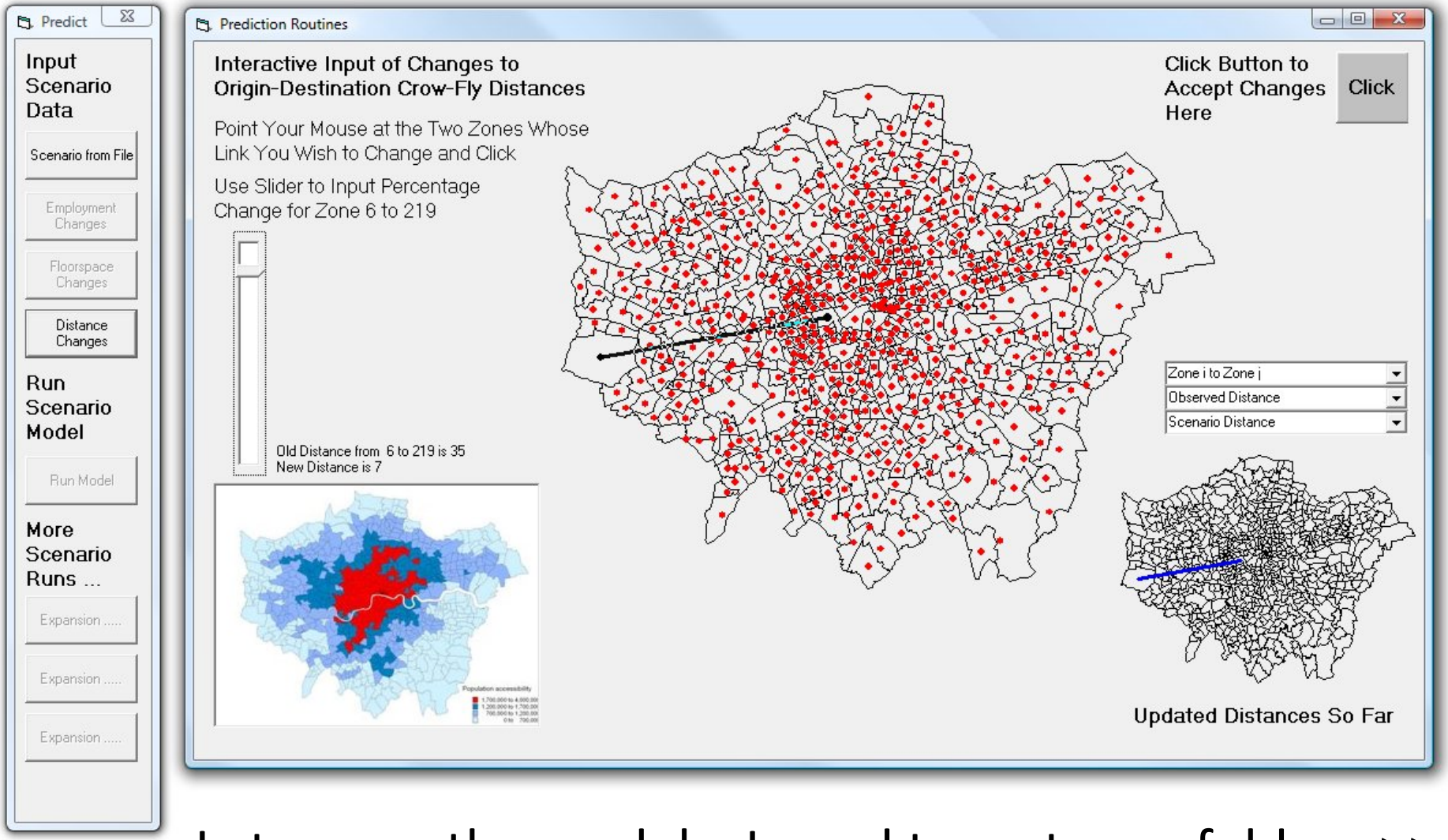
(Form6.frm)
(Form7.frm)
(Form8.frm)
(Form9.frm)
(Module1.bas)

start

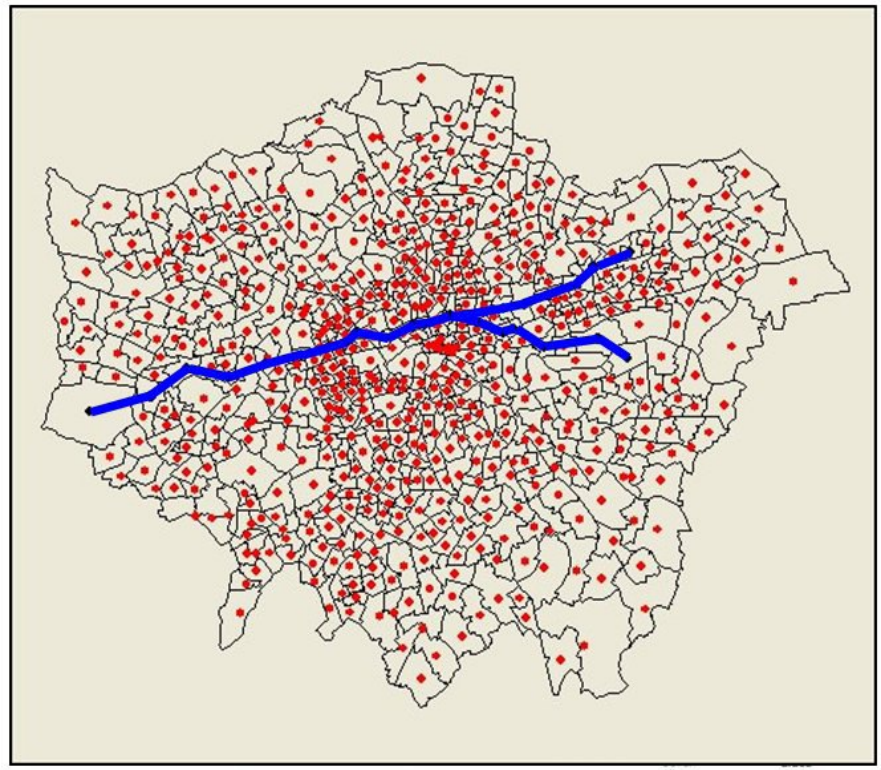
08:59

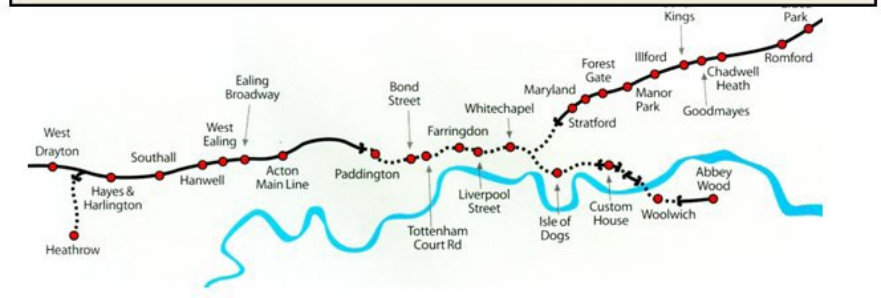

Predict
Input Scenario Data
Scenario from File
Employment Changes
Floorspace Changes
Distance Changes
Run Scenario Model
Run Model
More Scenario Runs ...
Expansion .....
Expansion .....
Expansion .....
Prediction Routines
Interactive Input of Changes to Employment-Origin Zone Data
Point Your Mouse at 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

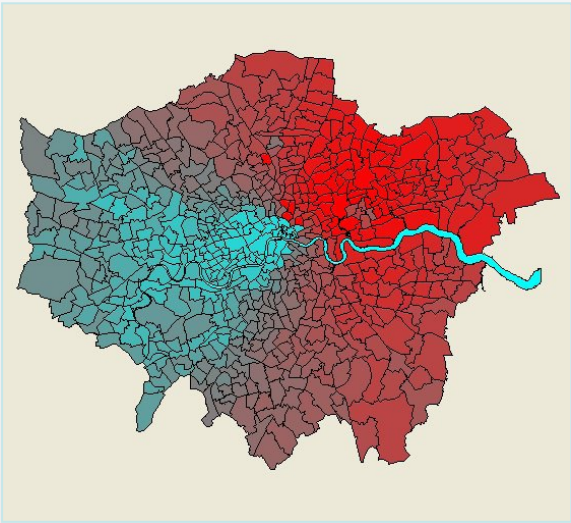


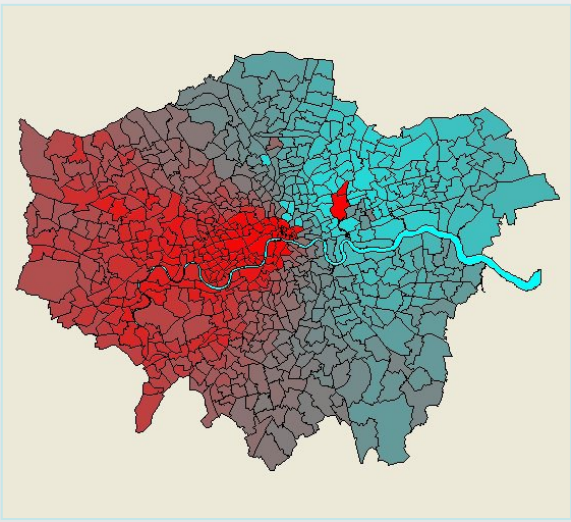
Let us ***run*** the model… I need to go to my folder…>>

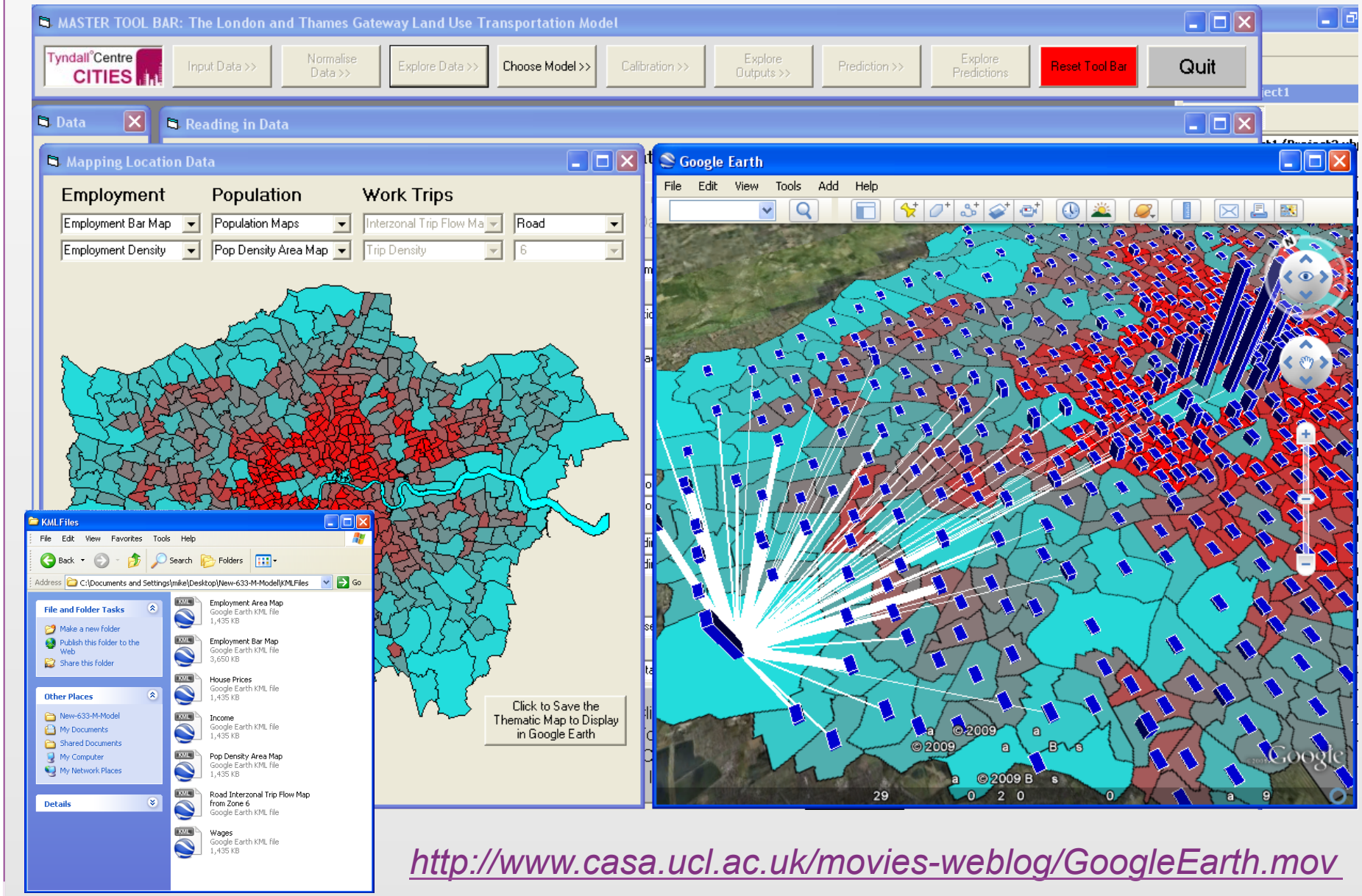
Testing the impact of Cross Rail-1











http://www.casa.ucl.ac.uk/movies-weblog/GoogleEarth.mov

SIMULACRA: ARCADIA and SCALE Projects

SIMULACRA[1] is a generic set of models that we are building for a series of projects, first the ARCADIA project that is an extension of Tyndall, and then for another EPSRC Project called SCALE which deals with energy change in large cities

We can develop lots of variants, which test the robustness of any approach while at the same time, enabling models to be tuned to the problem in hand.

But let me tell you essentially how these kinds of models are constructed and build on what Alan has told you in the last three weeks.

---

[1] *SIMulation of Urban Landuse, And Commercial and Residential Activities*

We want to be able to do the following:

Alter and aggregate the zoning system quickly and easily, on the fly almost

Alter by adding and deleting different model sectors, so for example running a model based on simply the retailing and other employment sectors without the residential and so on

Subjecting the model to various kinds of physical constraints, at will and according to external policies

Extending all sectors to not only predict endogenous activities but to also be subject to exogenous inputs of the same

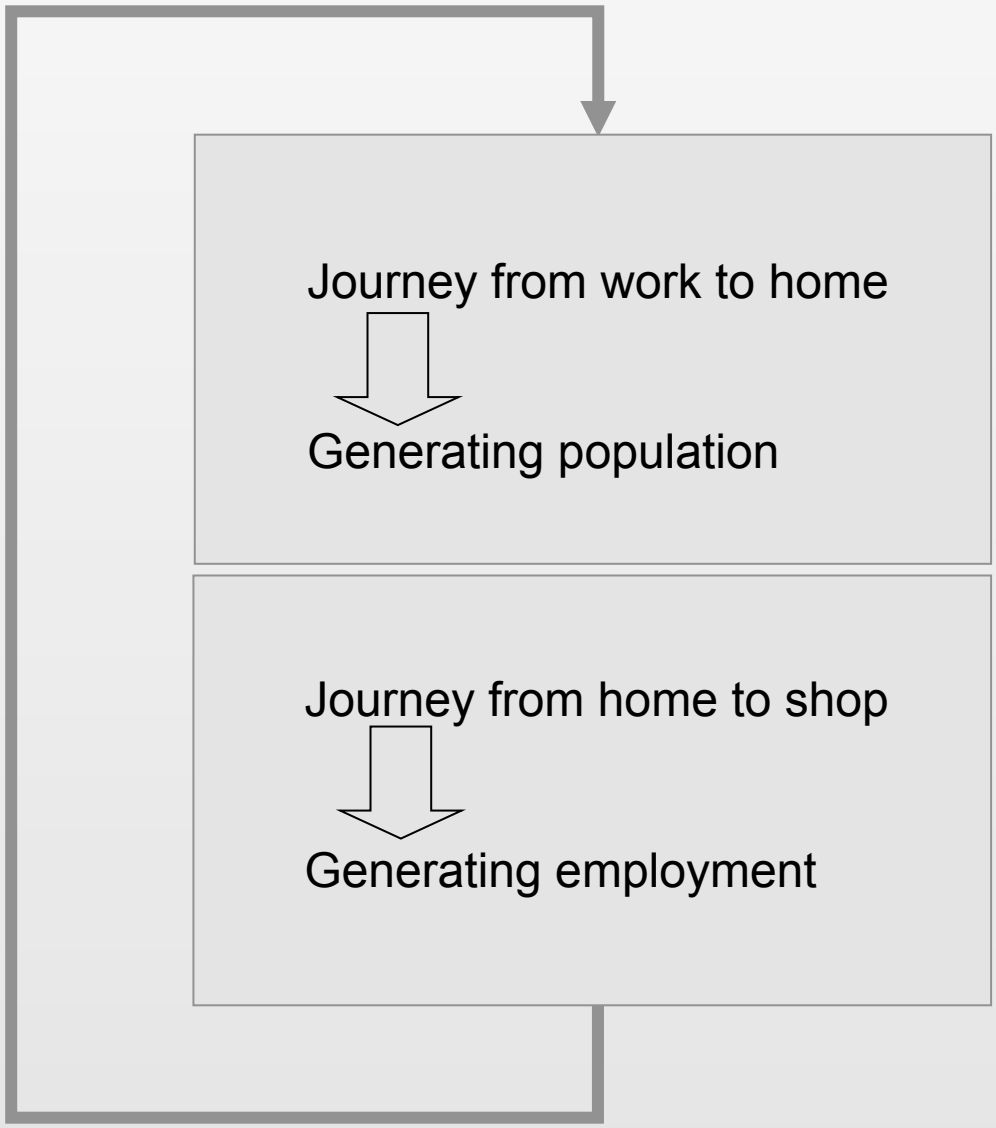
To interface the models easily and quickly with other sectoral models, particularly demographic and possibly more established transport models

Requirements: The Model Design: Models Flows: Physical Movements, Money & the Residential Model

We will now show the current model to present the logic of our framework. Our model has now been scaled up massively to include the outer met area – 1767 zones (33 – 633 – 1767)

It is now a three sector model, not simply a residential location model as it includes internal employment location, retail location and residential location

So far, we do not have modal split or any disaggregation of the sectors but we will have five modes and then probably 5 population categories and maybe 5 employment types in terms of occupations – in short the model will ultimately scale up to some 100 times the size of the current model



We have two or more sectors where each sector is build around a gravity or spatial interaction model

And the sectors are coupled

They forward and backward into one another

Here are the detailed submodels

$$T_{ij} = E_i \frac{D_j \exp(-\beta c_{ij})}{\sum_j D_j \exp(-\beta c_{ij})}$$

$$P_j = \sum_i T_{ij}$$

Journey from work to home

Generating population

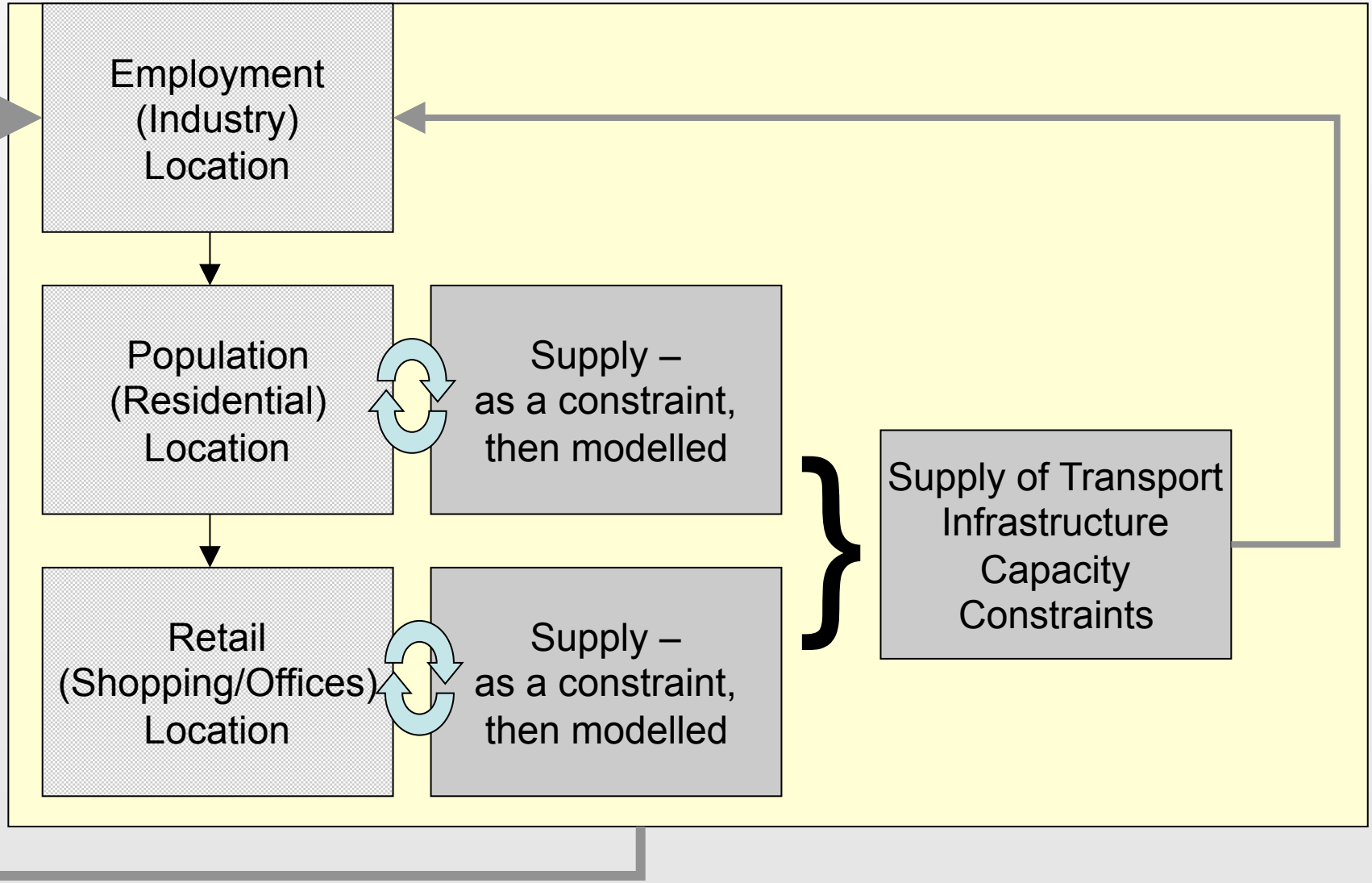
$$S_{jk} = P_j \frac{D_k \exp(-\lambda c_{jk})}{\sum_k D_k \exp(-\lambda c_{jk})}$$

$$E_k = \sum_j S_{jk}$$

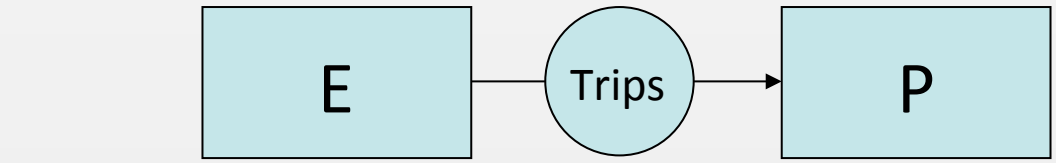
Journey from home to shop

Generating employment

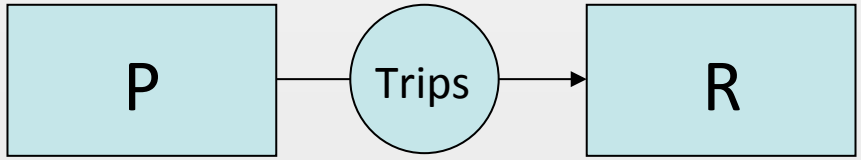
The model can be extended to embrace supply constraints



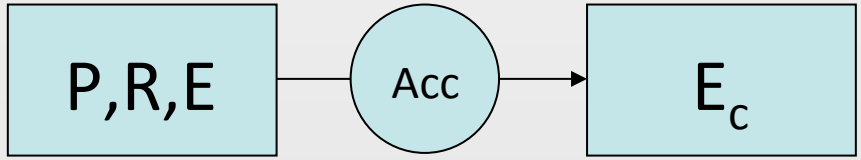
In fact it is easier to show the model structure as follows where we can see how we can elaborate it as a static or dynamic equilibrium model in terms of physical flows



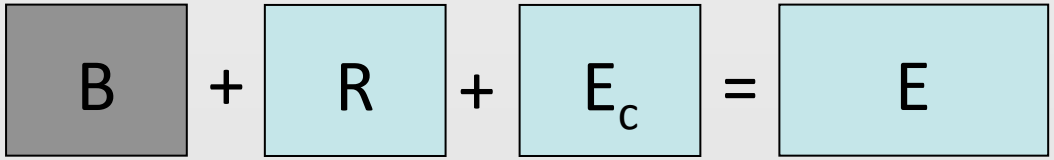
Residential



Retail

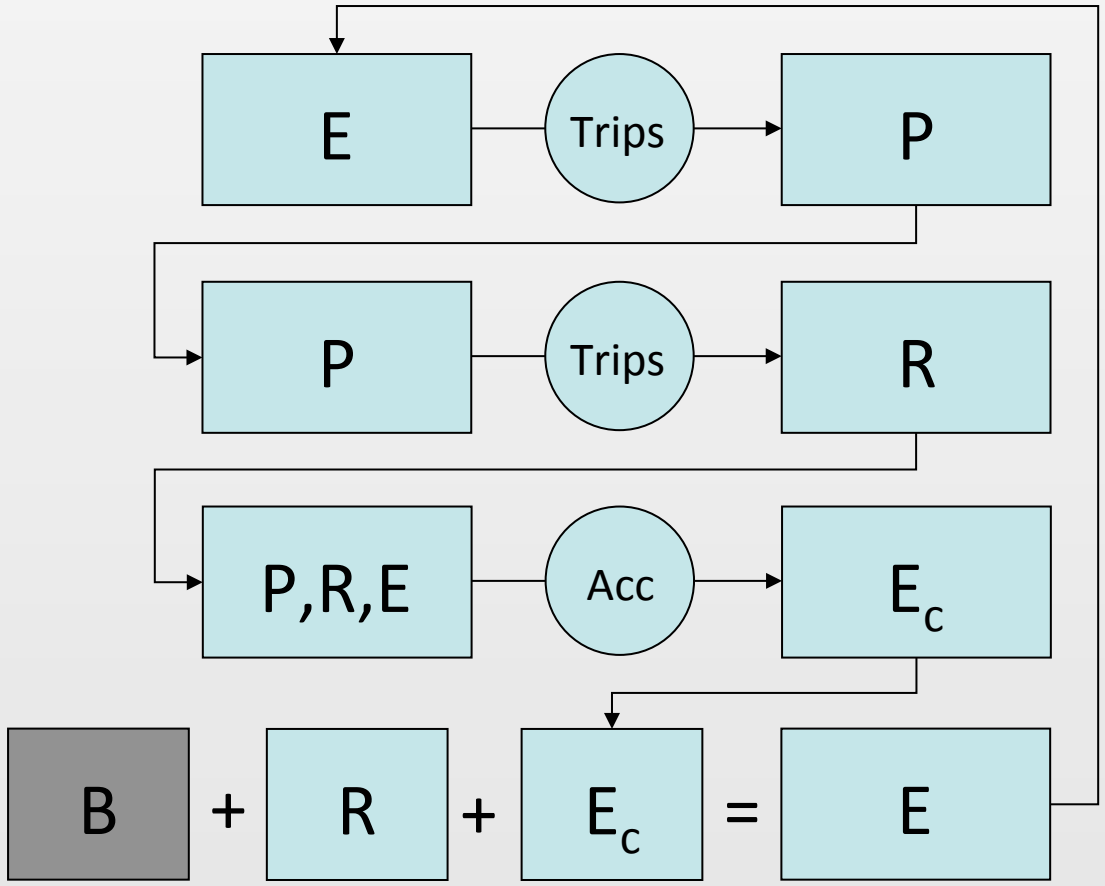


Non-Retail Employment



Total Emp

We can now show many ways in which these modules might be connected into an equilibrium framework: this is just one.



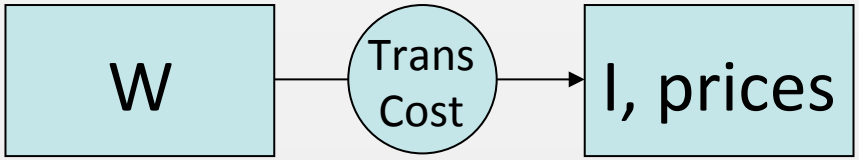
Residential

Retail

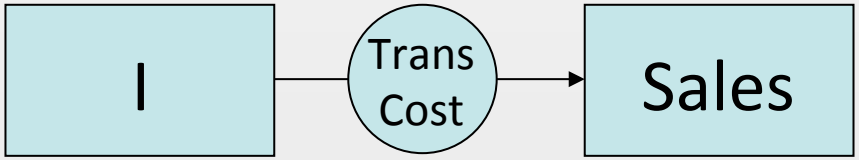
Non-Retail Employment

Total Emp

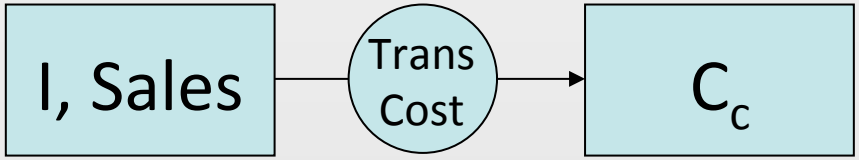
We can have also developed this model in money flows rather than physical flows with wages driving the process



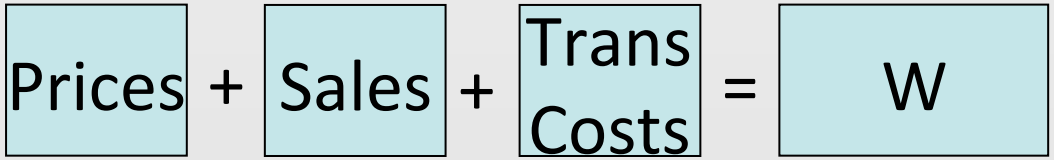
Housing



Retail Exp

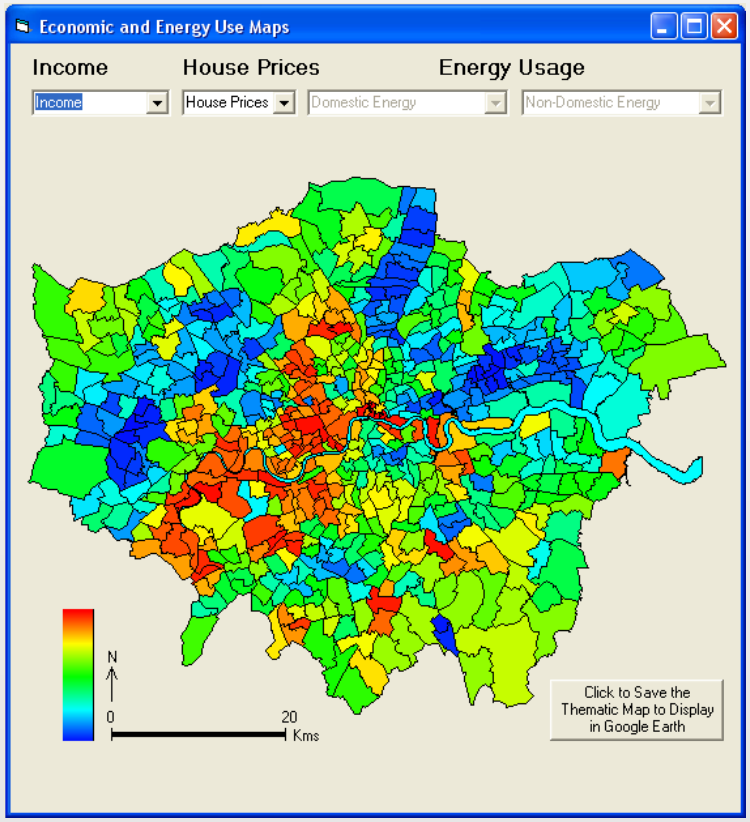


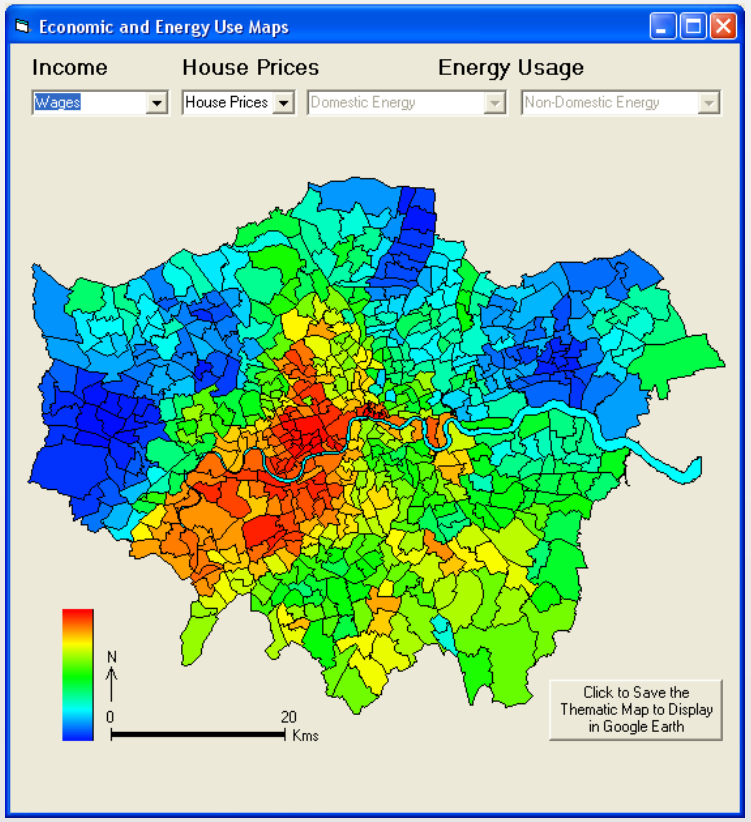
Services



Budget

I want to just show very briefly the sort of data that we have in the money sector that is driving this variant of the model and also state the residential location equation so you have some sense of what is going on





And the model is formalised as

with travel as a difference or variance σ^2 between these two sets of costs. Then, the system must satisfy the constraint

$$\sum_i \sum_j T_{ij}[(h_i + t_i) - (c_{ij} + \rho_j)]^2 = \sigma^2 \quad . \qquad (11)$$

The model that is generated from this constraint and which is the alternative residential location model in the current model variant is

$$T_{ij} = E_i \frac{A_j \exp(-\lambda[(h_i + t_i) - (c_{ij} + \rho_j)]^2}{\sum_j A_j \exp(-\lambda[(h_i + t_i) - (c_{ij} + \rho_j)]^2} \quad , \qquad (12)$$

which is subject to the usual origin constraint, generating population from equation (2) with (12) replacing equation (1).

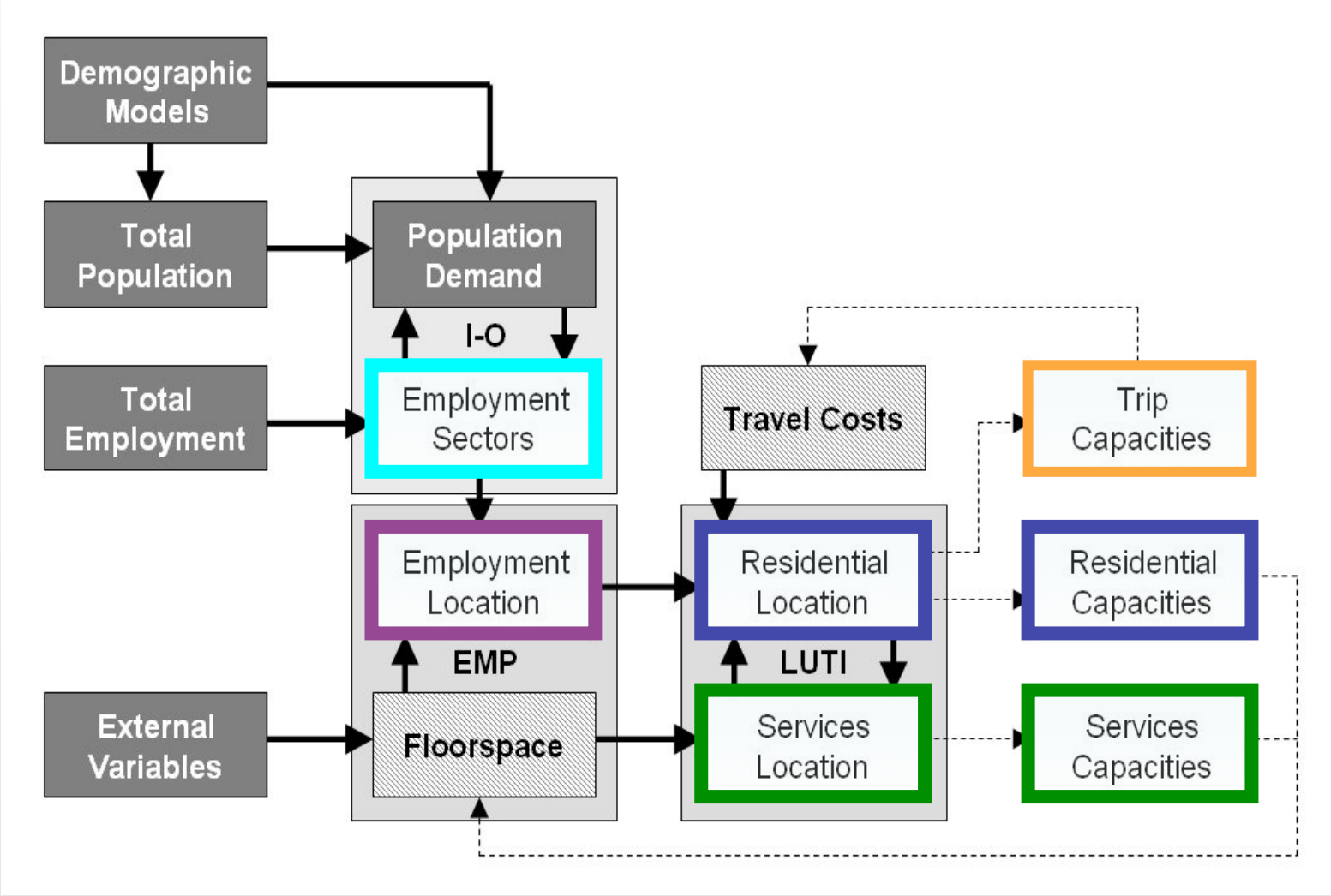
The Visual Template: The Desktop Model

Ok – let me quickly tell you our strategy – we are building a fully fledged model using state of the art software and various web–based interfaces which is highly visual and will be as fast as possible

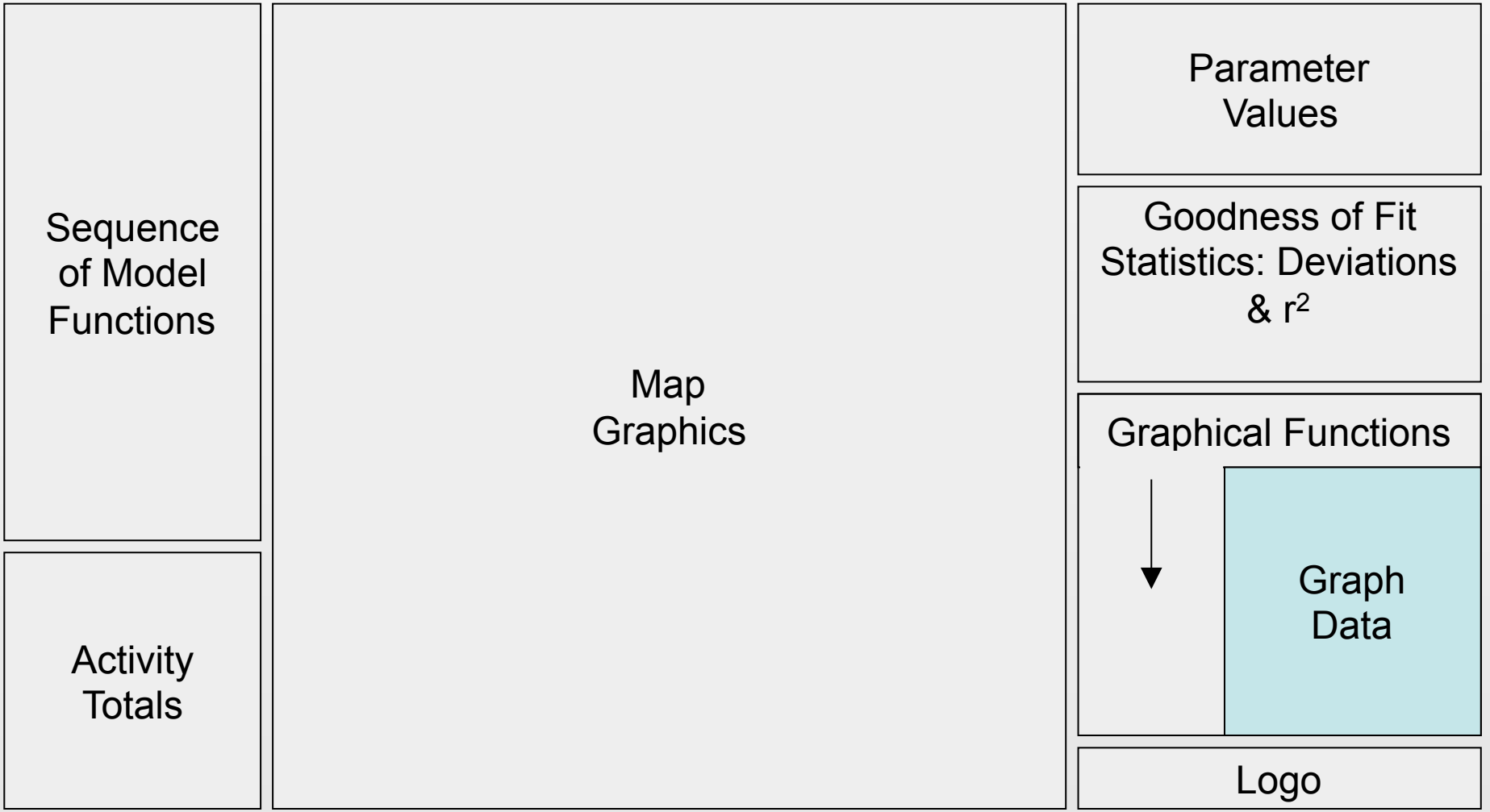
We are also building a mirror model on the desktop which is my contribution to the project and this is a one window minimal model which is for comparative purposes and to enable the bigger model to be tested

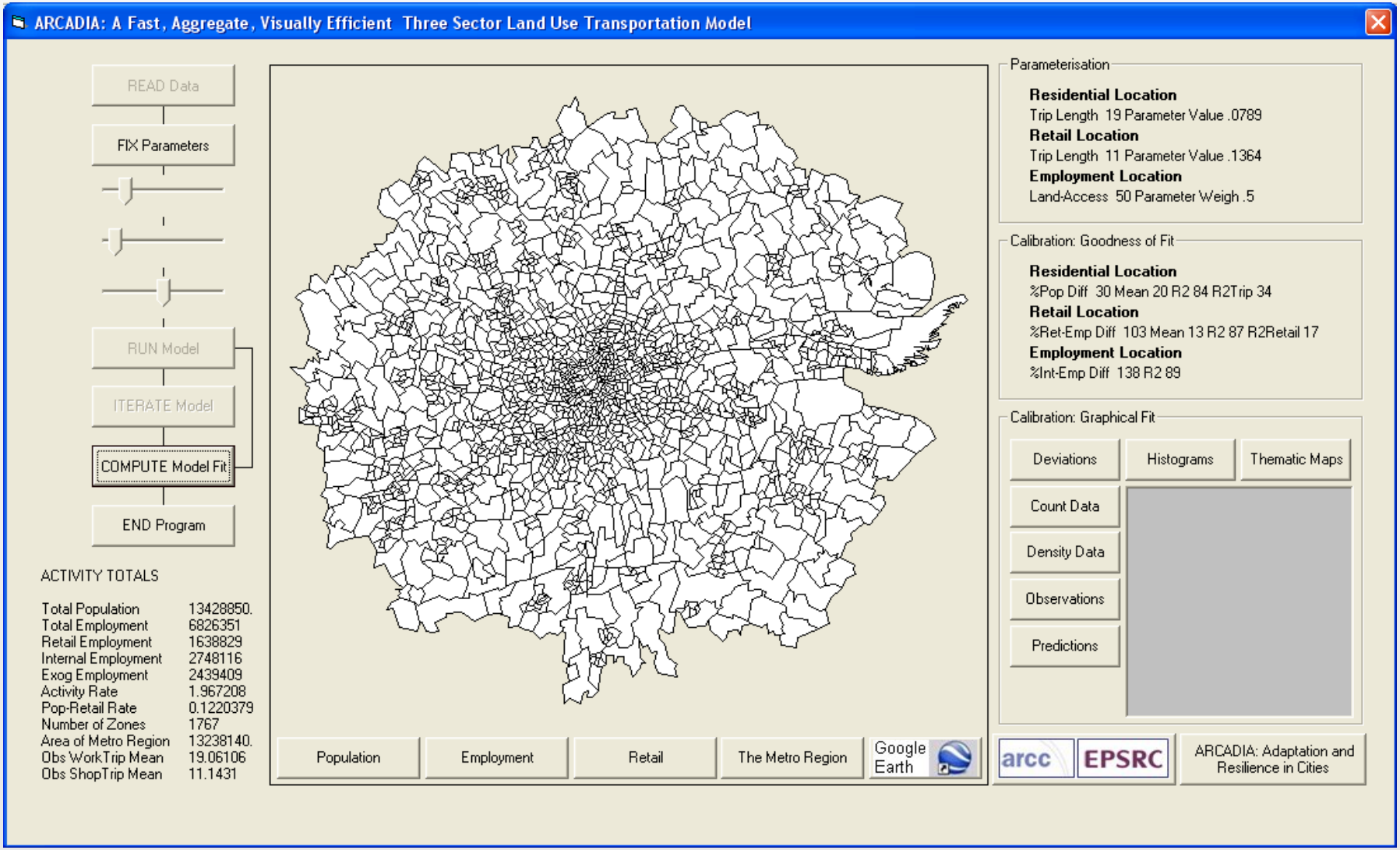
This is the model I will now show and then I will sketch the bigger application very briefly. Camilo in our group is developing this and he will then outline the web application.

The Structure of SIMULACRA

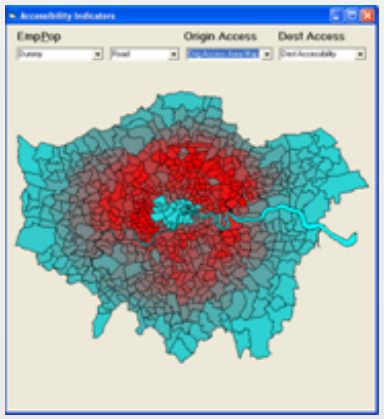


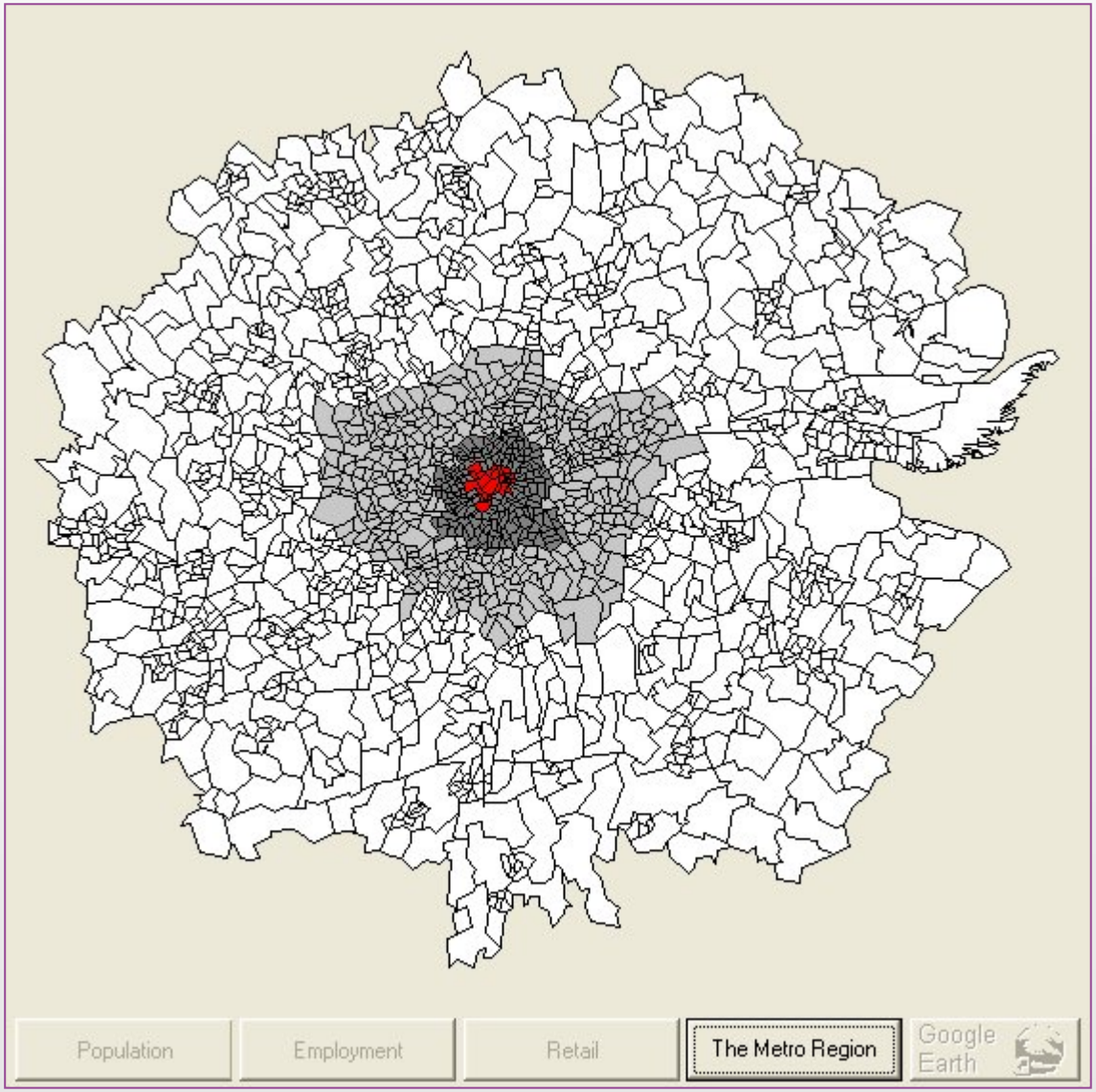
This is the order in which the operations take place



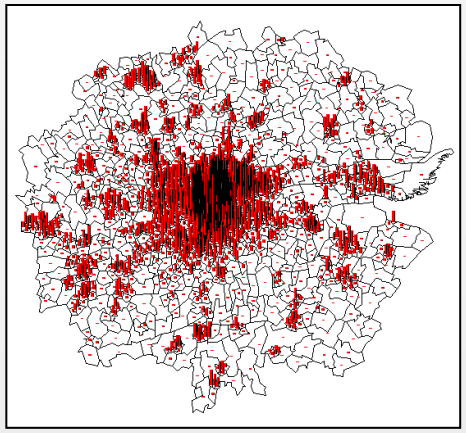

ARCADIA: A Fast, Aggregate, Visually Efficient Three Sector Land Use Transportation Model
READ Data
FIX Parameters
RUN Model
ITERATE Model
COMPUTE Model Fit
END Program
ACTIVITY TOTALS
Total Population 13428850.
Total Employment 6826351
Retail Employment 1638829
Internal Employment 2748116
Exog Employment 2439409
Activity Rate 1.967208
Pop-Retail Rate 0.1220379
Number of Zones 1767
Area of Metro Region 13238140.
Obs WorkTrip Mean 19.06106
Obs ShopTrip Mean 11.1431
Population
Employment
Retail
The Metro Region
Google Earth
Parameterisation
Residential Location
Trip Length 19 Parameter Value .0789
Retail Location
Trip Length 11 Parameter Value .1364
Employment Location
Land-Access 50 Parameter Weigh .5
Calibration: Goodness of Fit
Residential Location
%Pop Diff 30 Mean 20 R2 84 R2Trip 34
Retail Location
%Ret-Emp Diff 103 Mean 13 R2 87 R2Retail 17
Employment Location
%Int-Emp Diff 138 R2 89
Calibration: Graphical Fit
Deviations
Histograms
Thematic Maps
Count Data
Density Data
Observations
Predictions
arcc
EPSRC
ARCADIA: Adaptation and Resilience in Cities

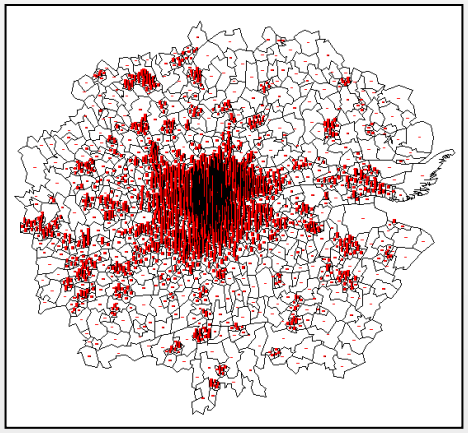

Employment
Population
Work Trips

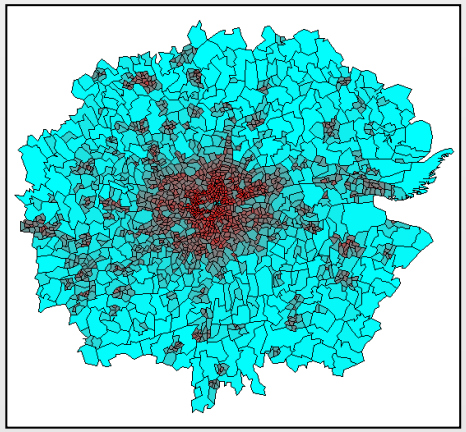

EmpPop
Origin Access
Dest Access

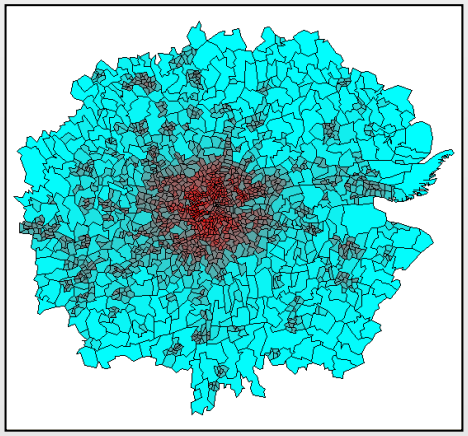

Population
Employment
Retail
The Metro Region
Google Earth

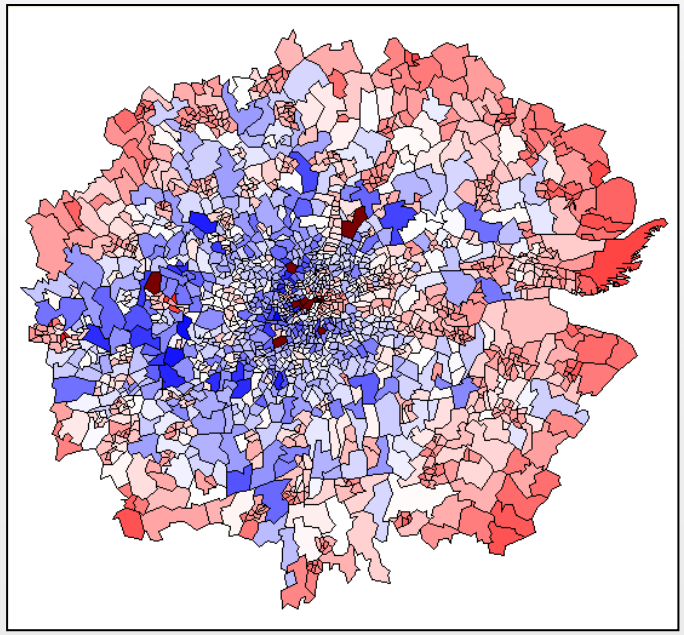
Here are some sample outputs – I will run the model as speed is important – here goes



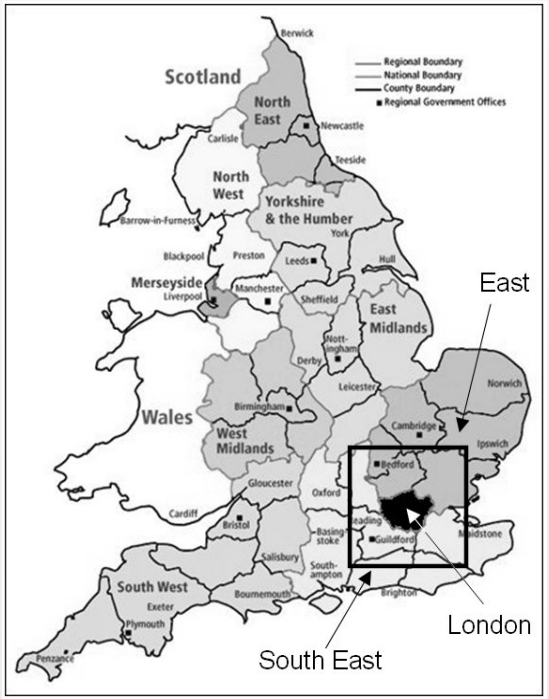




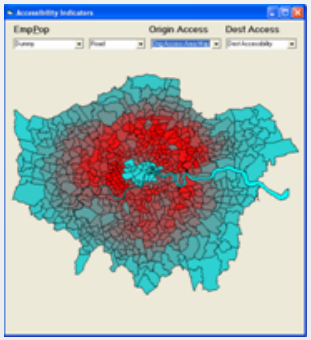


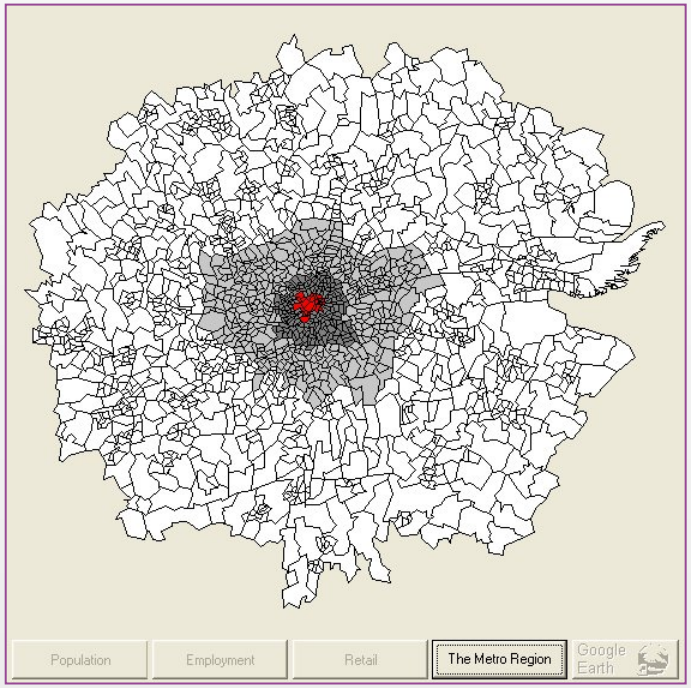


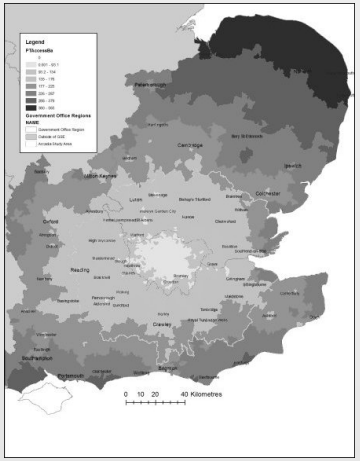
Ok I will run the model from here – in fact I need to go to the file

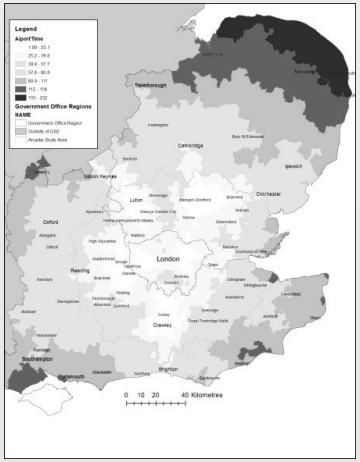

Regional Boundary
National Boundary
County Boundary
Regional Government Offices
Scotland
North East
Newcastle
Carlisle
Teesside
North West
Yorkshire & the Humber
York
Barrow-in-Furness
Blackpool
Preston
Leeds
Hull
Merseyside
Liverpool
Manchester
Sheffield
East Midlands
Nott-ingham
Derby
Leicester
Norwich
Wales
Birmingham
West Midlands
Cambridge
Ipswich
Bedford
Gloucester
Oxford
Cardiff
Bristol
Basing-stoke
Reading
Guildford
Maidstone
Salisbury
South-ampton
South West
Bournemouth
Brighton
Exeter
Plymouth
Penzance
East
London
South East

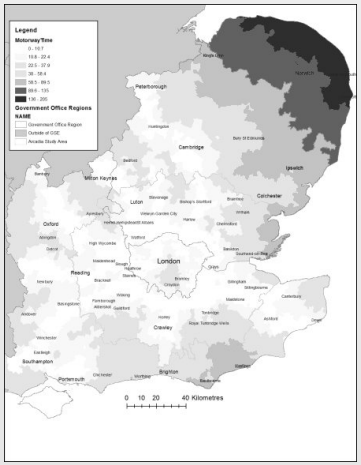

Employment
Population
Work Trips


EmpPop
Origin Access
Dest Access

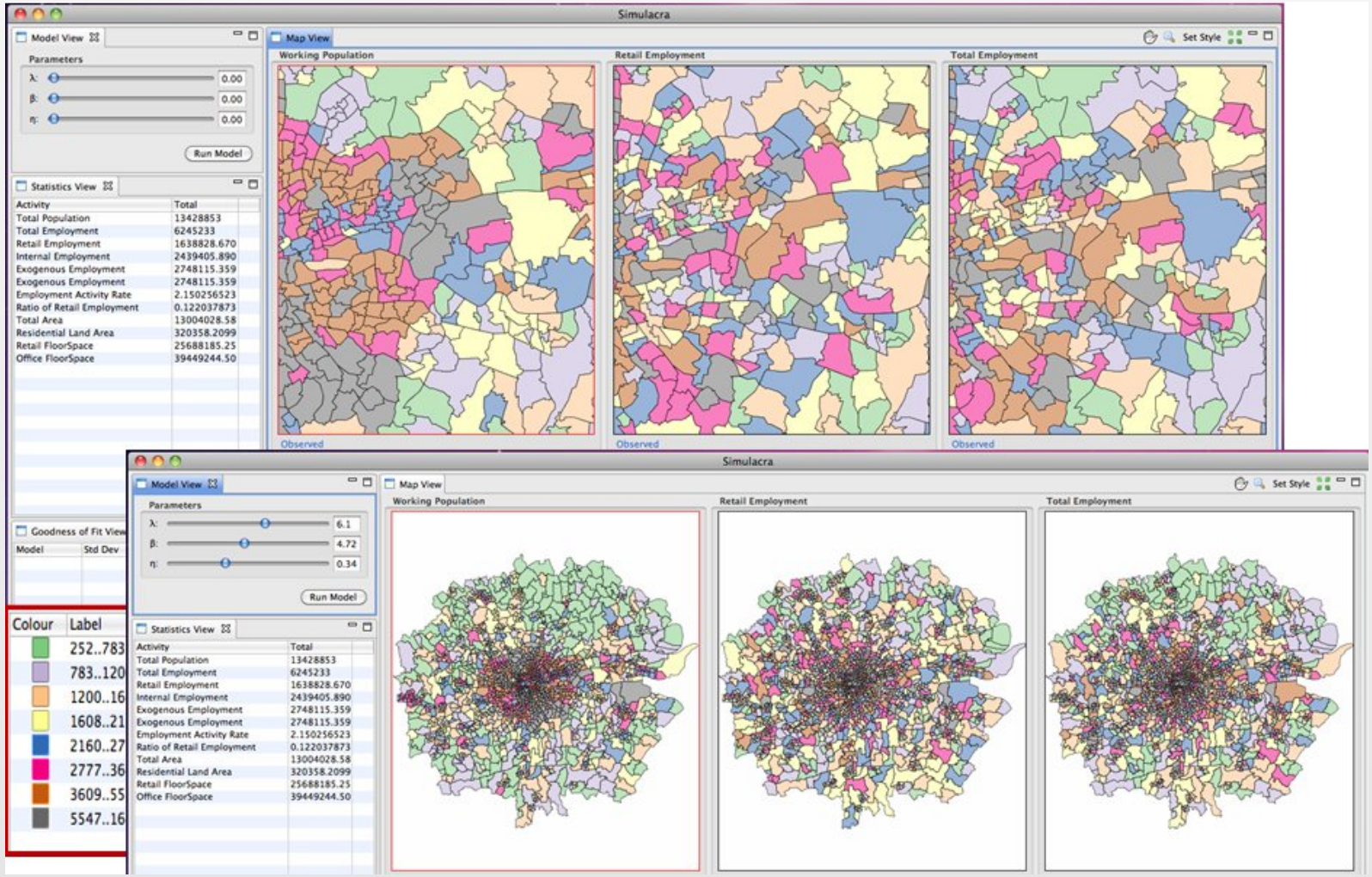

Population
Employment
Retail
The Metro Region
Google Earth

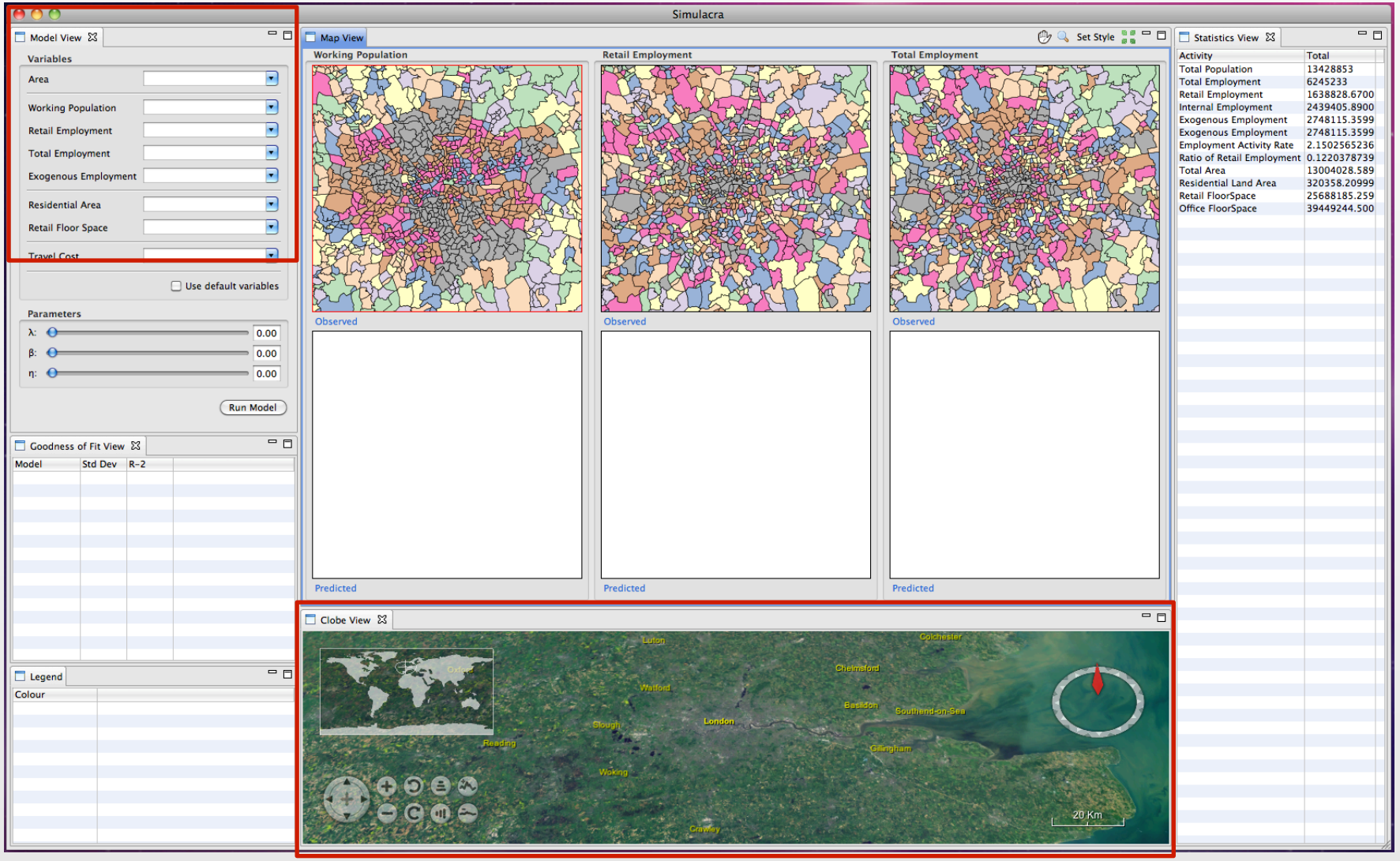






And here are some screen shots from the desktop version of this ultimately to be a web based application – on Mac and PC




Simulacra
Model View
Variables
Area
Working Population
Retail Employment
Total Employment
Exogenous Employment
Residential Area
Retail Floor Space
Travel Cost
Use default variables
Parameters
λ: 0.00
β: 0.00
η: 0.00
Run Model
Goodness of Fit View
Model
Std Dev
R-2
Legend
Colour
Map View
Set Style
Working Population
Retail Employment
Total Employment
Observed
Predicted
Clobe View
Luton
Colchester
Oxford
Chelmsford
Watford
Basildon
Southend-on-Sea
Slough
London
Reading
Gillingham
Woking
Crawley
20 Km
Statistics View
Activity
Total
Total Population 13428853
Total Employment 6245233
Retail Employment 1638828.6700
Internal Employment 2439405.8900
Exogenous Employment 2748115.3599
Exogenous Employment 2748115.3599
Employment Activity Rate 2.1502565236
Ratio of Retail Employment 0.1220378739
Total Area 13004028.589
Residential Land Area 320358.20999
Retail FloorSpace 25688185.259
Office FloorSpace 39449244.500

Data Bases: Location, Interactions & Networks

We have a big problem in getting the networks sorted out for the aggregate model as these networks are at a very fine scale

We need them to be at a coarser scale for the model as we need to do all the assignment and capacity checking at the level of the model

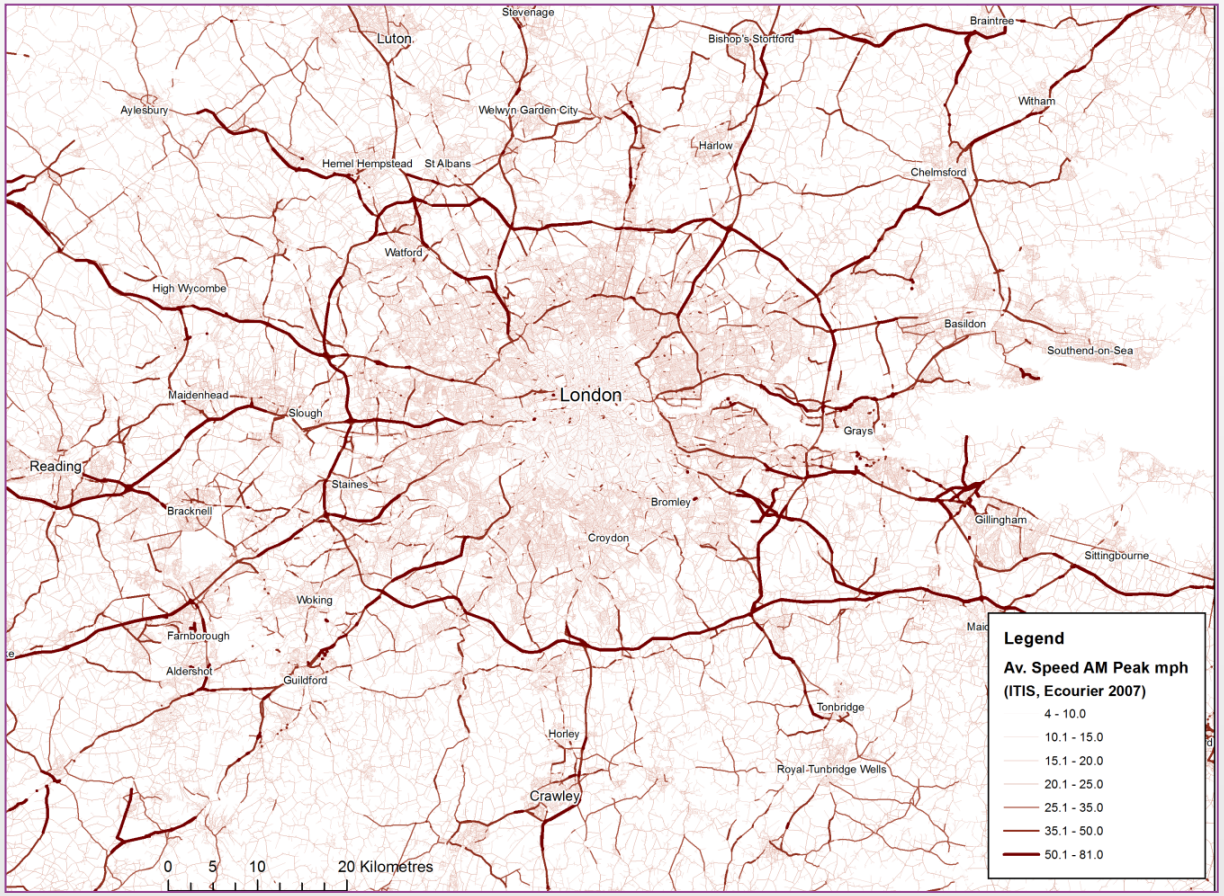
This is a long standing issue, we know, but we cannot afford to move down the local fine scale level to do the assignment of trips to the network because this would simply destroy our basic principle of accessibility of the model to users and also the speed requirements we need

We will show some of the detail we have by way of illustrating our work in progress.

Road Costs

Used GPS data for realistic road speeds across the South East. Sourced from ITIS and Ecourier.

Future improvements with dynamic consideration of congestion.

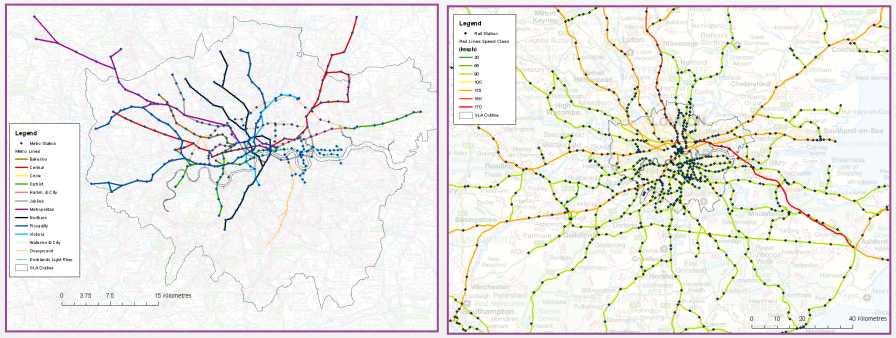


Public Transport Costs

Based on network geometry and timetabled services. Initially using model presented by Duncan last term. Allows multi-modal PT trips.

TransXchange

Full UK PT timetable available in XML format. Could be used to automate process of generating PT networks.



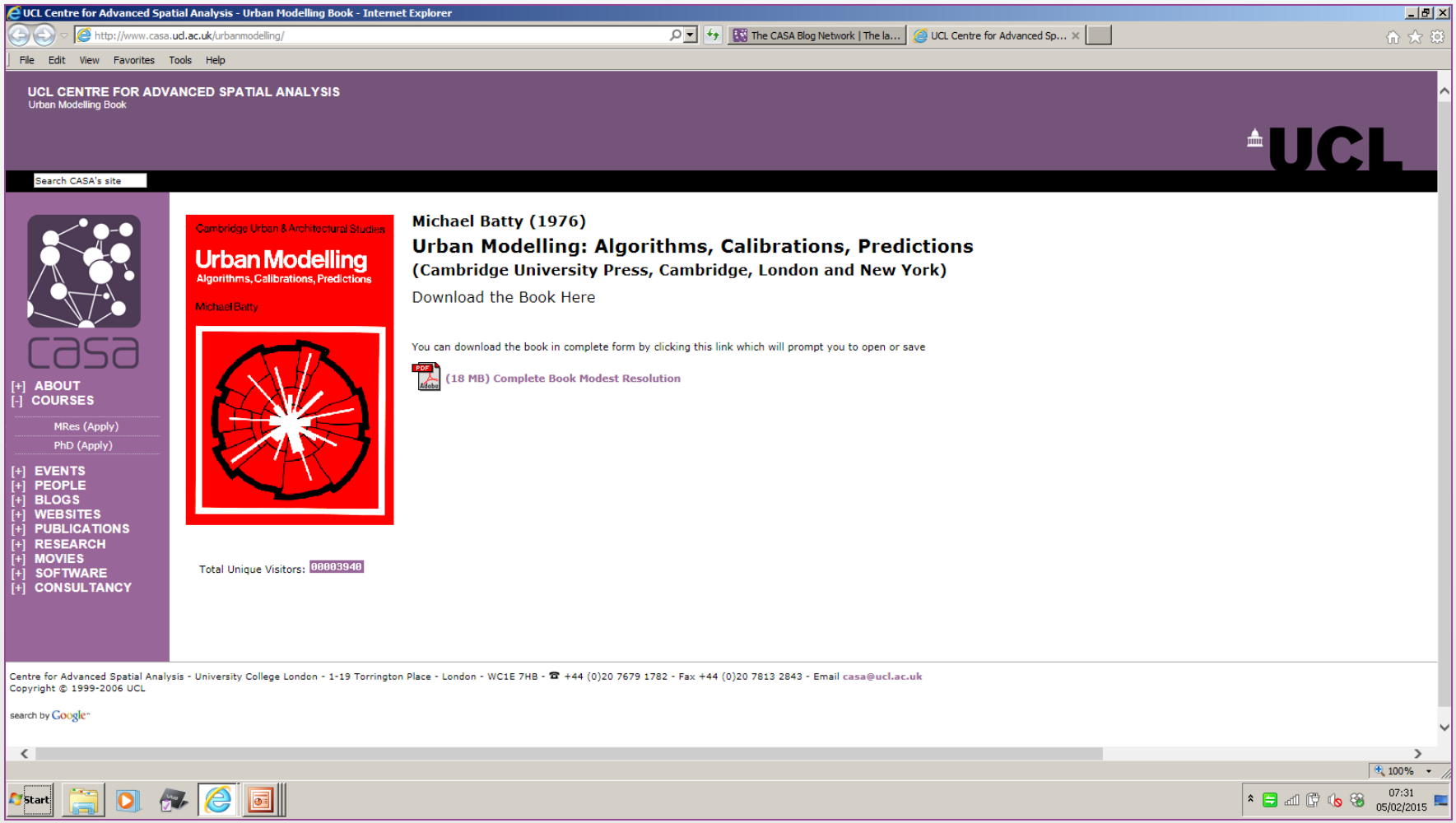
Key Challenges for Immediate Developments

- Speed of Models
- Quick and Effective Visualisation
- Running the Model with Users/Stakeholders
- Building a Residential Model Based on the Housing Market Cost, prices, travel and energy costs etc - The Wegener Principle
- Moving to a Semi-Dynamic Model with Inertia and Internal Migration
- A Local UK Dimension: Thinking of the Modelling Strategy as being Informed by National Data Bases such as Neighbourhood Statistics

Some stuff on these models is at

http://www.complexcity.info/

And my very old book
can be downloaded from
www.casa.ucl.ac.uk/urbanmodelling



www.casa.ucl.ac.uk/urbanmodelling