CSiS Center for Spatial Information Science The University of Tokyo 東京大学 THE UNIVERSITY OF TOKYO

3rd November 2010

SIMULACRA:

A New Quasi-Dynamic Land Use Transportation Model for the London Region

（SIMULACRA：ロンドン地域の新たな土地利用交通擬似ダイナミックモデル）

Michael Batty
University College London

m.batty@ucl.ac.uk
http://www.casa.ucl.ac.uk/

Centre for Advanced Spatial Analysis UCL

Outline

- Challenges in Large Cities: Climate & Energy Change
- The Tyndall Cities Project
- The London Model
- Visual Driven Models and Relations to Stakeholder
- The Economic-Energy Focus: Extending the Software
- Energy Changes: Rising Costs of Transport
- Integrated Assessment using Sketch Simulation
- Next Steps

Centre for Advanced Spatial Analysis UCL

Challenges Facing Large Cities: Climate Change, Energy Change

Many large cities are by the sea and sea level rise is thus an issue. UKCIP and IPCC forecast levels of up to 2 metres increase by 2100 as an upper but possible value

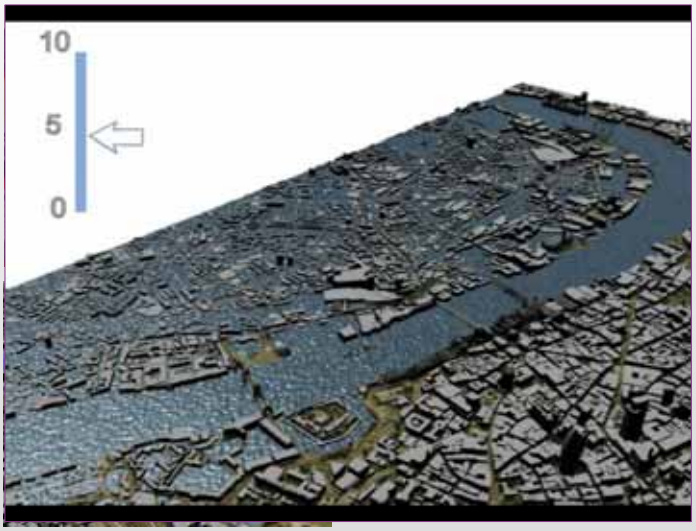
Energy change – end of oil – peak oil 2020?

Pollution is a key issue as people get wealthier and there are more cars; also as people insulate their buildings more to conserve energy, they use more energy

There are many intricate and subtle ways in which people are adapting to these changes – e.g. bikeways in London and increase in walking, mitigation through congestion charging

Here are some examples to see what we are interested in.

Pollution – Nitrogen Dioxide as an example, Flooding - Sea Level rise



Energy Change – what happened in LA when gasoline went to $145 a barrel 2 years ago

The Tyndall Cities Project

Model-based predictions to inform stakeholders

1. Predictions:

1. Very long time horizons suggests that dynamics is less, not more important? Climate change wrt to sea level rise is relevant for 50 to 100 year forecast periods
2. Very short time horizons suggests the same: rapid changes in energy costs due to gasoline prices rises
3. *Equilibrium models* are useful to predicting responses where we simply do not know how the system will adapt
4. Such models address directly "What If" types of scenario
5. Predictions are to inform the debate, they cannot produce magical results

2. Stakeholder Involvement:

The need for *simple immediate models* that can be used over and over again to focus debate on "What If?" questions formulated as a dialogue

The need to explain model inputs, processes and outputs visually using maps etc as well as *visual analytics.* It is as important for stakeholders to understand the data as the model

3. Complex Problems over Many Scales and Fields:

Integrated assessment – wrt to climate and energy change – melding physical with social and economic – the need for visual analytics to communicate with scientists from different fields and to identify potential errors in extensive data sets

The need for simple fast models in all of this

4. Flexibility in Model Design and Extension:

The need for developing new but related models quickly retaining with powerful visualisation

The need to tailor models to questions and data which can be defined by stakeholders quickly and often casually

The need to evolve and build more dynamic model types

5. The Need to Embrace Organisational Constraints:

To build models understood by all members of the Consortia, stakeholders and scientists alike, where the process is dominated by resource constraints, different expertise in different locations, and by stakeholders directly defining the problems and absorbing the predictions. *All this implies, fast, simple, visual, and accessible models*

Let me address these issues by way of telling you what we have and are doing before I get into the land use transport models we are developing

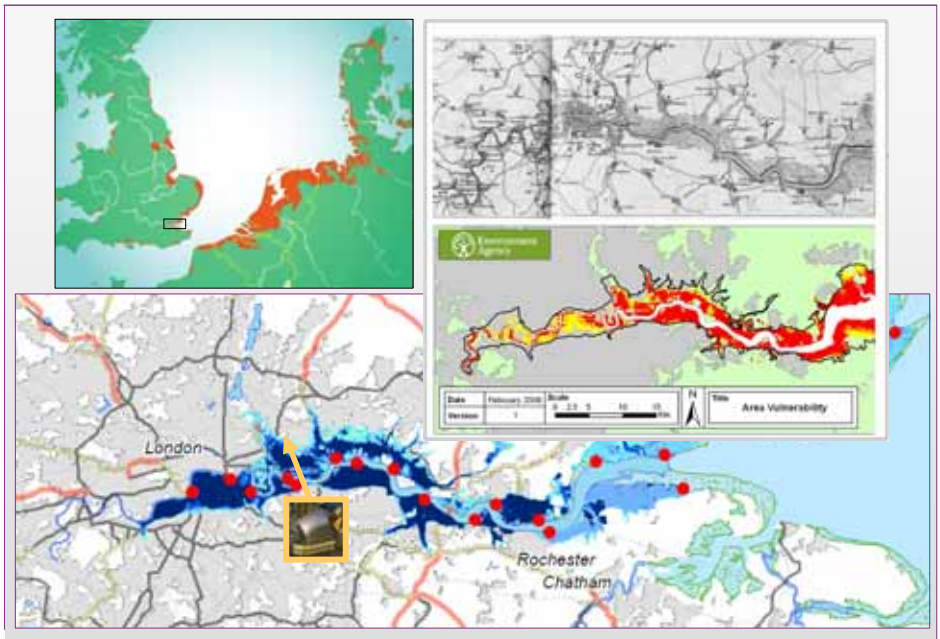
First climate change and then energy change. In London we already have a major response to climate change which was put in place in the early 1980s in response to major flooding in the early 1950s – this is the Thames barrage. It wasn't seen as being part of climate change then.

We also have in place congestion charging with road pricing a distinct possibility in the near future, to save money due to extensive current gridlock, for strategic reduction of gasoline usage (fossil fuel depletion and rising costs) and because of a growing awareness of 'green issues'

A public bike scheme was introduced on July 30, 2010, last week.

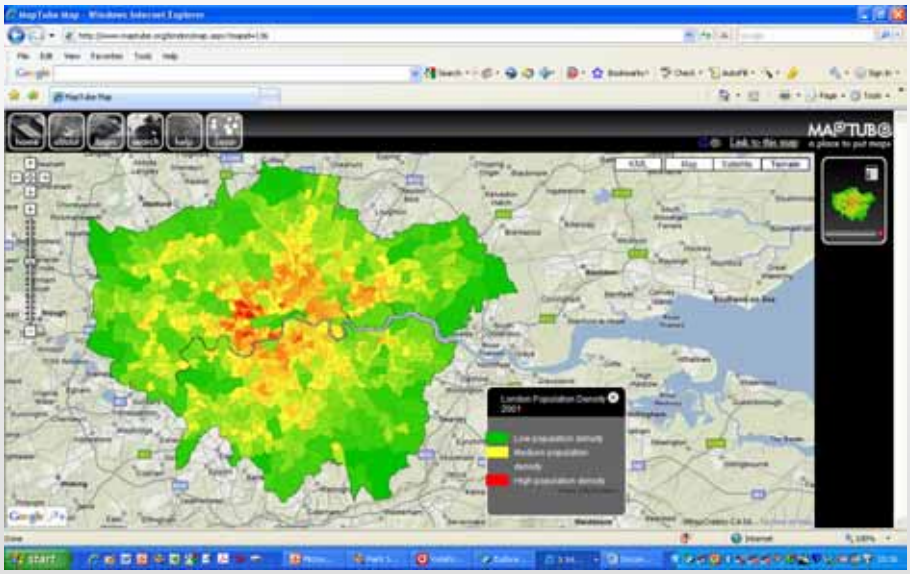
Centre for Advanced Spatial Analysis UCL

The Thames Barrier built 1978 to 1984 in operation, likely to be ineffective by 2040? due to new predictions of sea level rise forecast at 1-2 metres by 2100 – somewhat debatable, but ….



Centre for Advanced Spatial Analysis

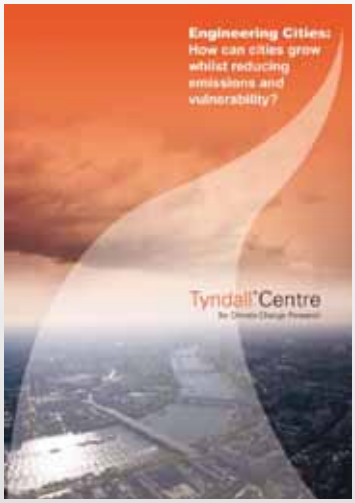
UCL

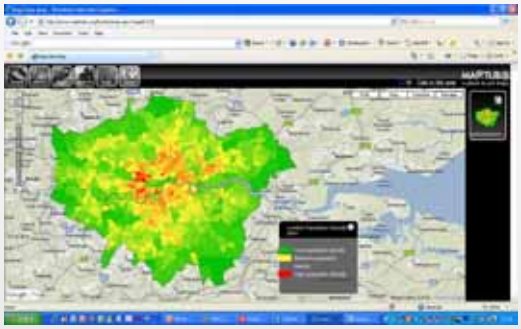


The Greater London Region consists of 33 Boroughs, 7.8 million population & 4.4 million jobs

Centre for Advanced Spatial Analysis

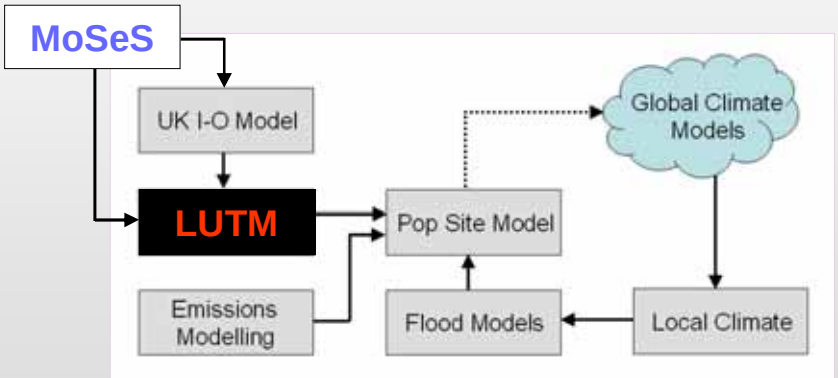
UCL





The IPCC forecasts moderated by UKCiP suggest North Sea will rise 2m by 2010, hence serious flooding of Central and East London

The model sits lies at the core of a process of chaining models together built by different groups and coming from different traditions – predicting economy, employment, population location, detailed development, flood risk



The London Model

Our models begin with those like TRANUS, MEPLAN, to an extent IRPUD and so on – they are potentially quite detailed in terms of disaggregation – the current one is 5 employment types and 5 population types, 4 transport modes and so on – although the one that we will show is the most aggregative

They are essentially input output structures but with the flows being between conventional quantities such as types of population, employment, other sectors such as education, shopping and so on

They differ from all these models in that they contain exogenous totals that can be exogenous in space and *time*, thus enabling the model system to distinguish between movers and stayers

This suite of possible models – the suite is called SIMULACRA – I won't unpack the acronym – it does unpack in more than one way

The model structure that we have under construction essentially has two sectors – population and employment – and it is structured as a spatial I-O model with the flows being modelled using mode split spatial interaction submodels

It is formulated as

A four mode residential location model, origin constrained but subject to capacity constraints, with competition between locations and modes of travel determined respectively by land availability and travel costs.

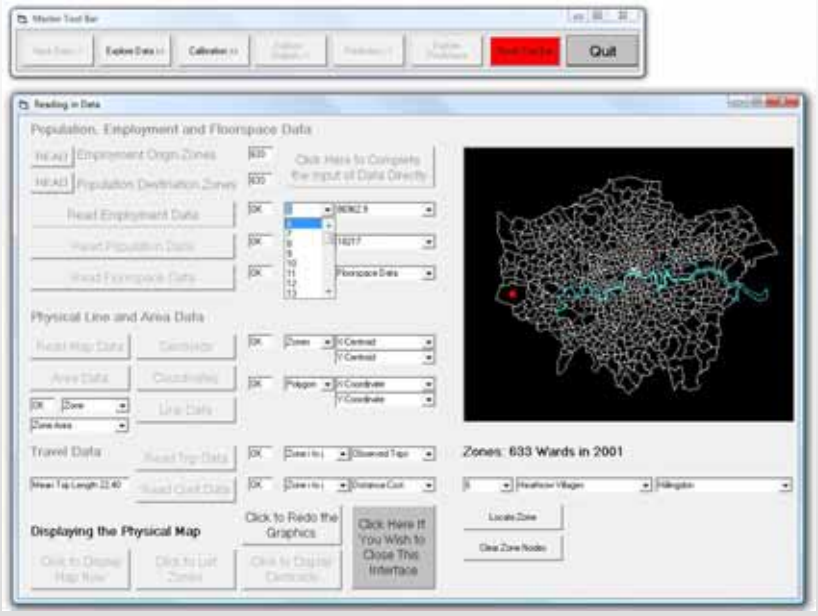
The capacity constraints are introduced exogenously and can be formulated as policy levers but this as in all such model application introduces a degree of arbitrariness.The modes are road, bus, heavy rail and light rail (Tube and DLR)

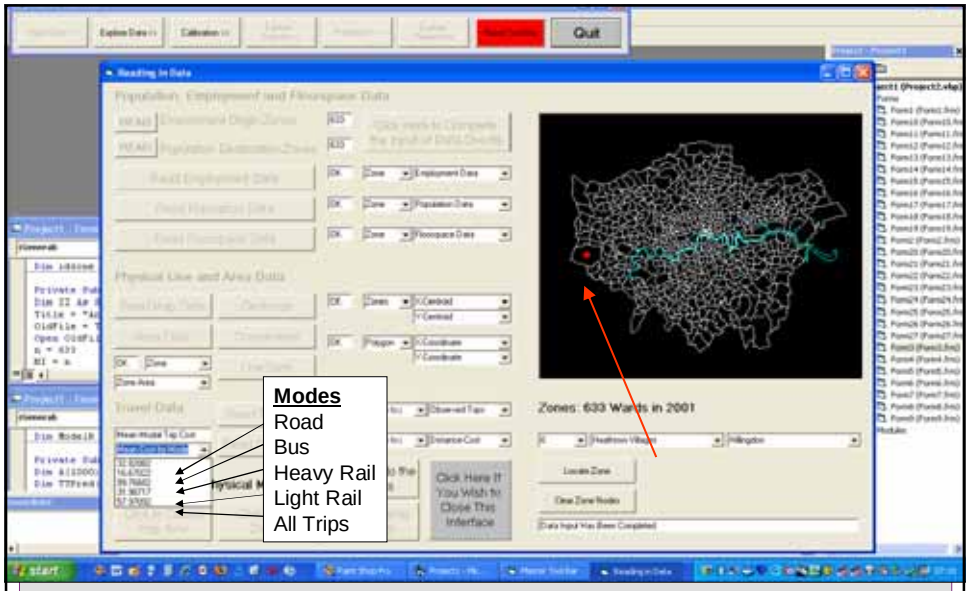
There is an option implemented in the version to look at energy changes for equilibrating the transport flows with respect to capacities. The package is structured as a sequence of:

1. Data exploration
2. Model calibration and validation, and thence
3. Prediction

The entire process is visually driven and I will first show some screen shots before running the model. You can find a version of the model in my old book of 1976.

Visual Driven Models and Relations to Stakeholder

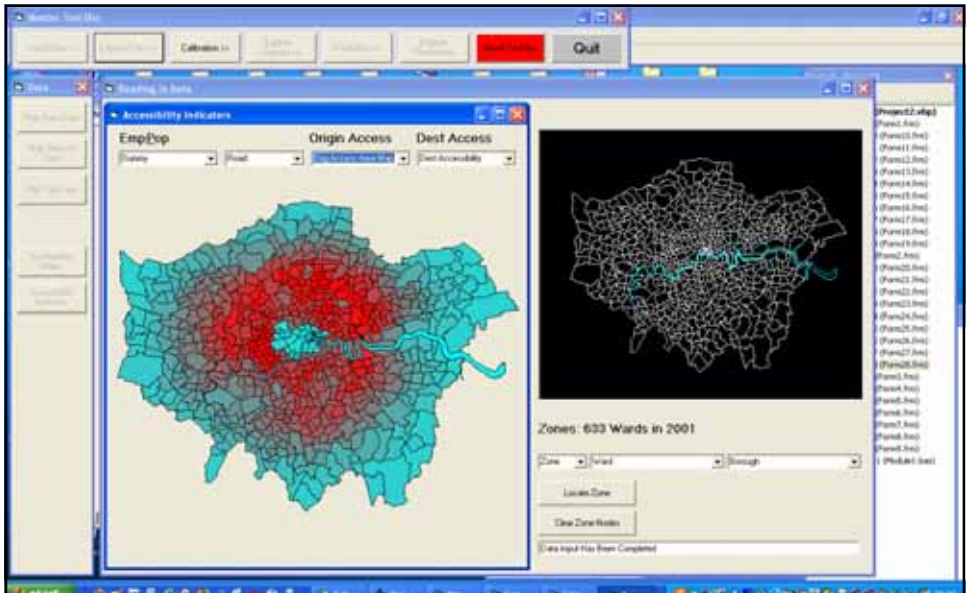




Road: 38%; Bus: 12%: Heavy Rail: 12%: Light Rail 19%; Other (Walk, Bike, Fly): 19%

Centre for Advanced Spatial Analysis

UCL

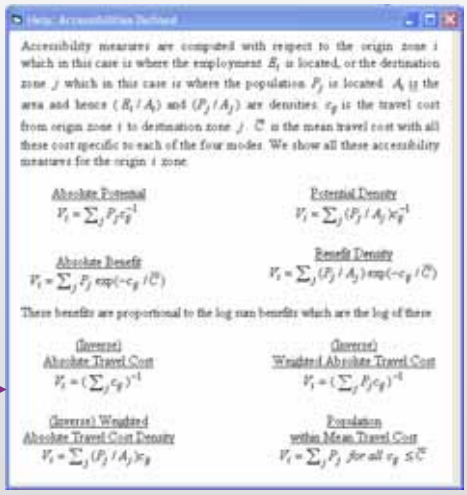


Centre for Advanced Spatial Analysis

UCL

Accessibility from the LUTM model

Many different accessibility measures, 8 in all



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. $\bar{C}$ 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
$V_i = \sum_j P_j \exp(-c_{ij} / \bar{C})$

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

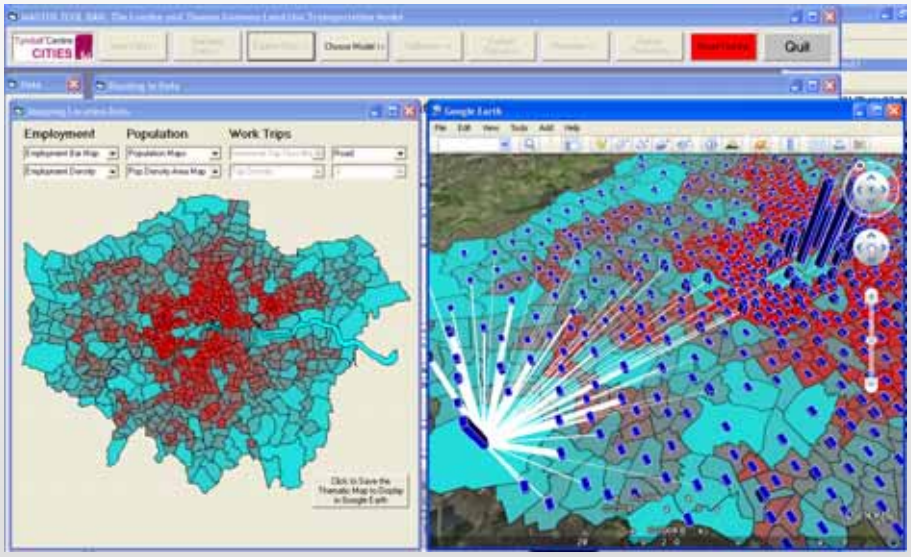
These benefits are proportional to the log sum benefits which are the log of these

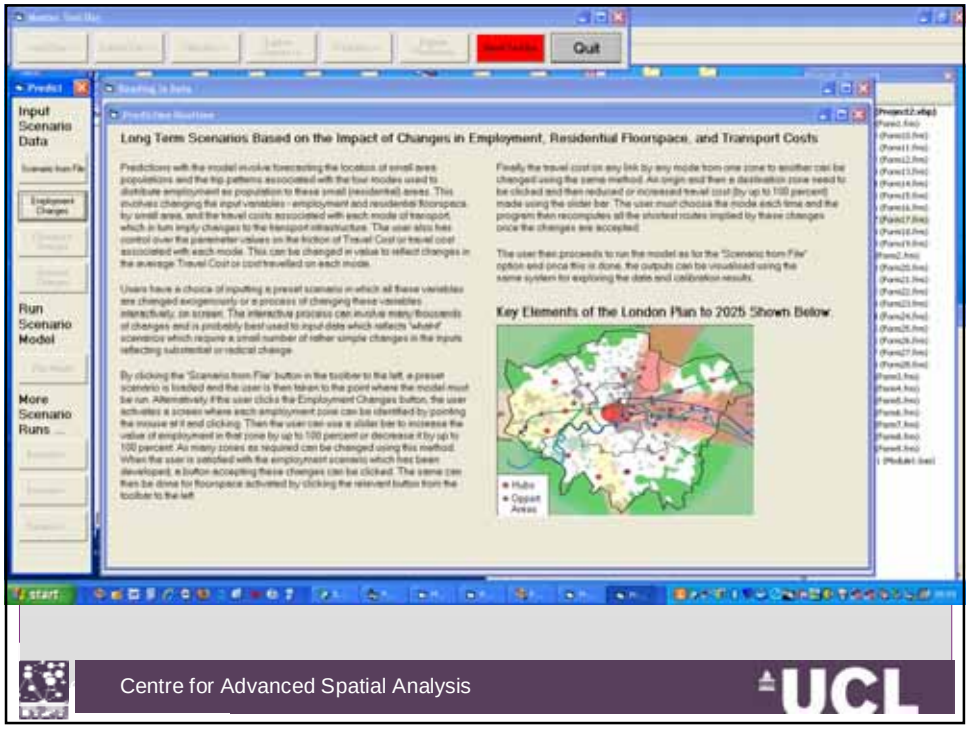
(Inverse)
Absolute Travel Cost
$V_i = (\sum_j c_{ij})^{-1}$

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

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

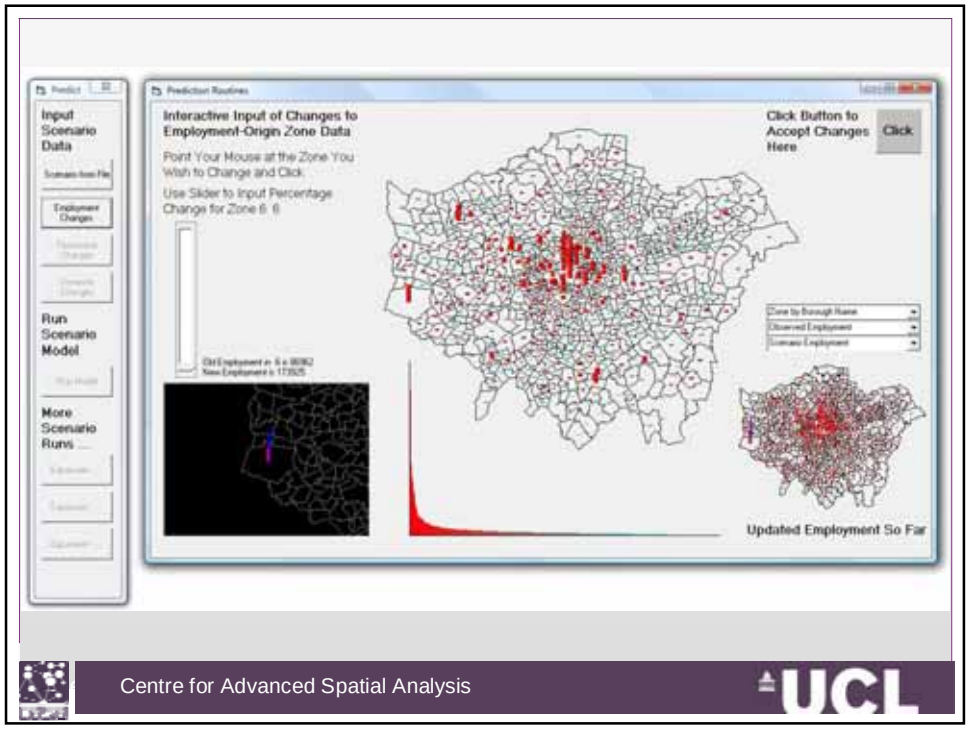
Population
within Mean Travel Cost
$V_i = \sum_j P_j$ for all $c_{ij} \leq \bar{C}$





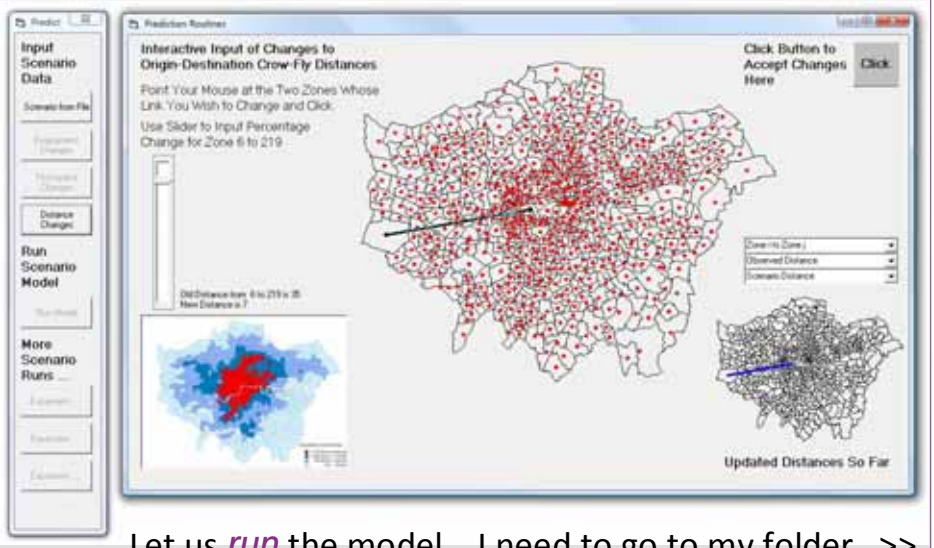
Centre for Advanced Spatial Analysis

UCL



Centre for Advanced Spatial Analysis

UCL



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

Run

For a movie of all this go to our web site
http://www.casa.ucl.ac.uk/transportmodel/transportmodel.asp

And now a little bit more about the model ……looking at the version we are currently building

The Economic-Energy Focus

- We have replaced the simple travel cost function with one that relates to wages, travel cost and housing cost
- In essence, we compute the proportion of a wage in any origin (employment zone) which is available for a) travel and b) housing, and we separate housing and travel costs into energy and non-energy related components
- Monies for travel are then compared to the actual travel cost on any link and those closest to the cost have a greater probability of determining a trip
- Monies for housing at origin i are then compared to the actual house price at location j and those closest to the housing price have a greater probability of determining the trip

- The model is built around variances between monies available for travel and housing and the actual costs of these as

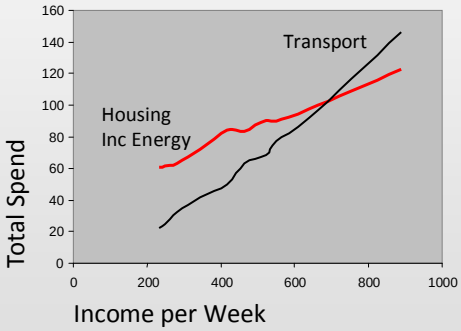
Interaction:

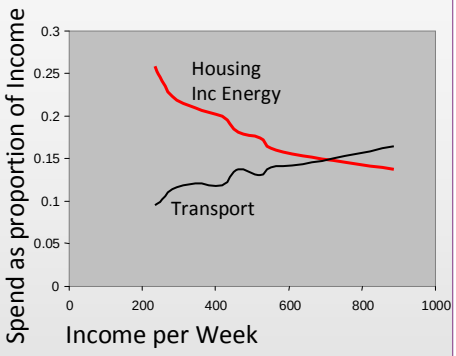
$$T_{ij}^{m} = E_i \frac{A_j \exp(\alpha p_j)\exp(-\lambda^m c_{ij}^m)\exp(-\beta(p_i(w)-p_j)^2\exp(-\beta(c_i(w)-c_{ij}^m)^2}{\sum_j A_j \exp(\alpha p_j)\exp(-\beta(p_i(w)-p_j)^2 \sum_m \exp(-\lambda^m c_{ij}^m)\exp(-\beta(c_i(w)-c_{ij}^m)^2}$$

- Again we solve the model from its maximum likelihood equations
- There are several variants of all these models which can be chosen in real time by the user based on different patterns and combinations of moments and related constraints
- We need to look at the data which is aggregate as we have wages at the origin end and income at the destination end

Transport & Housing Costs from the '09 Spending Survey

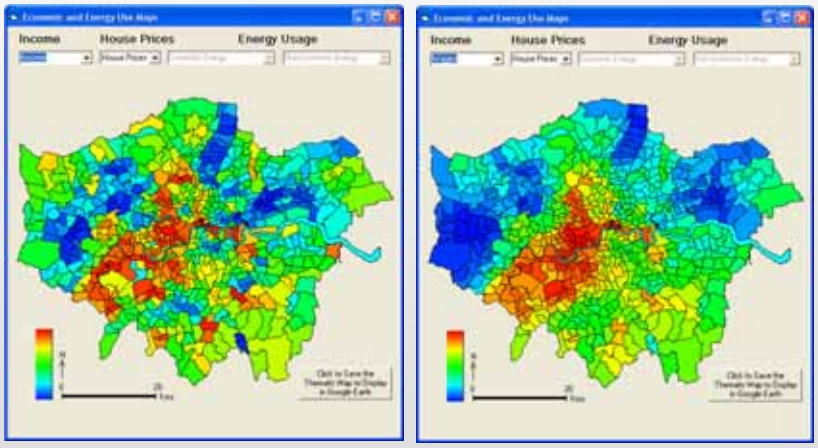
Here are the absolute costs





The above the relative costs to income

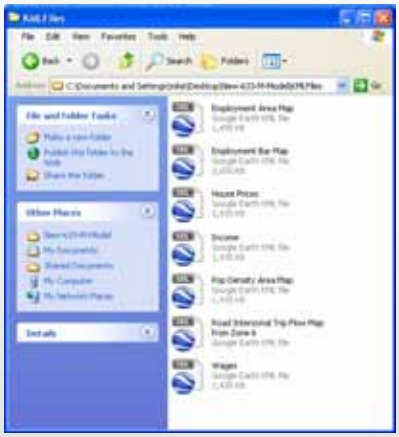
- Let is look at incomes where people live and wages where people work



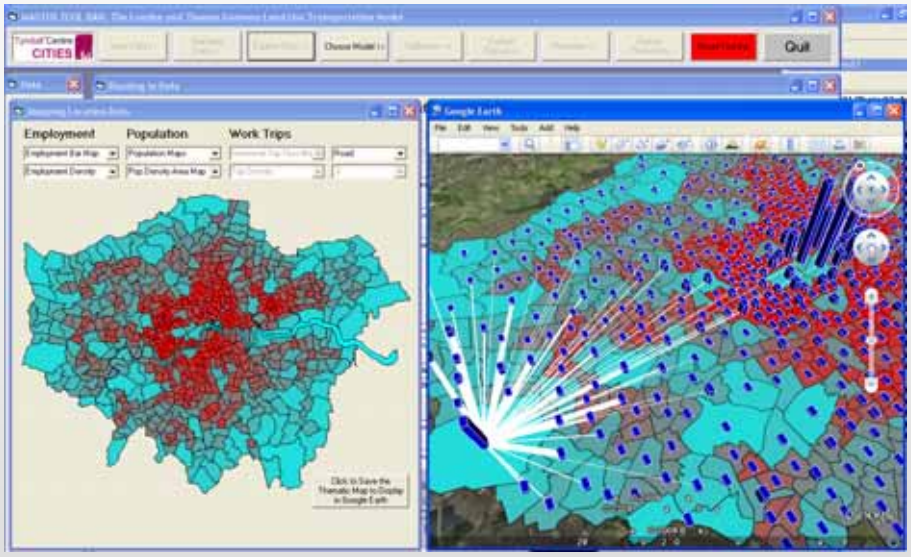
Extending the Software

- Currently we do not have good zoom, pan, overlay facilities in the model due to difficulties of such programming in VB. I suspect these could be developed but we also need to share the data and the predictions and a quick possibility is to use a non-proprietary open map visualisation system to link on the fly to the model: this should be web-based
- The best way forward at present is to generate KML files in the program and then feed them to Google Earth where we have overlay, 3D, and external data facilities. You have seen this.

- In this way, we can extend massively our ability to visualise as well as providing a storage facility for the model input and output data
- What is impressive about this is that the speed of doing all this is not slower than the interactive program in VB

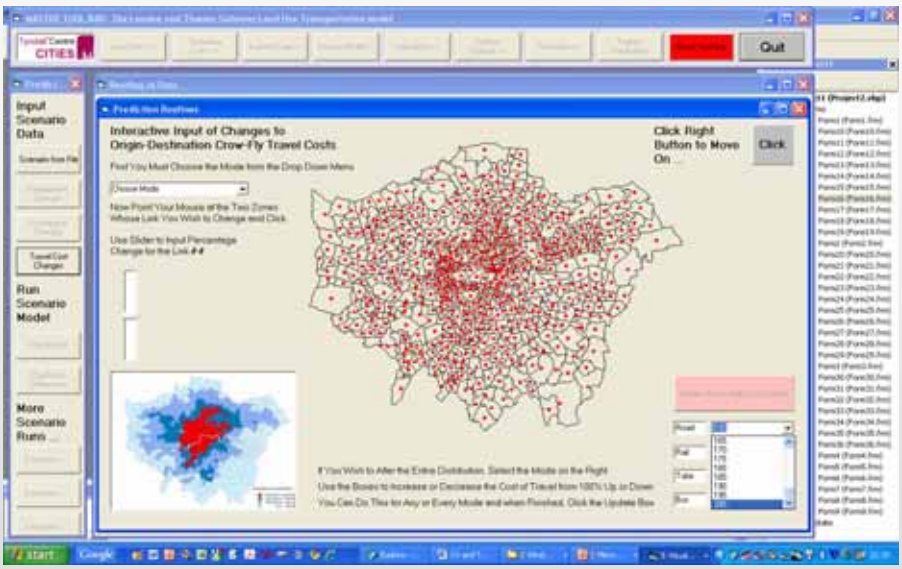


It is based on pragmatic use of available software but it generates familiarity. It also lets us store data in a convenient fashion and add other external data as KML files – particularly physical data which is hard to store in the customised software

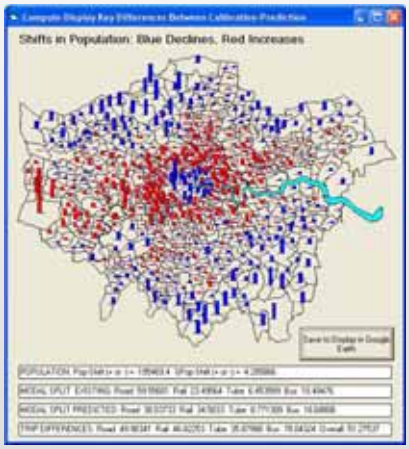


Energy Changes: Rising Costs of Transport

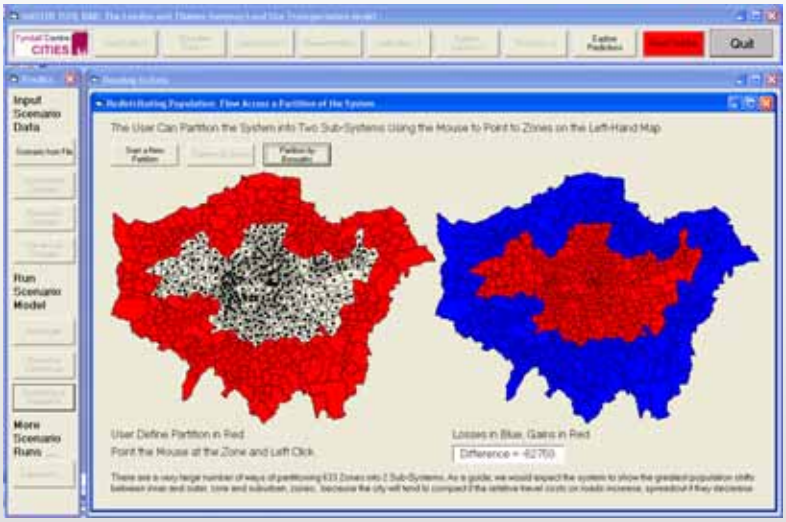
- I now want now to show you how we are using the model to handle energy costs in terms of rising costs of transport
- What we can do is increase the cost of gasoline for road users relative to other modes and see what the effect is
- If we double the cost of gas we then can see how users shift mode of travel and also how location of the population changes. The key issue is to assess this kind of shift in terms of interaction and location
- We will show some screen shots of the model doing this



- The following figures show what happens if gas costs rise by 100% i.e. double



Mode	*Observed*	*Percent Shift*
Road	39%	-50%
Rail	12%	+48%
Tube	33%	+36%
Bus	16%	+73%
Population Shift		4%



Loss of Population from the Suburbs to central City – i.e. Big increases in travel costs on the road lead to compacting

The Impact of Fares-Free Public Transport Upon Urban Residential Location

TRANSPORTATION RESEARCH FORUM

Volume XV • Number 1 1974 347-353

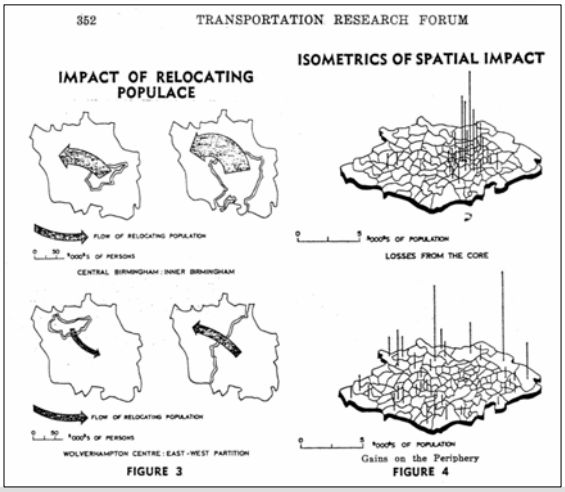
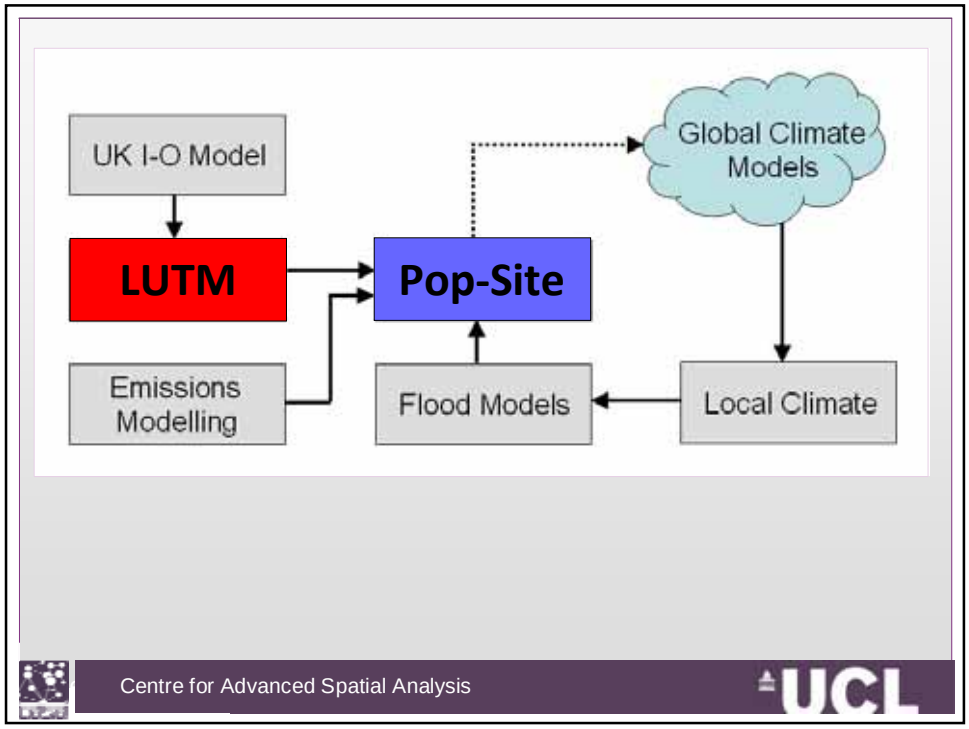
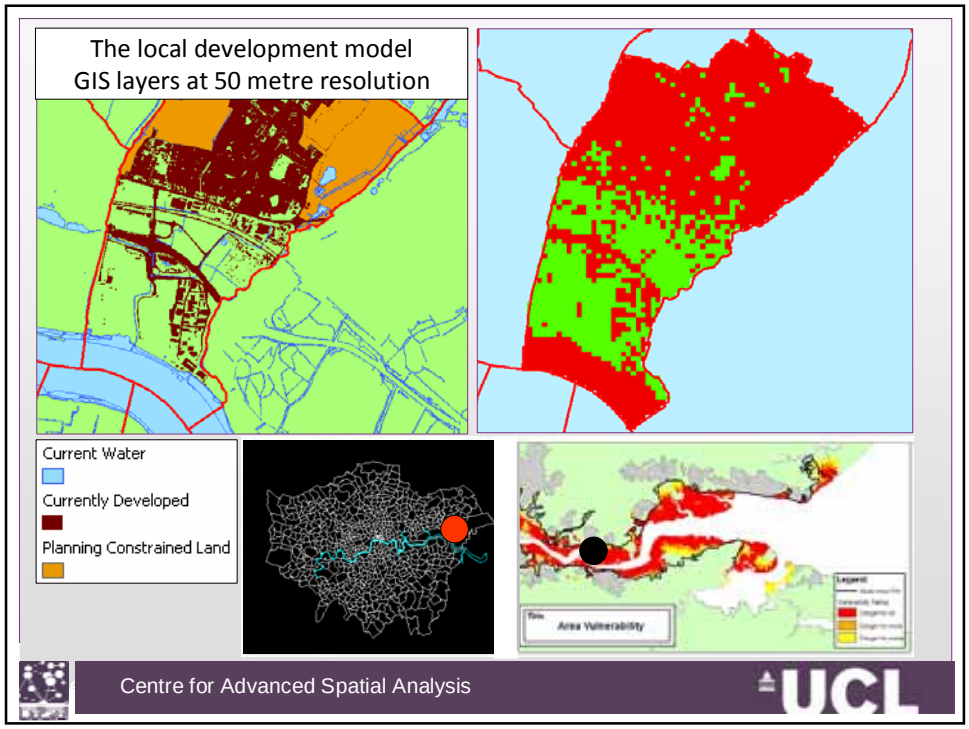


FIGURE 3 FIGURE 4

Integrated Assessment using Sketch Simulation

- I have said nothing at all about how this model is embedded in the integrated assessment – the string of models that are used to scale national regional forecasts to very small scale. I cannot show you all these models but let me just talk briefly about the next stage down – how we go from 633 zones in London to 50 metre grid squares and this sort of hooks up to another style of modelling
- In GIS ….. Here is the integrated assessment block diagram again


UK I-O Model
Global Climate Models
LUTM
Pop-Site
Emissions Modelling
Flood Models
Local Climate
Centre for Advanced Spatial Analysis
UCL


The local development model
GIS layers at 50 metre resolution
Current Water
Currently Developed
Planning Constrained Land
Centre for Advanced Spatial Analysis
UCL

This particular version of the model is being extended in a second phase of Tyndall under the ARCADIA project http://www.ukcip-arcc.org.uk/

Next Steps

- Extending the area to 2000 or so zones – wider south east region
- Building the extended set of sectoral models
- Building in market clearing and some simple dynamics
- Extending the energy use to locational factors
- Disaggregating the model into more population and employment types relative to data
- Specifying movers and stayers through the exogenous inputs and tying these to past model outputs
- Developing the stakeholder context with web and desktop access – exploring millions of futures

If there is time,
I will answer any

Questions

www.casa.ucl.ac.uk

Centre for Advanced Spatial Analysis

UCL