



中山大学地理科学与规划学院  
School of Geography and Planning, Sun Yat-Sen University



# Using Urban Models: Predicting the Impact of Large Scale Urban Infrastructures

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 @jmichaelbatty

*26 April 2017*

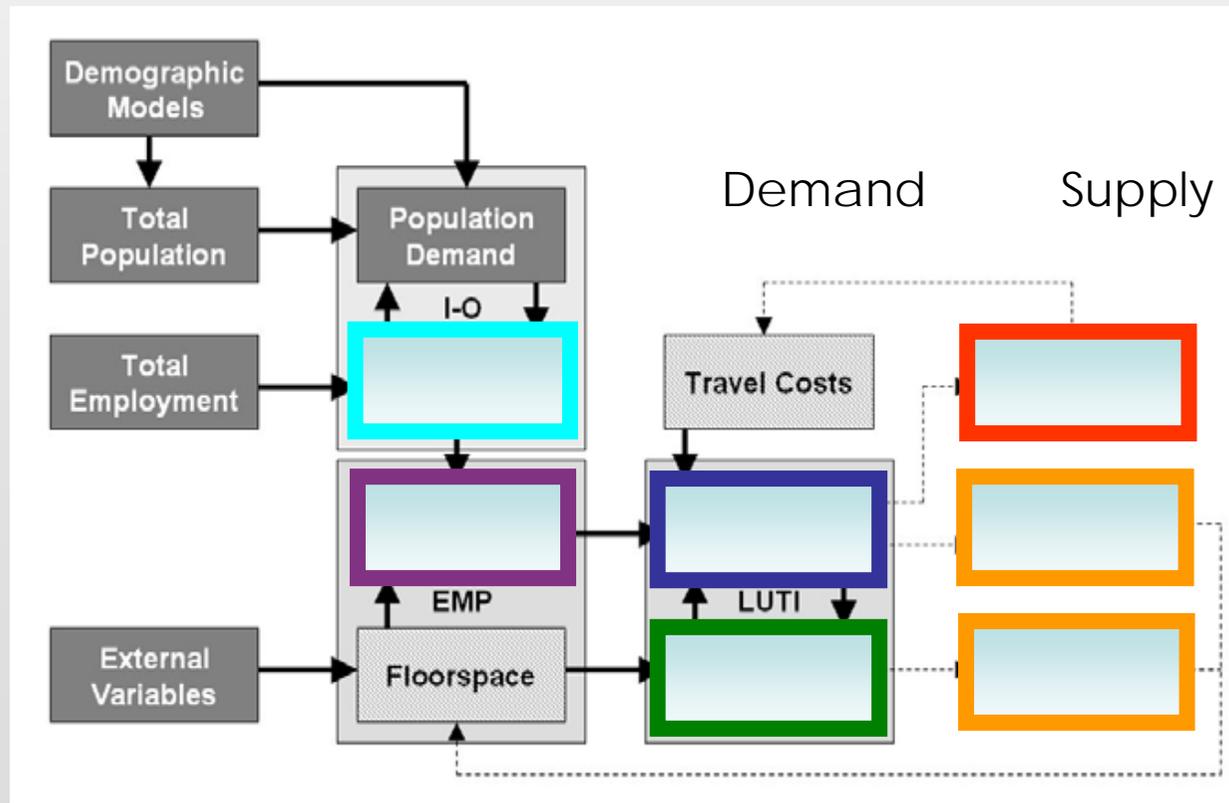
<http://www.spatialcomplexity.info/>

# Outline

- A Demonstration of a Generic Land Use Transportation Interaction (LUTI) Model
- Scaling The Models: More Zones, More Detail
- A Quick Demo of QUANT
- Problems with the Models
- Setting and Testing Scenarios
- Big Infrastructure Projects: Crossrail, HS2, The Third London Airport
- Future Urban Models and Use in Planning

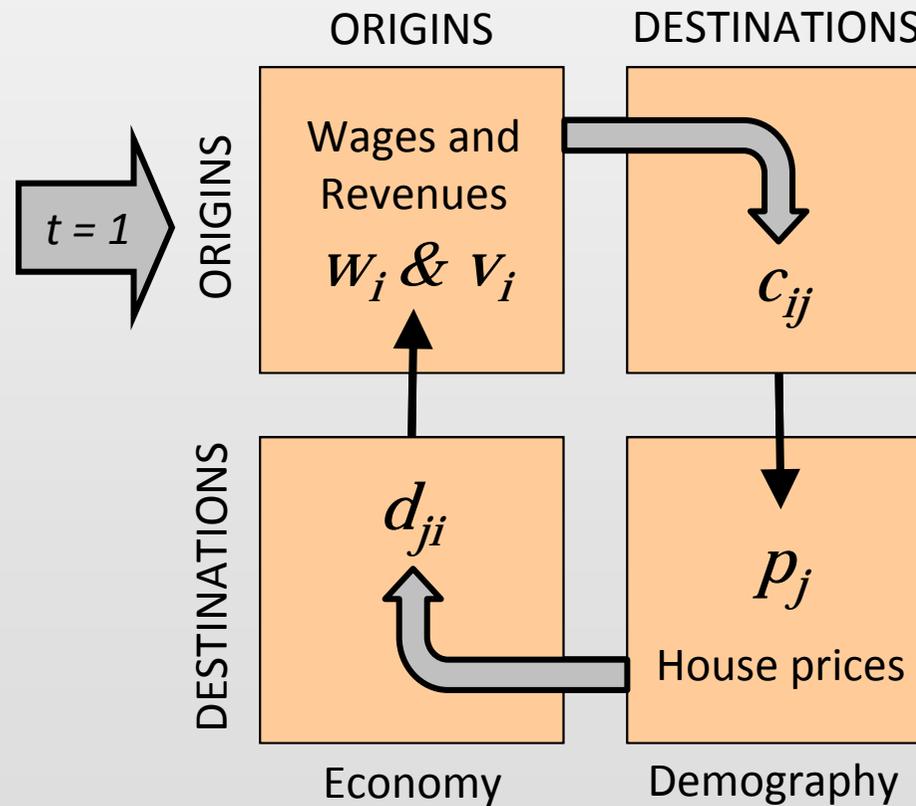
# A Demonstration of a Generic Land Use Transportation Model

Let me explain what the model is – LUTI – generic land use transportation – I talked about this type of model 31 years ago when I came here



# How They Work

Imagine two sectors – the simplest – population and employment; employment drives population and vice versa through spatial demand for labour (J-W) & spatial demand for products (J-S)



# A Very Important Key Point

The demand for various products in such models is subject to capacity constraints. For example a model producing J to W flows –  $T_{ij}$  – is subject to the capacity of the network and also when we add up the number of workers getting to any place to live, this must be less than the density limit. We need to iterate. This is the killer – it has been like this since the beginning of these models

$$T_{ij} = E_i p_{ij} \sim E_i A_j \exp(-\beta c_{ij})$$

if  $T_{ij} > C_{ij}$  then  $c_{ij}$  is increased, as  $c_{ij} = c_{ij} \frac{T_{ij}}{C_{ij}}$

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

if  $P_j > Z_j$  then  $A_j$  is decreased, as  $A_j = A_j \frac{P_j}{Z_j}$

I  
T  
E  
R  
A  
T  
E

It is made even worse by the fact that the networks are at a different (finer) scale than the aggregated zonal model. When we change  $C_{ij}$  we need to drill down and look at individual elements

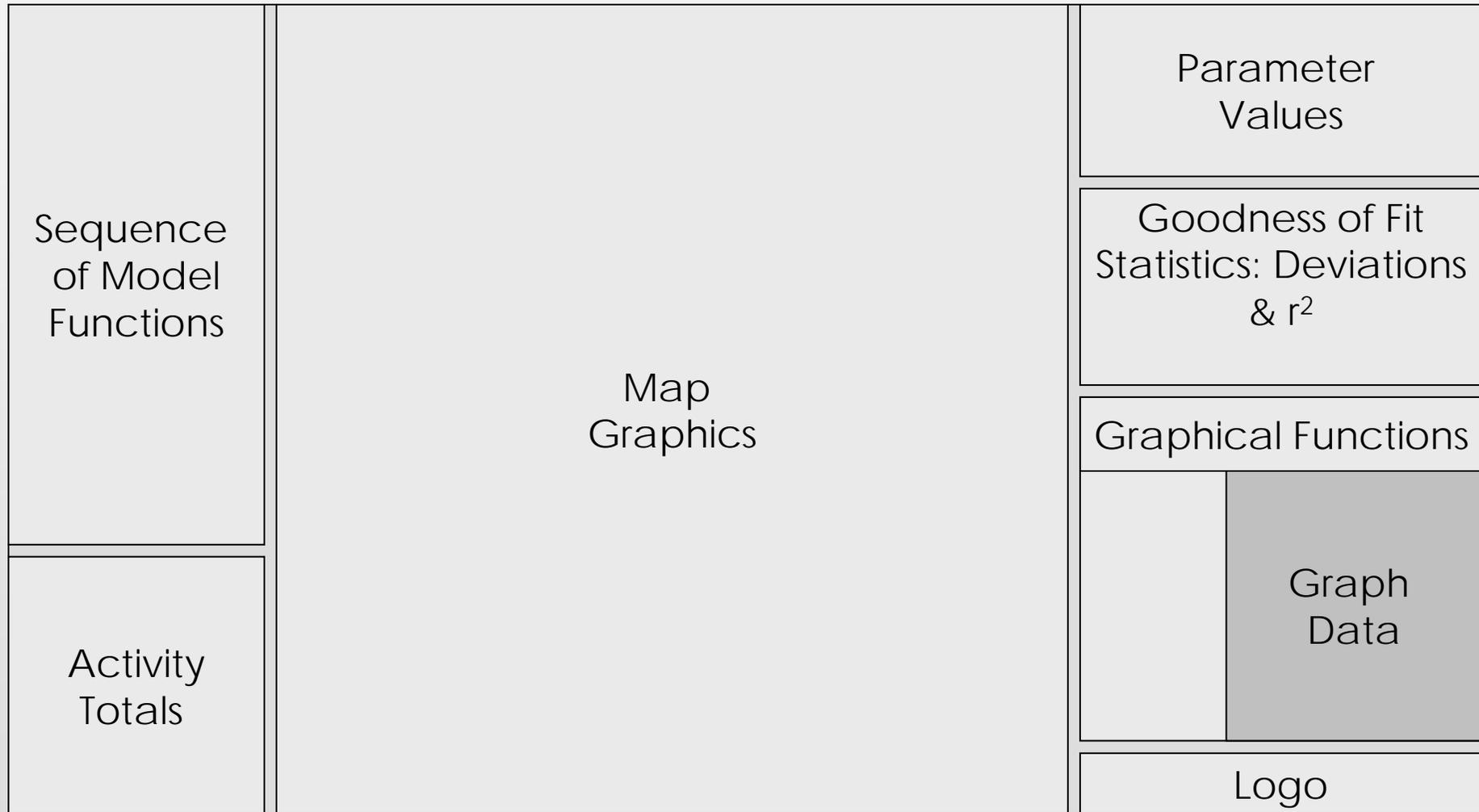
$$C_{ij} = C_{ij_1} + \boxed{C_{j_1 j_2}} + C_{j_2 j_3} + \dots + C_{j_n j}$$

It may be that the one in the red box needs to be increased but this segment might be common to other trips and thus it is impossible to figure out which ones to increase and in what order. We thus risk setting other trips out of equilibrium, and thus no overall equilibrium can be guaranteed.

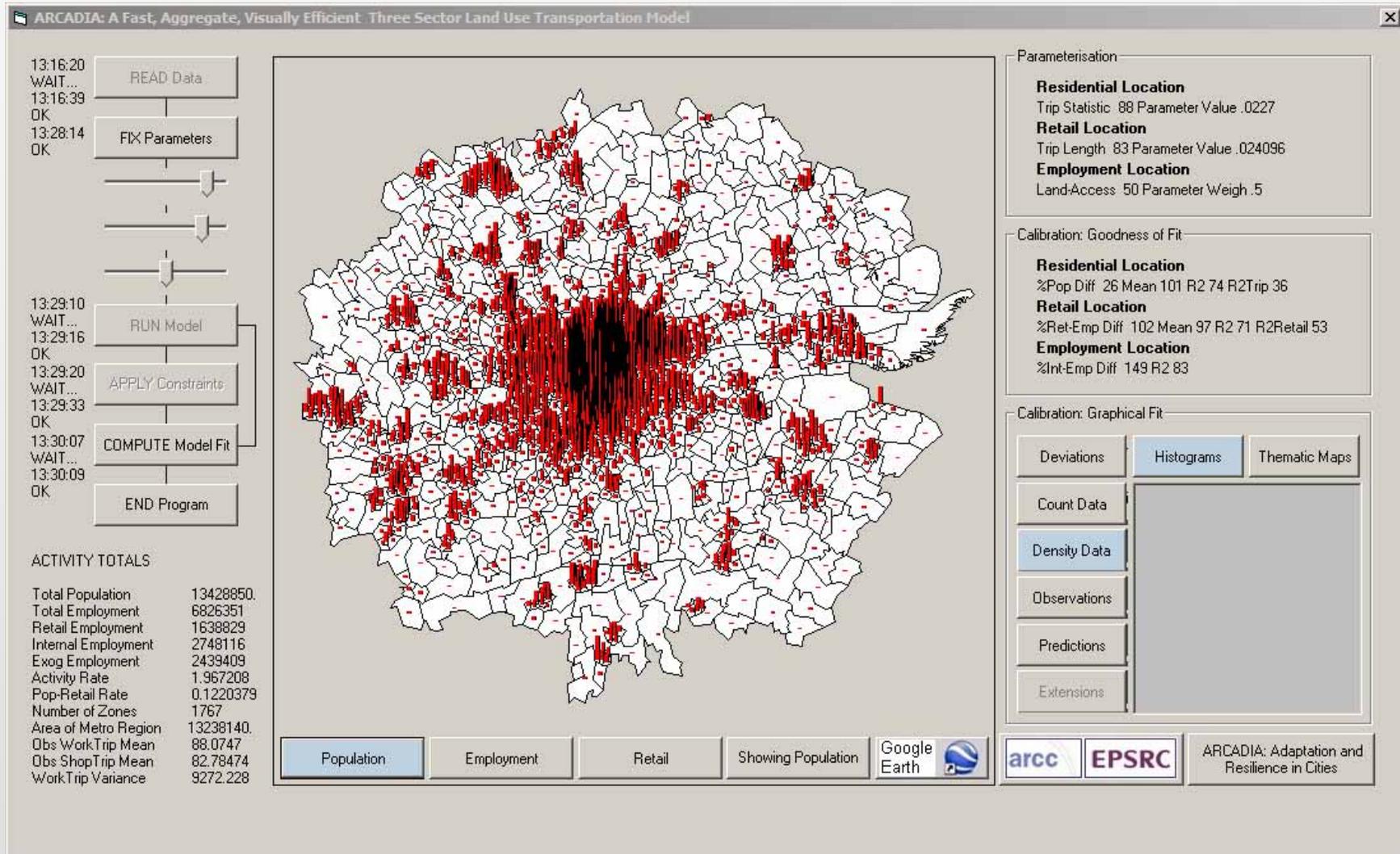
In fact if all we do is alter  $C_{ij}$  then we can be more certain that the model will converge but this may take many iterations.

If we have the simpler model where there is only one  $C_{ij}$ , then this is more likely to converge but for a very large model it might take many iterations

Now let us show one of these models where this is the desktop order of operations that take place with the inputs and outputs







# Scaling The Models

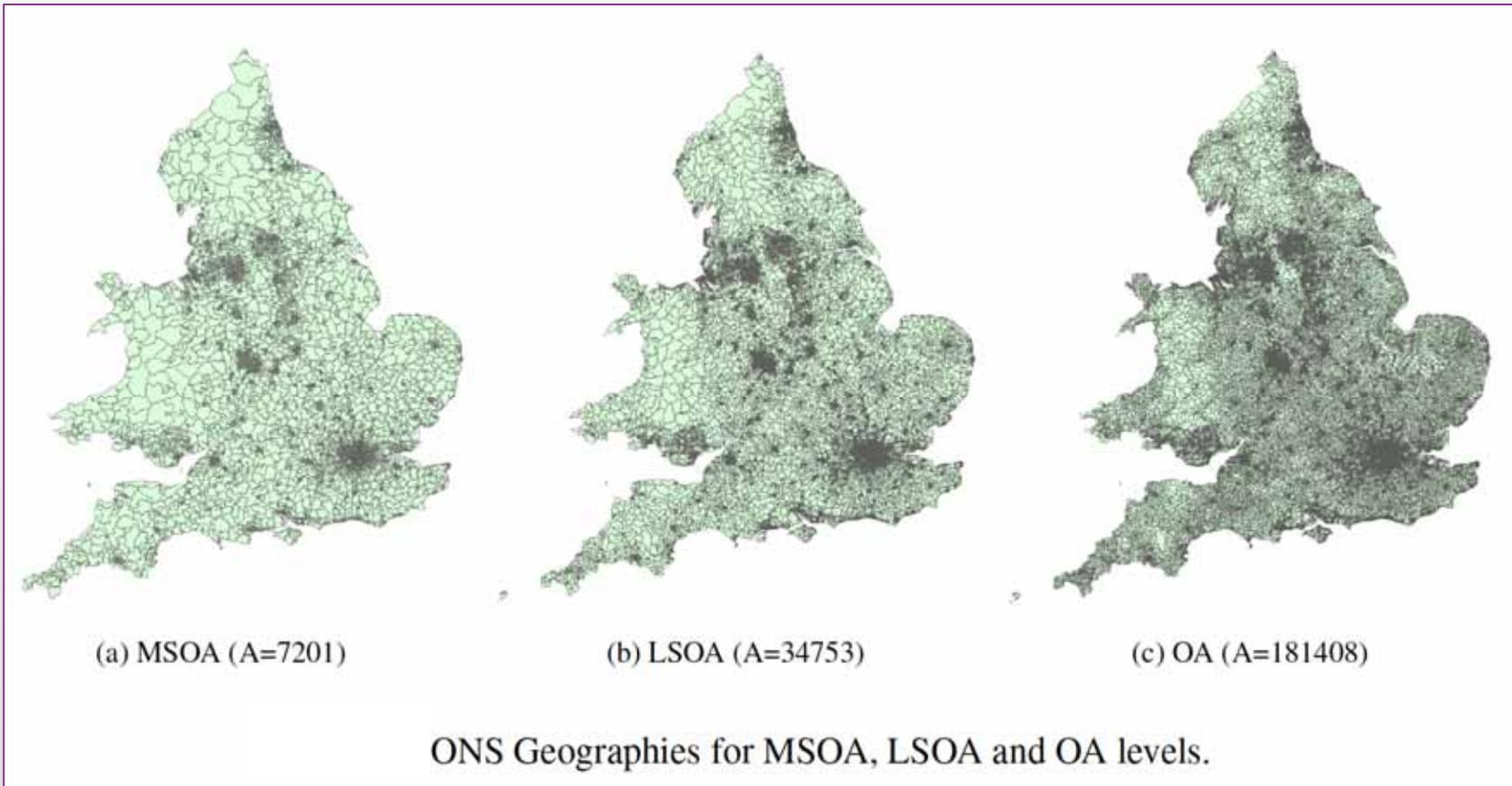
- We are building a model which is for the UK – currently England and Wales – at the same level as our current urban models. Absolutely essential to do this because of wider interaction effects – the ‘where does London begin and end’ problem
- The model is web based – any user can access it from anywhere – and in this sense, it has multiple users.
- It is fast to run – many problems of map delivery from server to client and so on but these are being sorted. Biggest issue is with transport networks and their updating at a very fine scale
- The model is called **QUANT** - a not very original title but easy on the eye so to speak – it means **Q**uantitative **U**rban **AN**alytics forecast**ing**, or some variant thereof
- It grew out of a version of the model just demoed
- It is designed to let any informed expert develop scenarios

Let me show you the spatial representation first – what we call middle layer super output areas – MSOAs – which have around 7000 persons per unit on average

There are some 52 million persons in E and W in 2011; there are some 27 million jobs; there are 7201 MSOAs

Why E and W and not Scotland or NI





We could build this at the finest geographical scale – it would take ages to run because our matrices would be of the order  $181K^2$  and then we would have to move to ABM ~ 150 p p zone

# A Quick Demo of QUANT

- Here is the web site that you can explore – caveat emptor – it's a prototype, its free, it is an alpha version not even beta
- <http://quant.casa.ucl.ac.uk> 
- It is based on a simple structure of letting the user explore the data, then run the model (and calibrate it although as this happens every time it like an initiation of variables), then the user can look at the model outputs (predictions of the observed cross section) and finally set up scenarios – currently changes in employment and changes in rail lines – due to our (the UK Govts) current obsession with infrastructure projects
- Many issues here that are not reported to do with computational and programming considerations
- Visualisation to date is quite primitive.

# QUANT Alpha version

Simulating the Impacts of Large Scale Change in UK

[Explore QUANT](#)

[About QUANT](#)



# QUANT

Alpha version

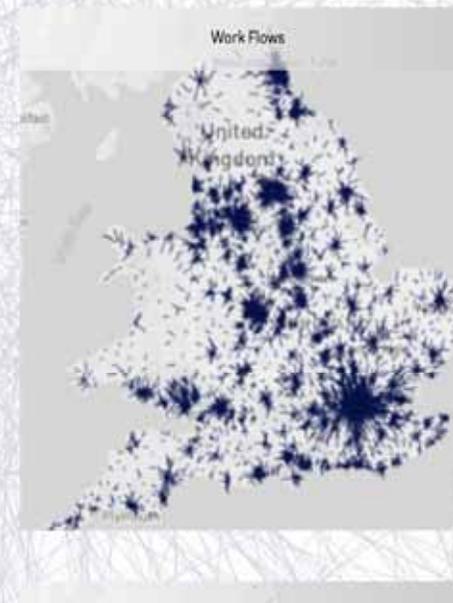
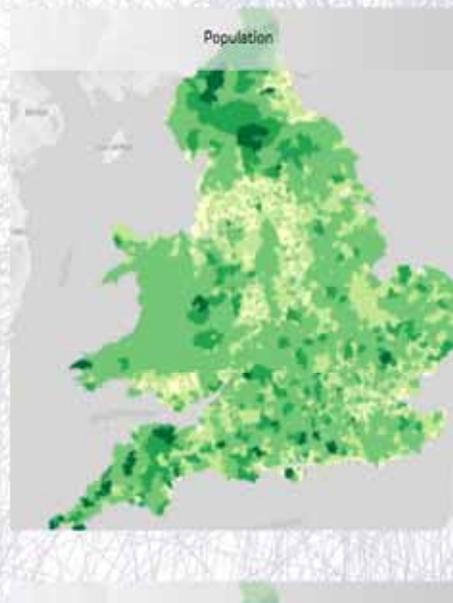
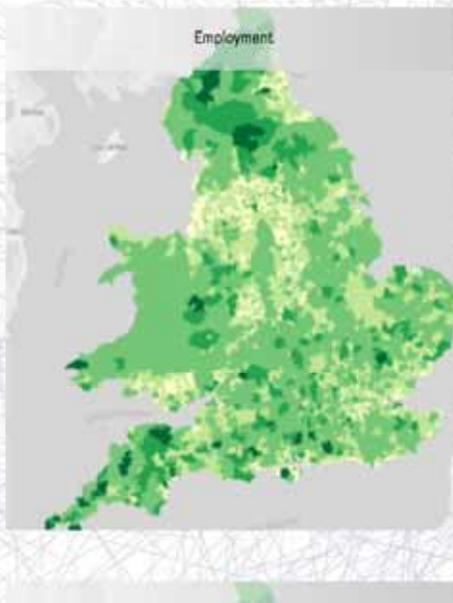


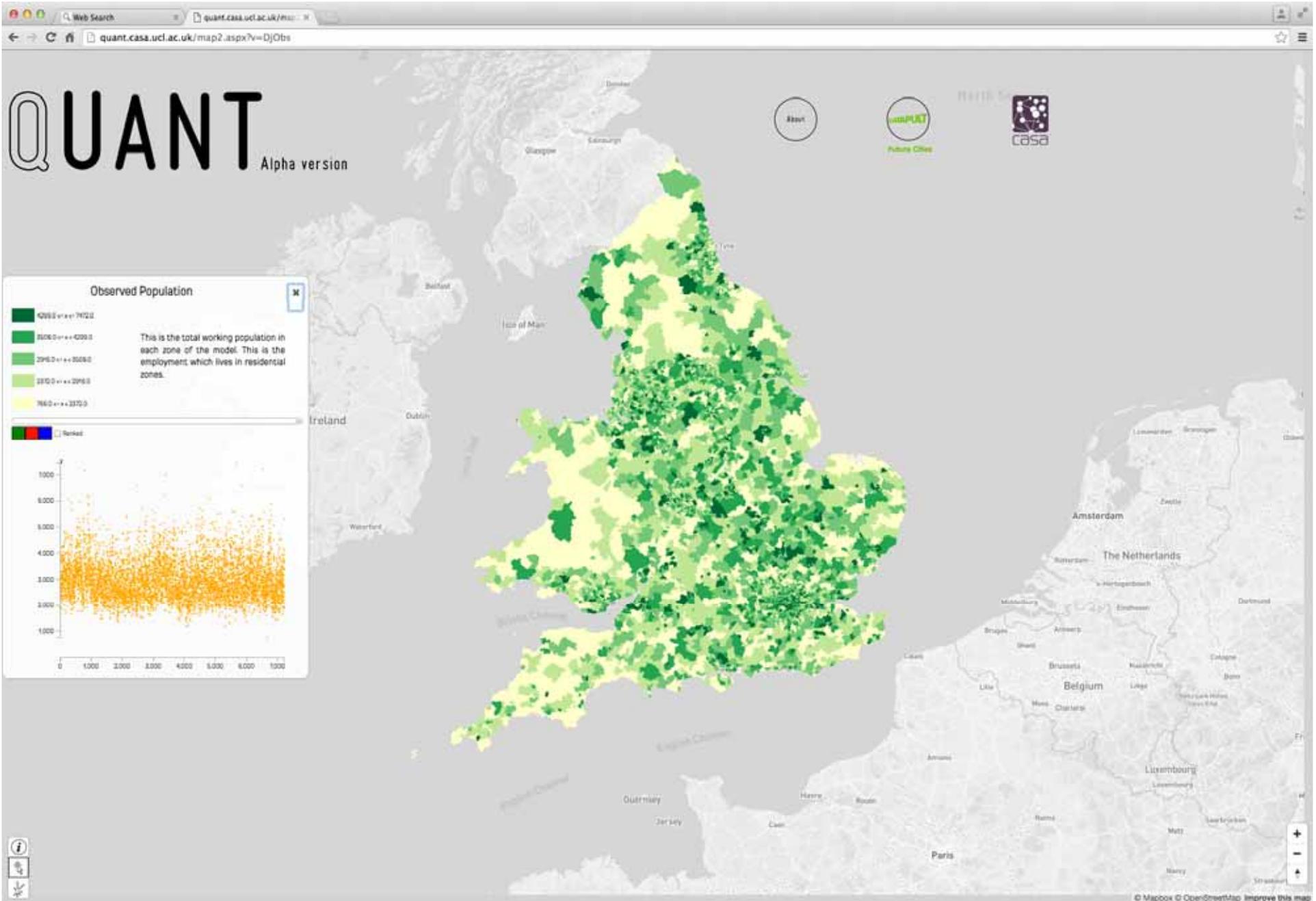
Explore Data

Run Model

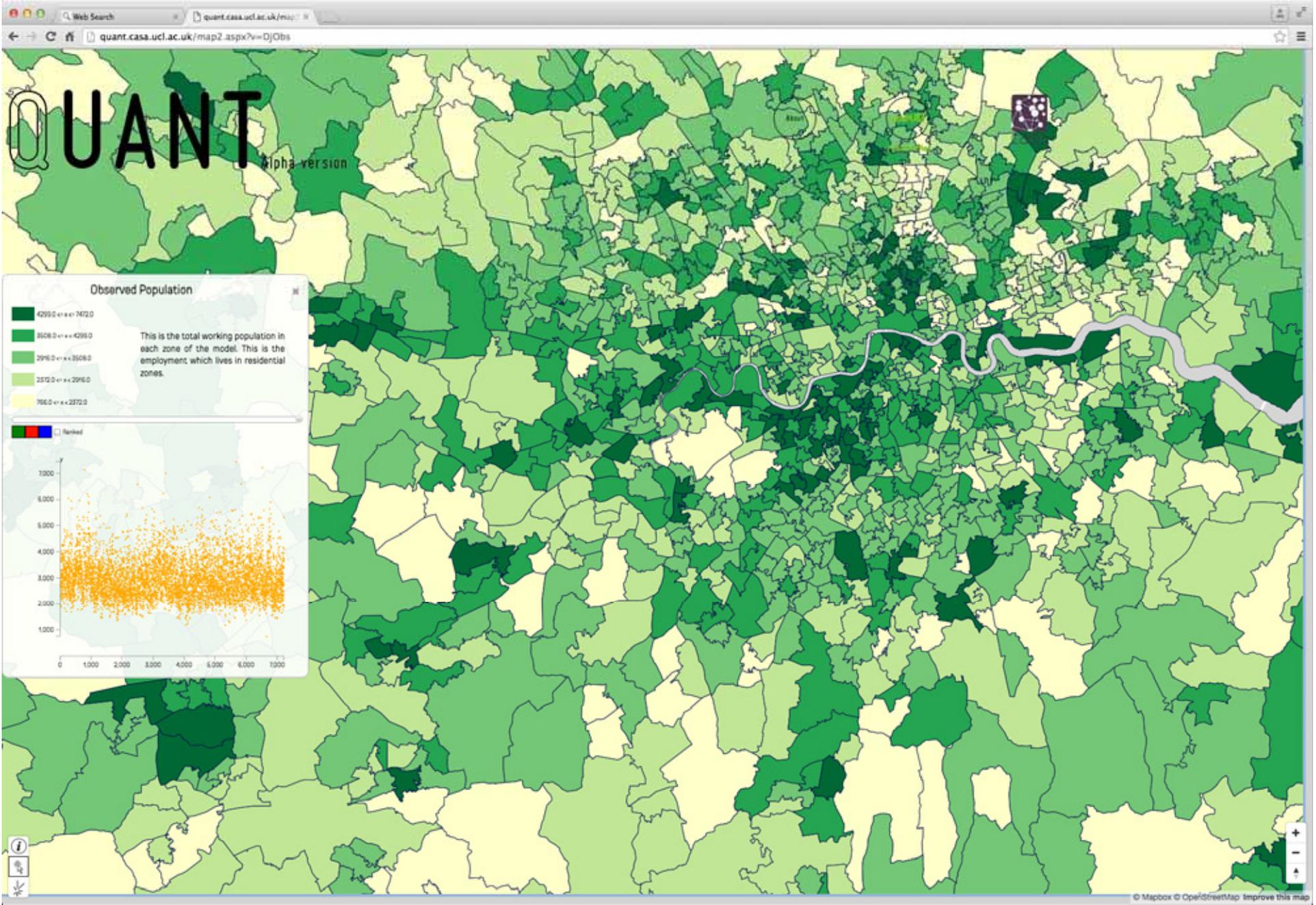
Set Scenarios

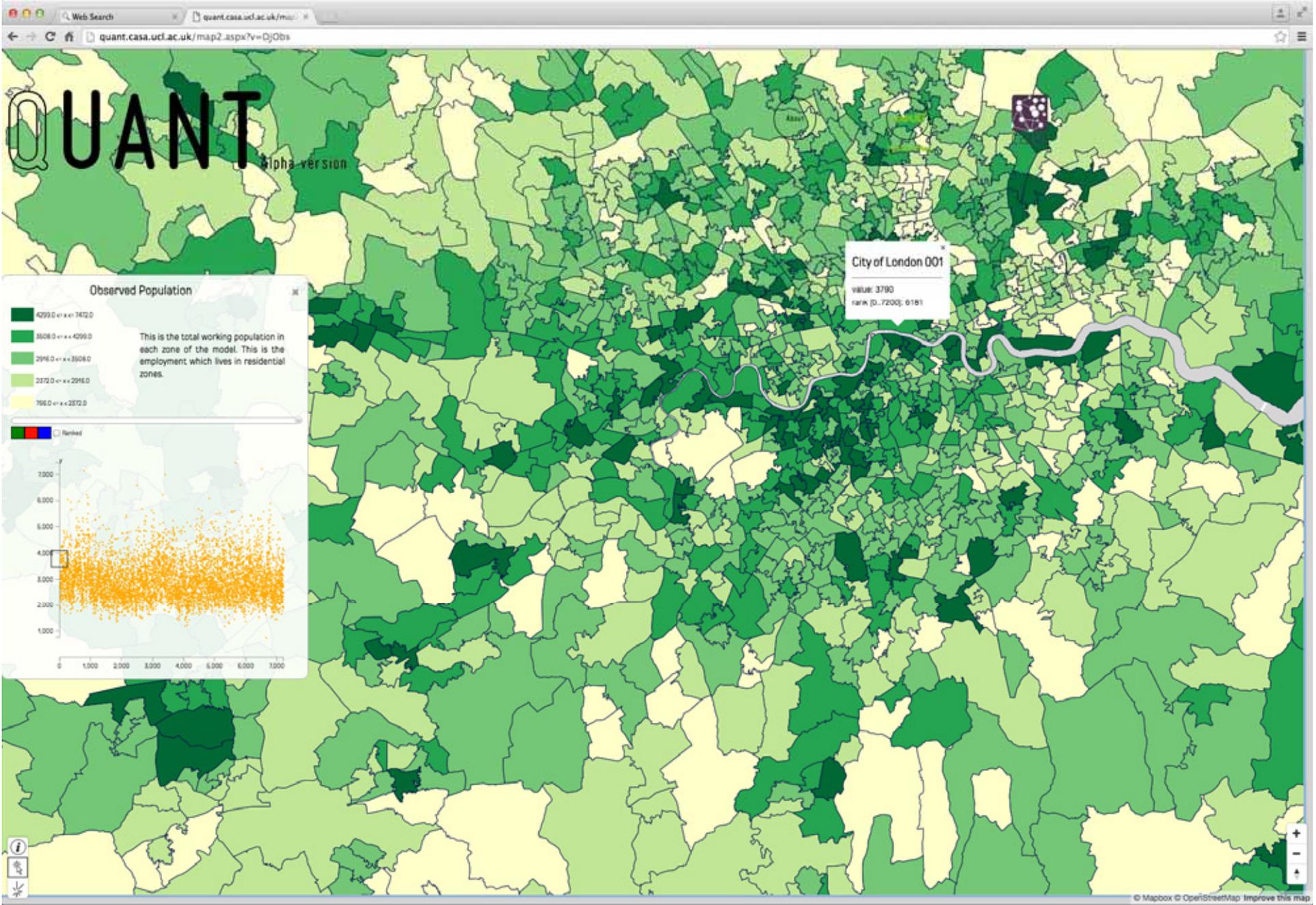
Home

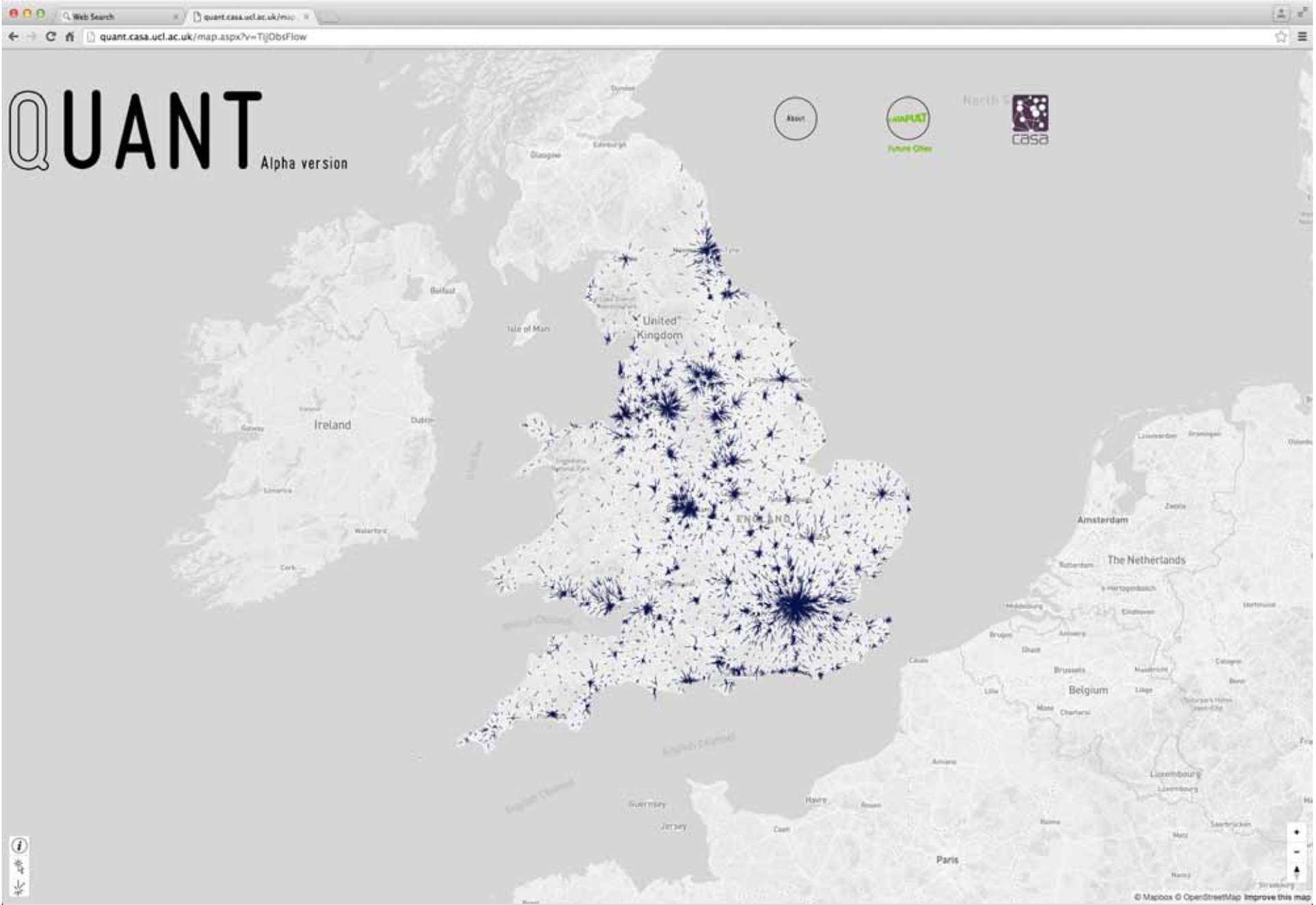


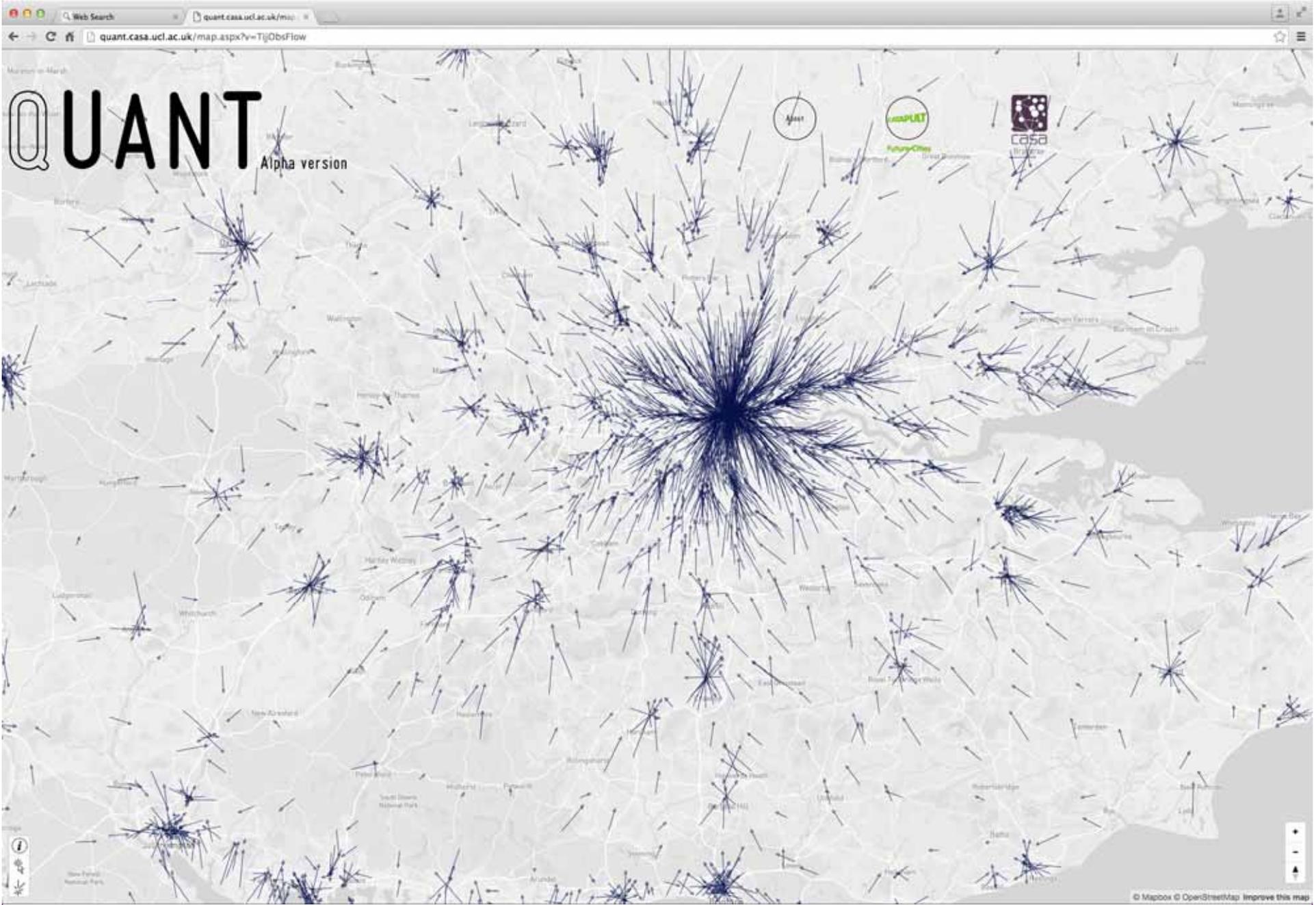




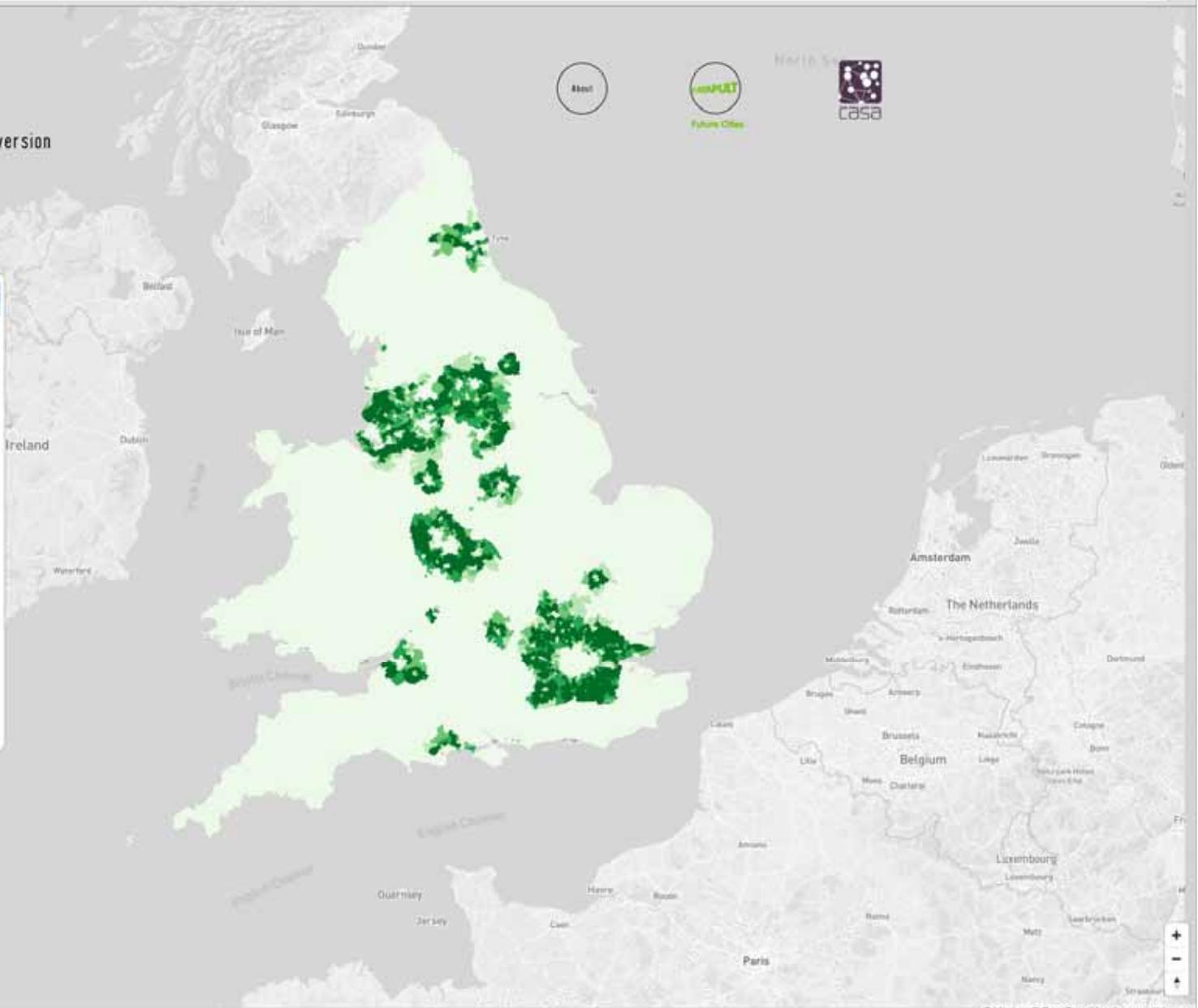
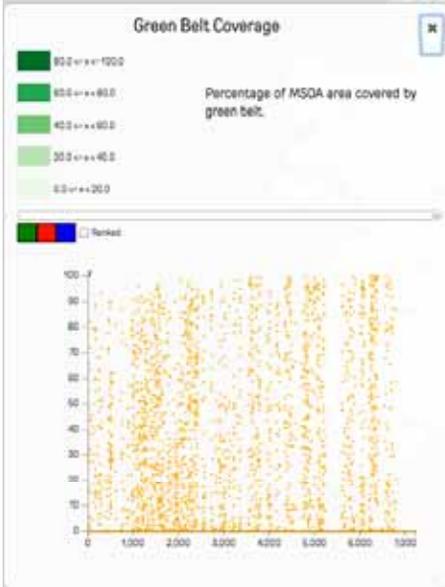


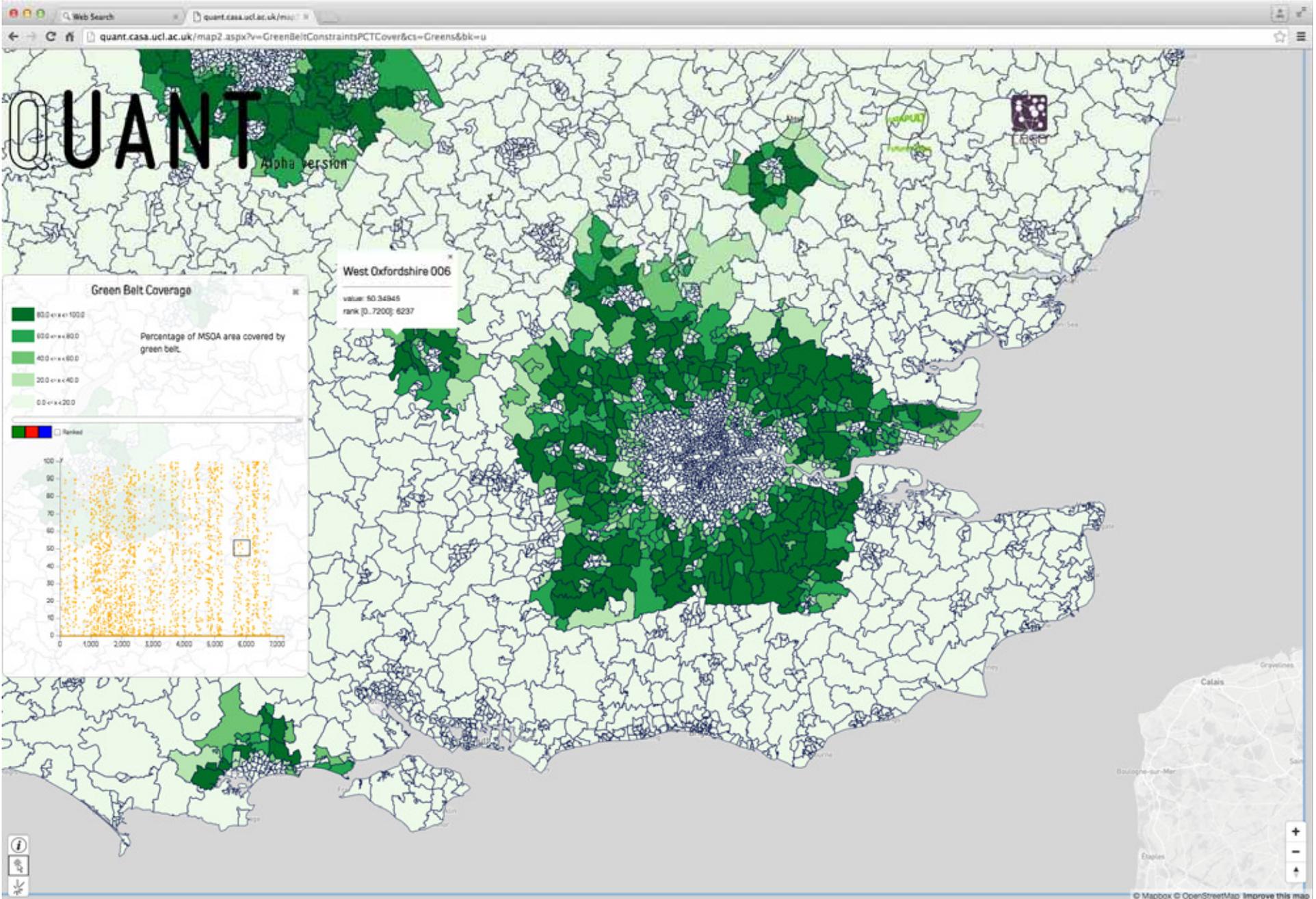


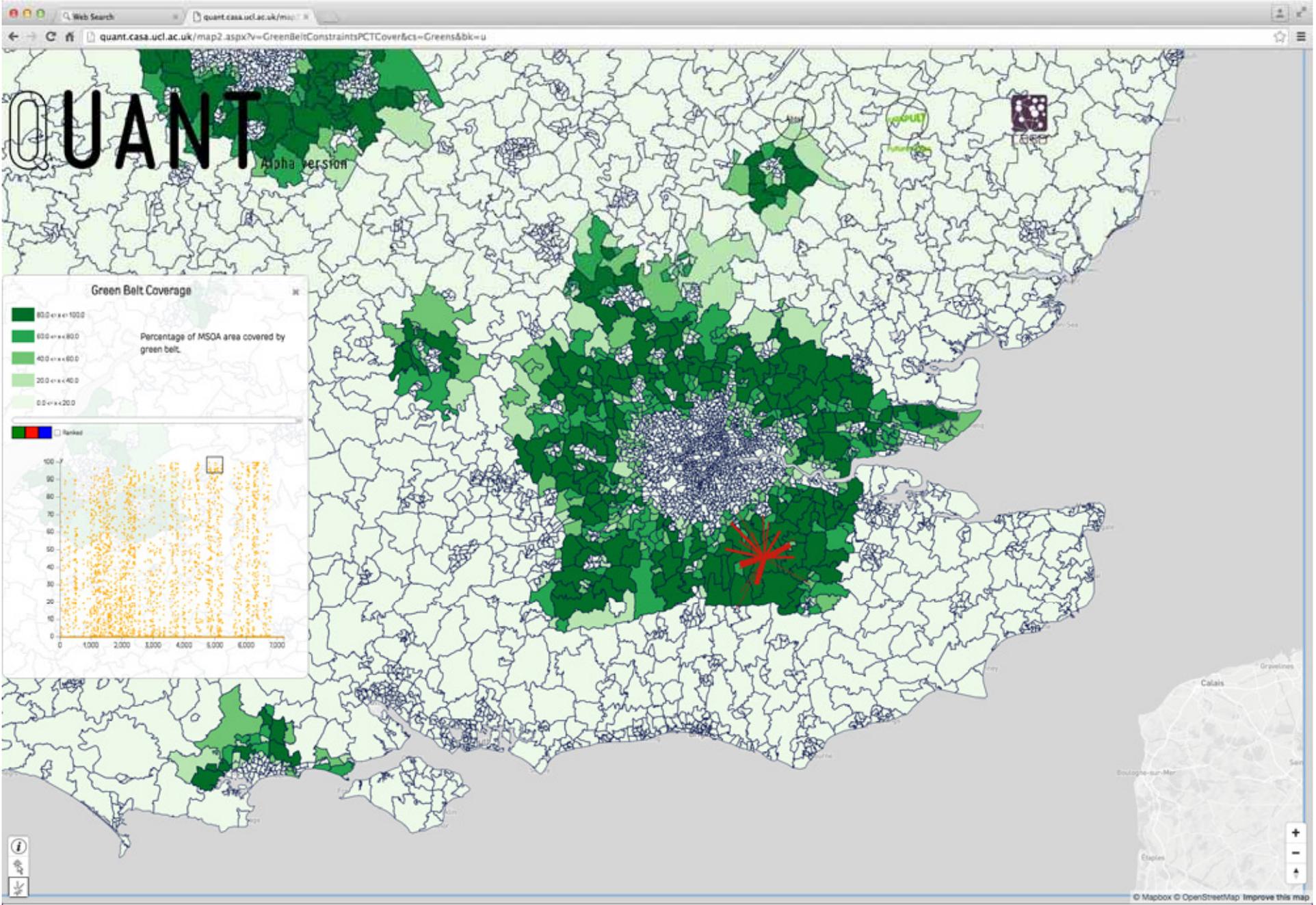




# QUANT Alpha version







# QUANT

Alpha version



Explore Data

Run Model

Set Scenarios

Home

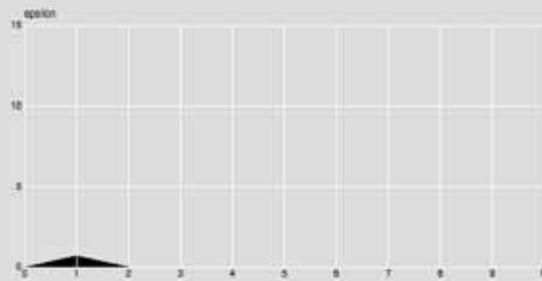
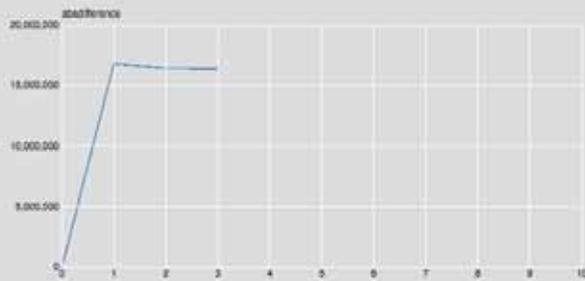
Before Running the model please calibrate the travel parameter to make sure the model is a good fit.

Constraints Off



Explore Model

Finished



# QUANT

Alpha version



Explore Data

Run Model

Set Scenarios

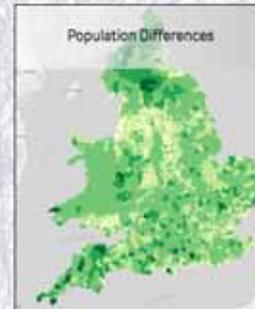
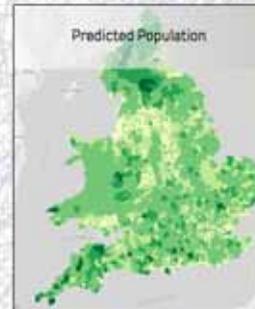
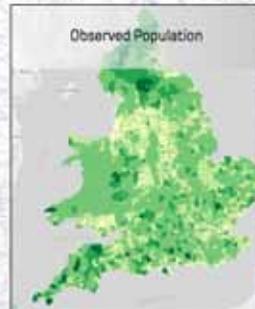
Home

Maps

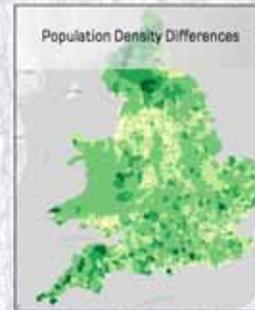
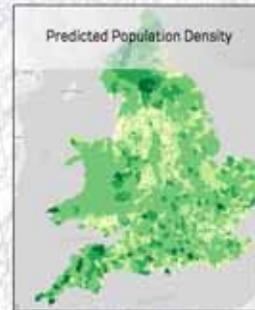
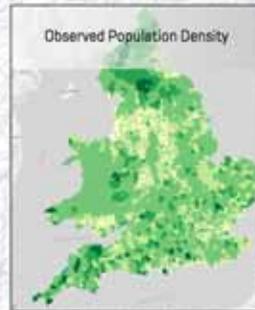
Graphs

Charts

**Population**  
This is total working population in each zone of the model. This is the employment which lives in residential zones.



**Population Density**  
This is working population divided by the land area of the residential zone.



# QUANT

Alpha version



Explore Data

Run Model

Set Scenarios

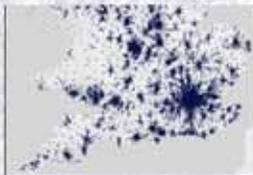
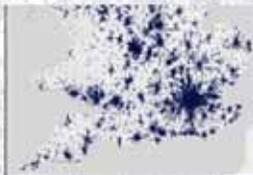
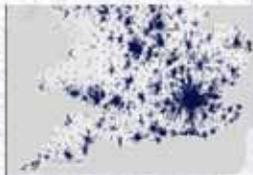
Home

Maps

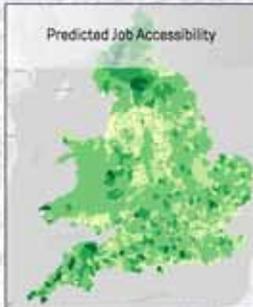
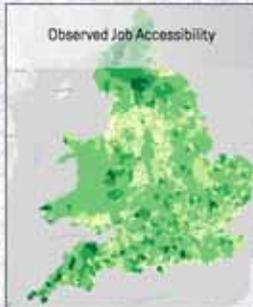
Graphs

Charts

trips from the residential zone to the employment zone.

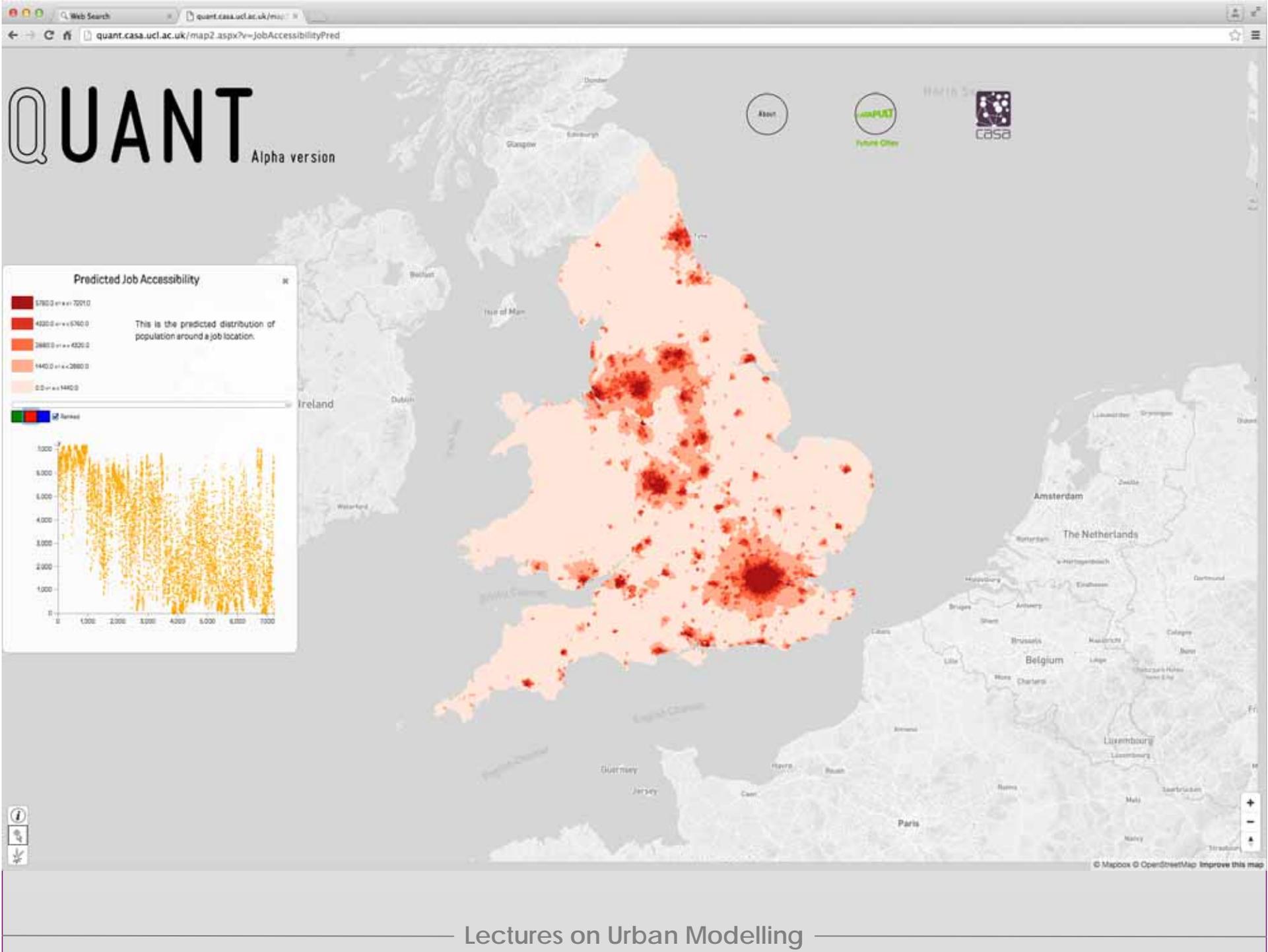


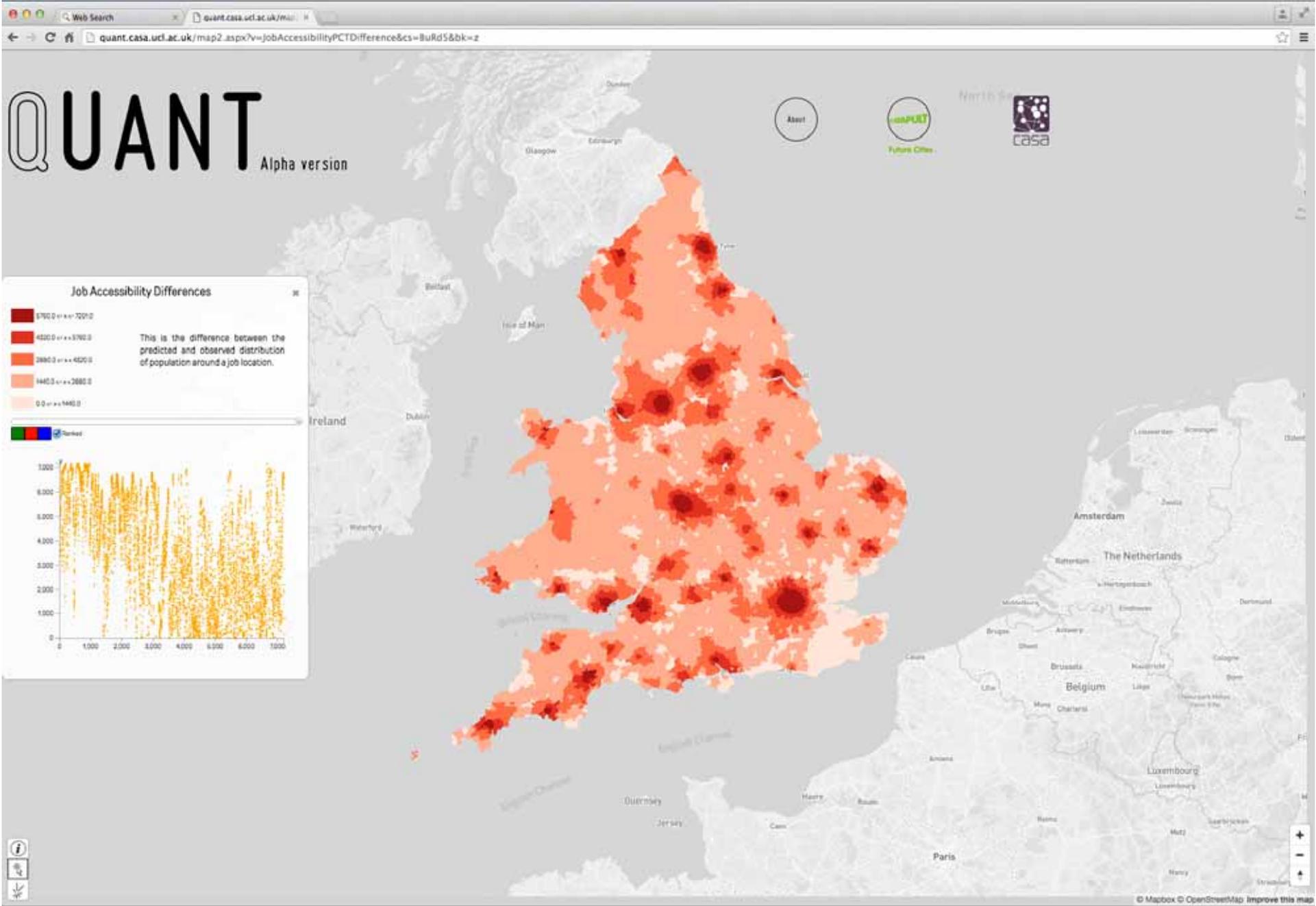
**Accessibilities Origins**  
This is the accumulated weighted distance from each individual workplace zone to all residential zones.



**Accessibilities Destinations**  
This is the accumulated weighted distance from each individual residential zone to all workplace zones.





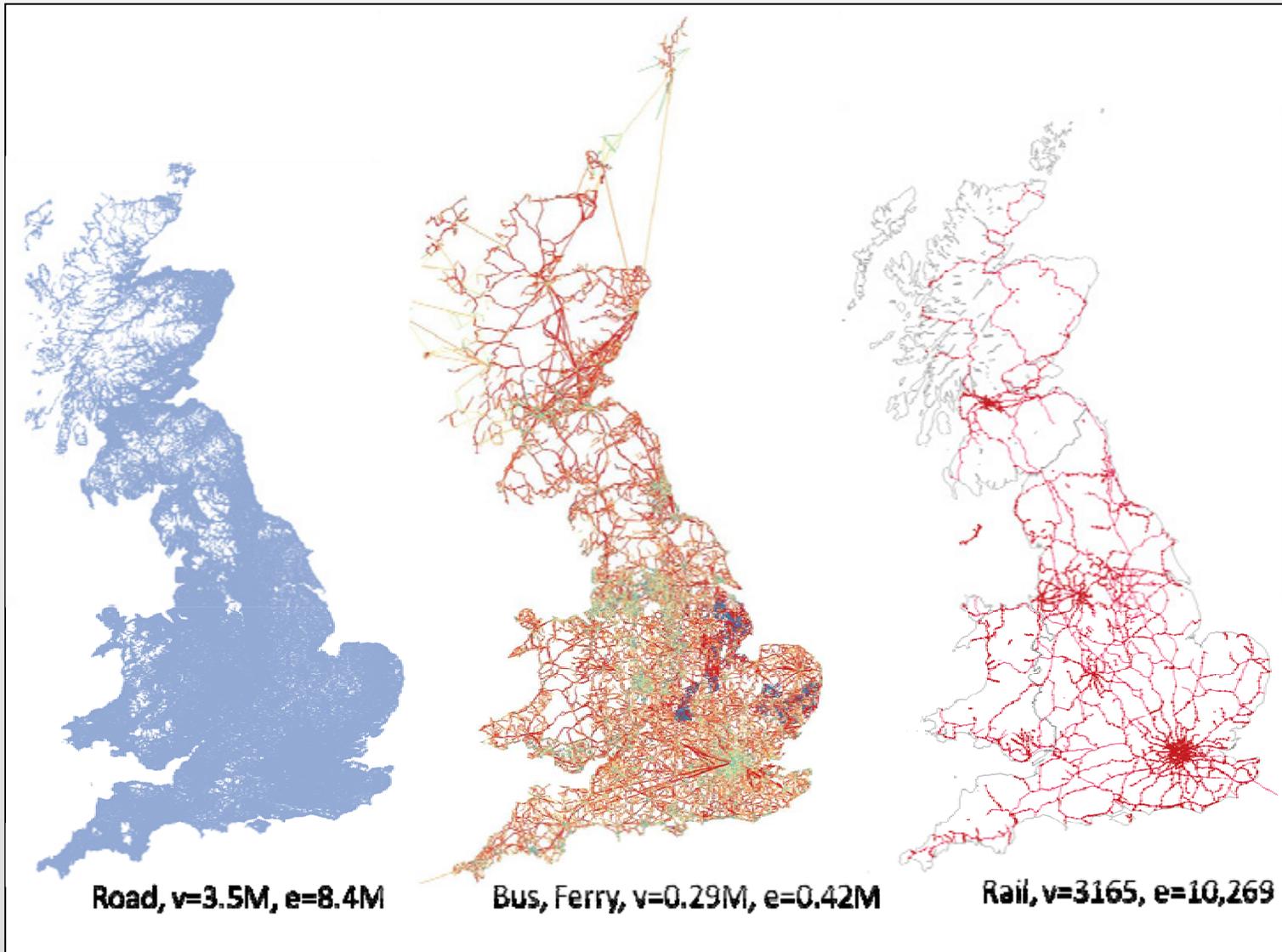


# Problems with the Models

The problem we have with getting the model to reach an equilibrium with respect to the supply of transport through the capacity of the network is that such an equilibrium is continually disturbed by the fact that the networks are at much more detailed scale

We need to assign trips to the networks and due the fact that they compete for network space, we cannot change travel costs in a simple way. To an extent this is the problem faced in MATSIMs – the ABM/Microsimulation model developed out of TRANSIMs which we are running also for London. It take four days to converge as the trips keep on disturbing those that have been predicted.

Some versions of these models have simply developed a separate transport model alongside and accepted that the urban model produces generic interactions not trips. But this is a fudge. Let me show the complexity of the networks underlying the model



If we work out the surplus trips that cannot be loaded onto the network which are

$$S_{ij} = (T_{ij} - C_{ij})$$

we can then allocate them differently, one at time as though they are agents.

We are experimenting with doing this – and so in essence we are making use of the aggregate model to allocate demand to meet supply and the surplus demand is then allocated using an ABM – or rather it is allocated for disaggregates – to the individual level where the supply constraints are reached incrementally

Yes it is a fudge, No it isn't an agent based model I hear you say.

But it is on the way and the logical outcome of proceeding in this direction is an ABM and probably like in our MATSIM model, would be based on a sample of employment – a 10% sample would be some 2.7 million employees

We think this is currently feasible. Ok let me show you some runs of the model and then I will wrap up

# Setting Up and Testing Scenarios

The screenshot displays the QUANT web application interface. At the top, the browser address bar shows the URL `quant.casa.ucl.ac.uk/explore.aspx`. The main header features the QUANT logo with the text "Alpha version" and navigation links for "About", "CATAPULT Future Cities", and "CASA". Below the header, four primary navigation buttons are visible: "Explore Data", "Run Model", "Set Scenarios", and "Home". The "Set Scenarios" button is highlighted with a thick border. The main content area contains three maps of the United Kingdom: "Employment" (green heatmap), "Population" (green heatmap), and "Work Flows" (blue network diagram). A vertical scrollbar is present on the right side of the map area.

Google | quant.casa.ucl.ac.uk/scenan | quant.casa.ucl.ac.uk/scenario-map2.aspx

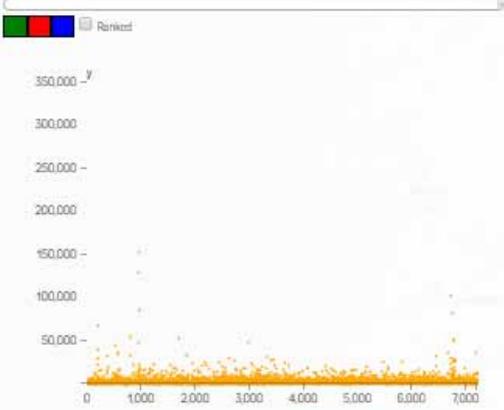
# QUANT Alpha version

[About](#)



### Scenario Changes

This is a blank map that allows changes for the scenario to be defined. The graph shows date for employment.



Ranked

### Scenario

Map

S     delta

**Employment (O<sub>i</sub>)**  
No changes

**Population (D<sub>j</sub>)**  
No changes

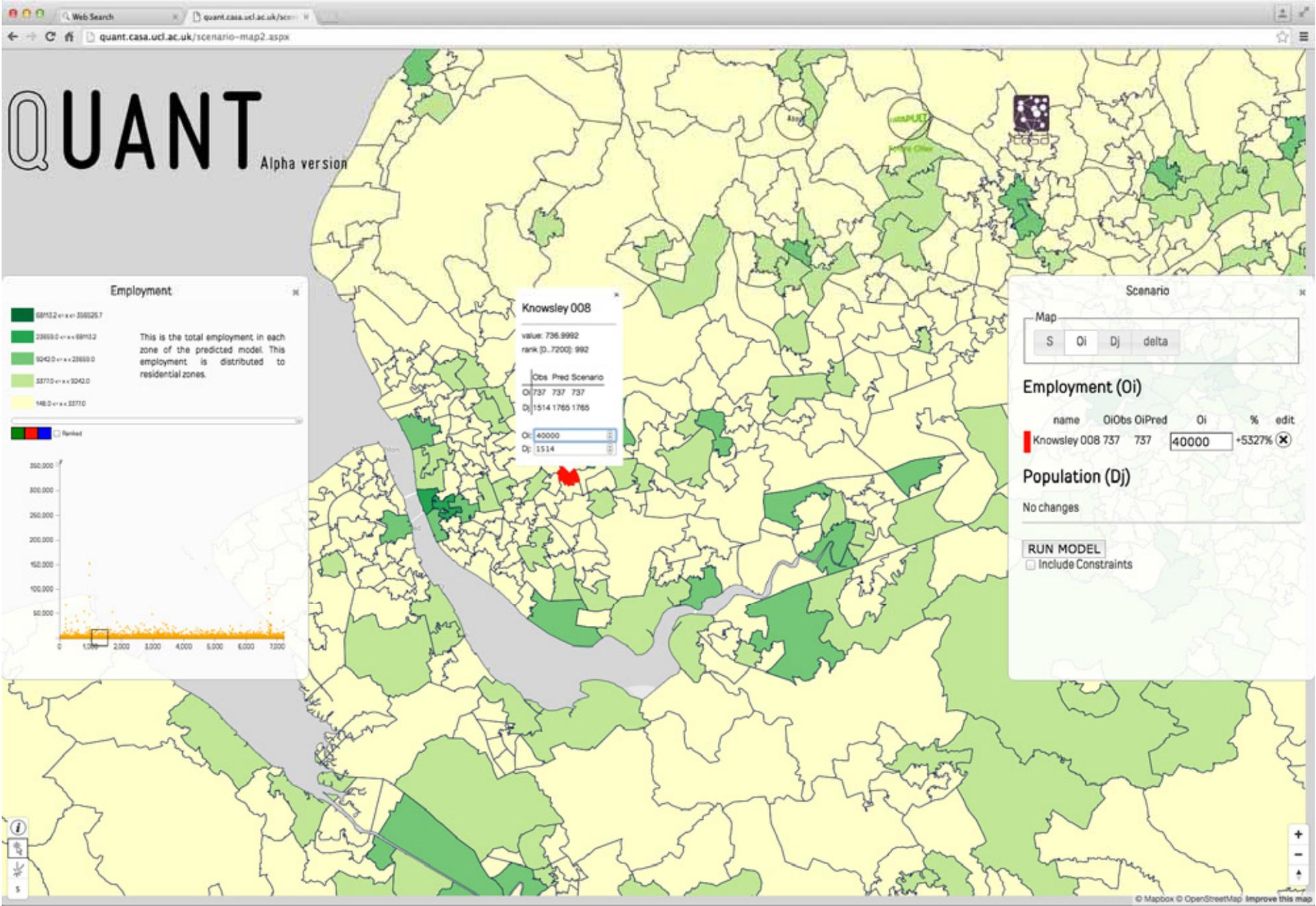
**RUN MODEL**

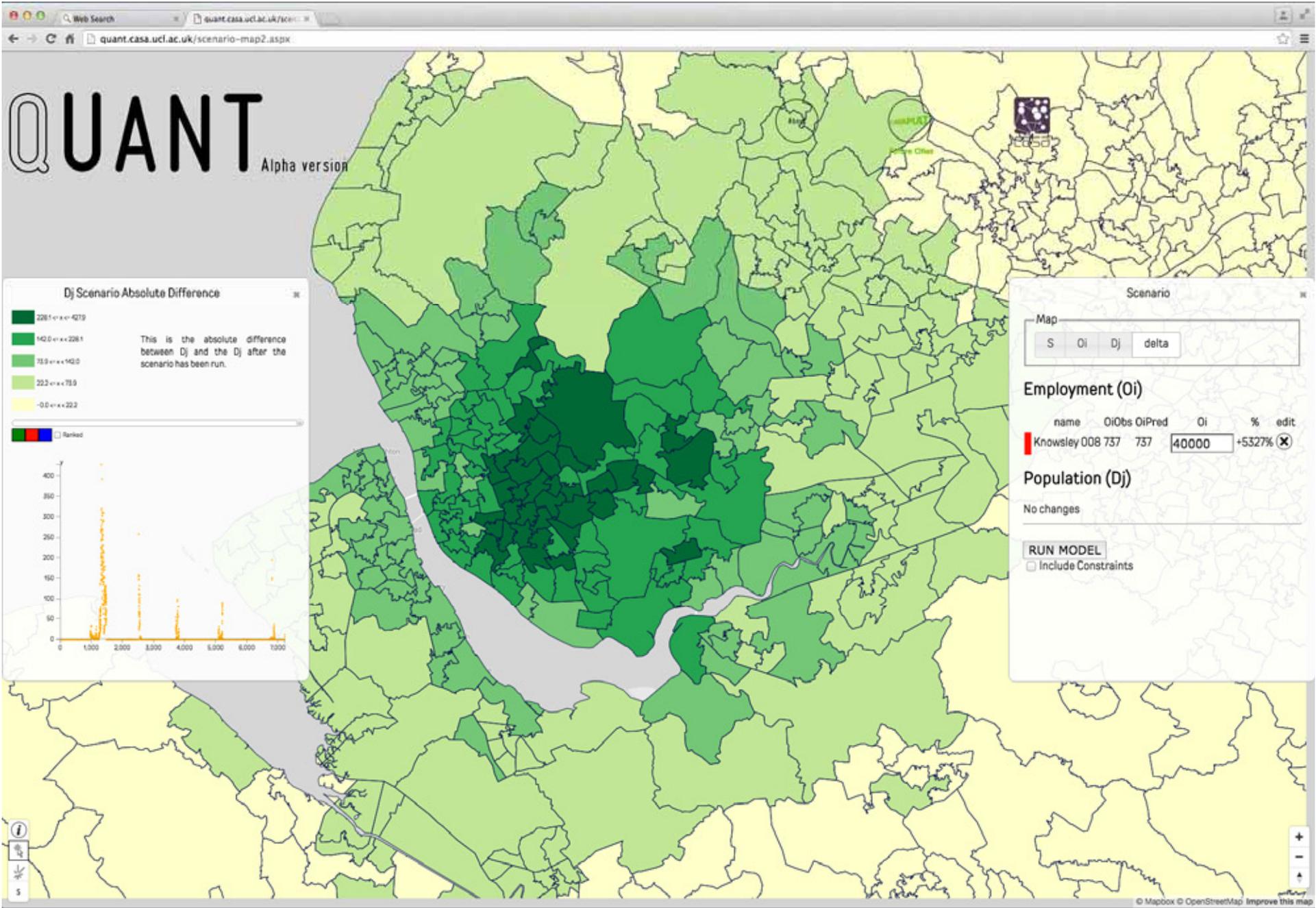
Include Constraints

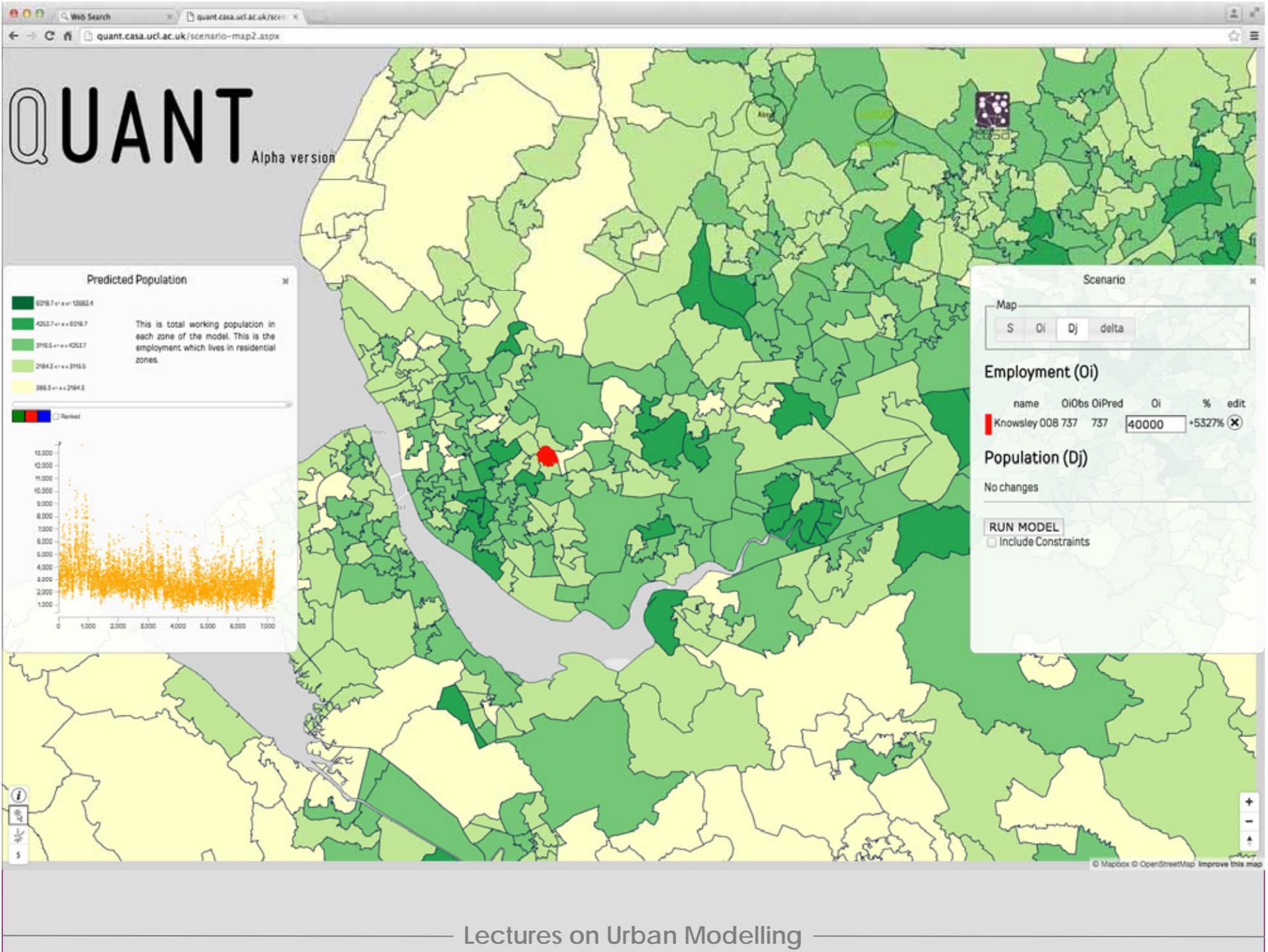
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Glasgow  
Edinburgh  
Londonderry  
Belfast  
Isle of Man  
Ireland  
Dublin  
Waterford  
North Sea  
Bristol Channel  
Middelburg  
Bruges  
Ghent  
Calais

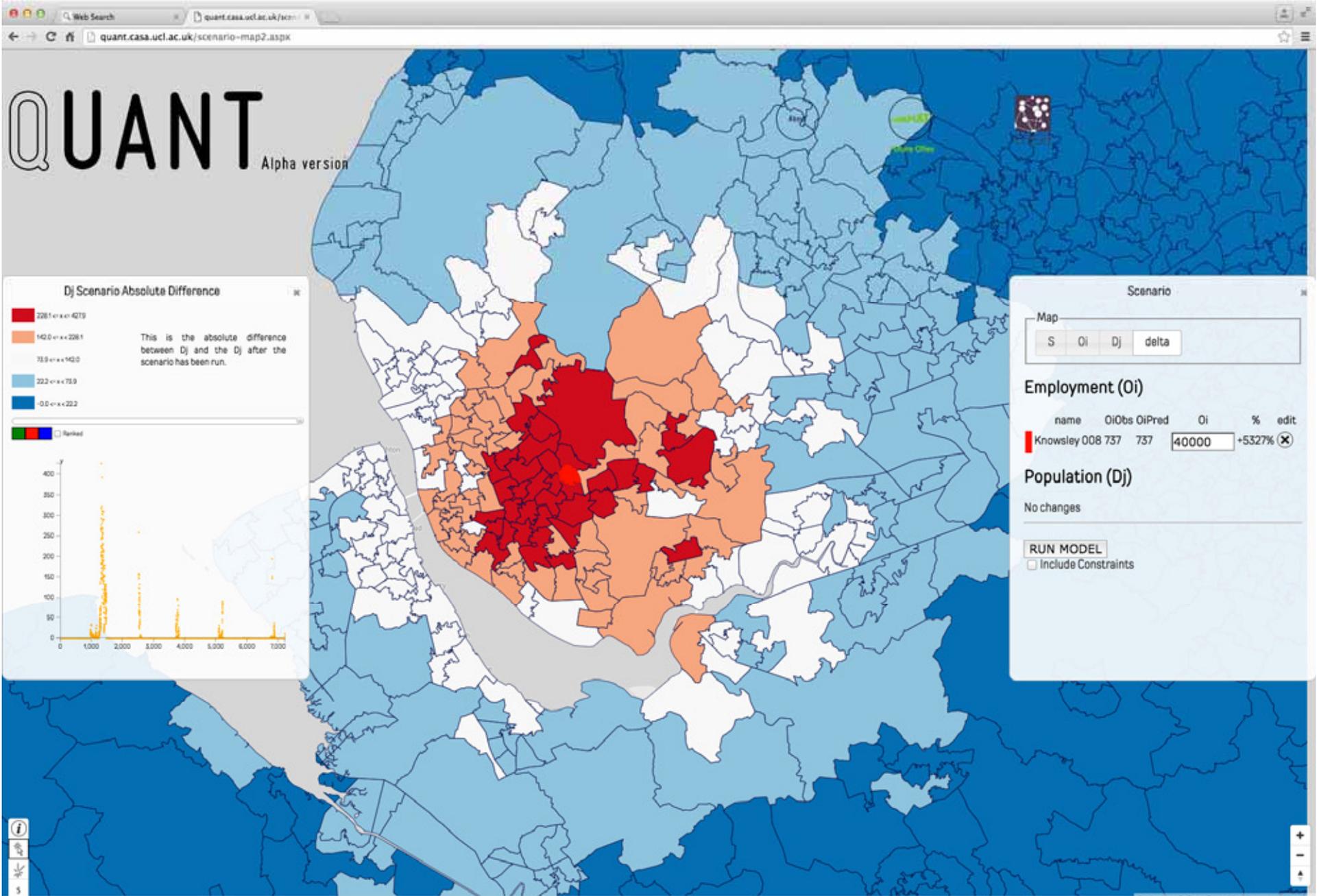
© Mapbox © OpenStreetMap Improve this map











# Big Infrastructure Projects: Crossrail, HS2, The Third London Airport:

Again I could spend a long time on these applications and all I can do here is show what is now possible – it is possible to test different alternatives over and over again. And any of us can do it – all you need a bit of training in the models – I suppose planning education should do this – but that is another story and not one for this evening

I will first show Crossrail and the HS2 because the impacts are much much wider than many of models can show. This reveals how important it is to make our model bigger spatial and to capture the widest economic benefits we can identify. And lastly I will deal with the Third Runway

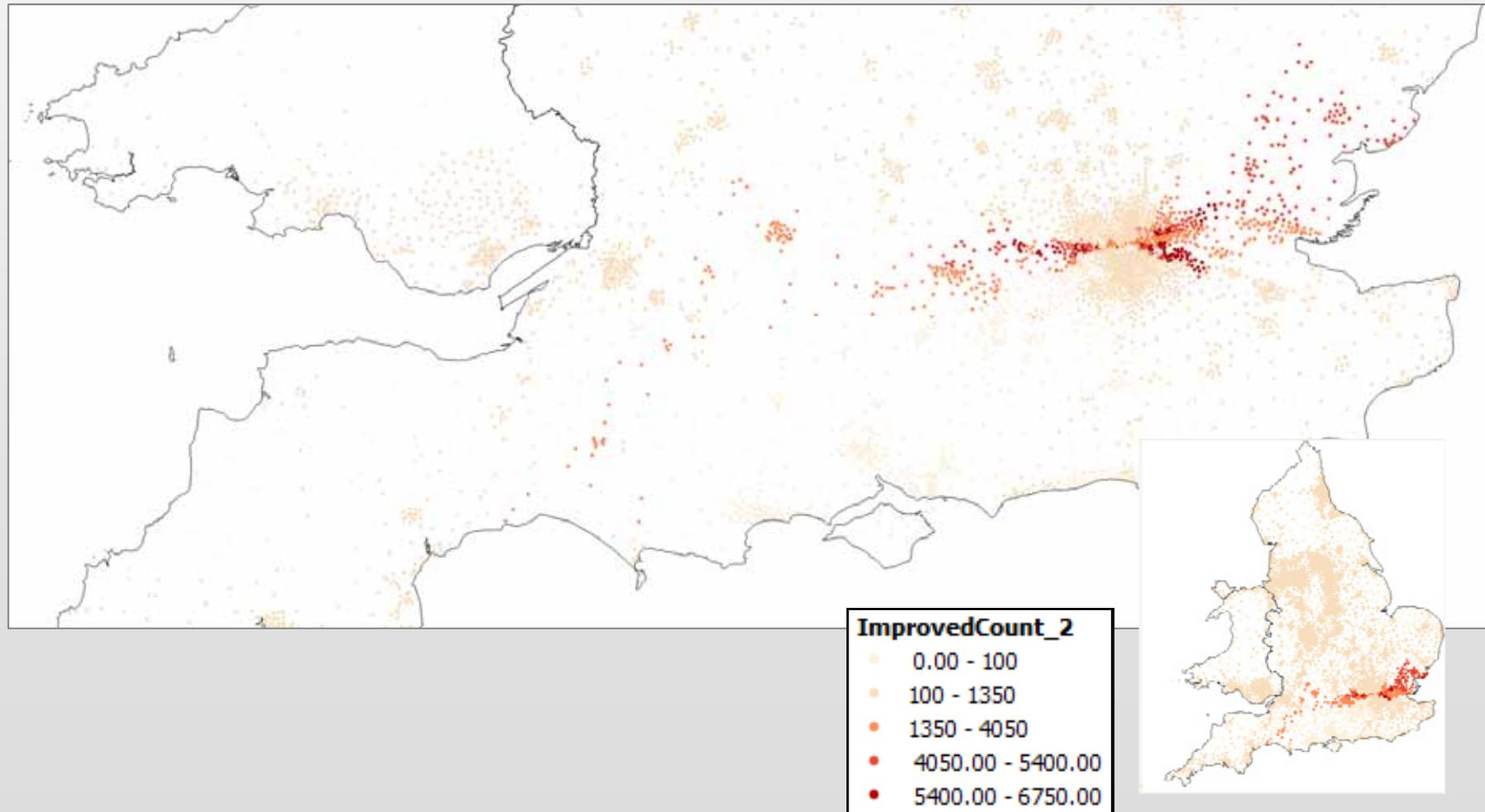
# Crossrail

Reading, Heathrow, Shenfield, Abbey Wood



# Crossrail

Number of Improved Journeys ( $n_j$ )



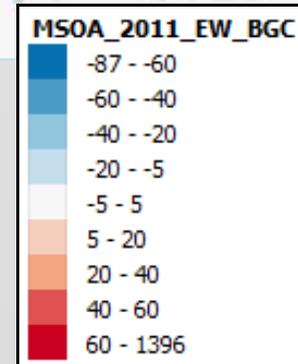
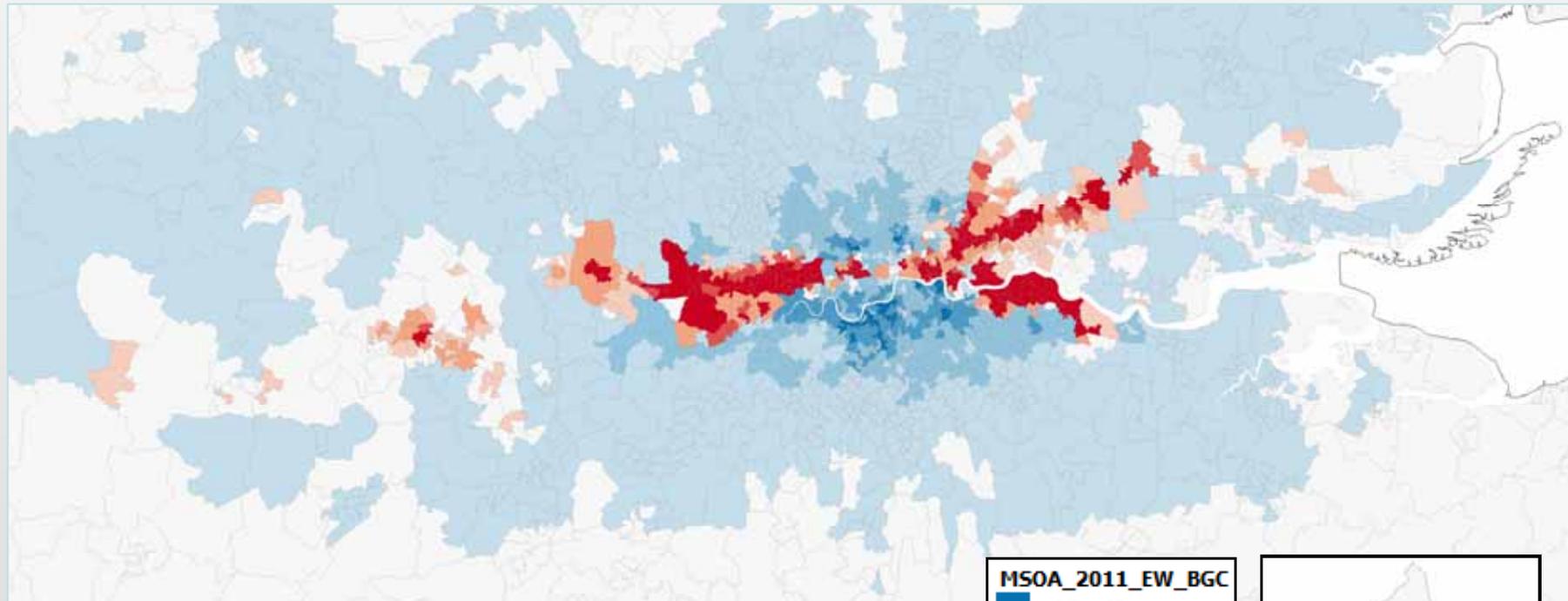
# Crossrail

Population change (rail mode only)



# Crossrail

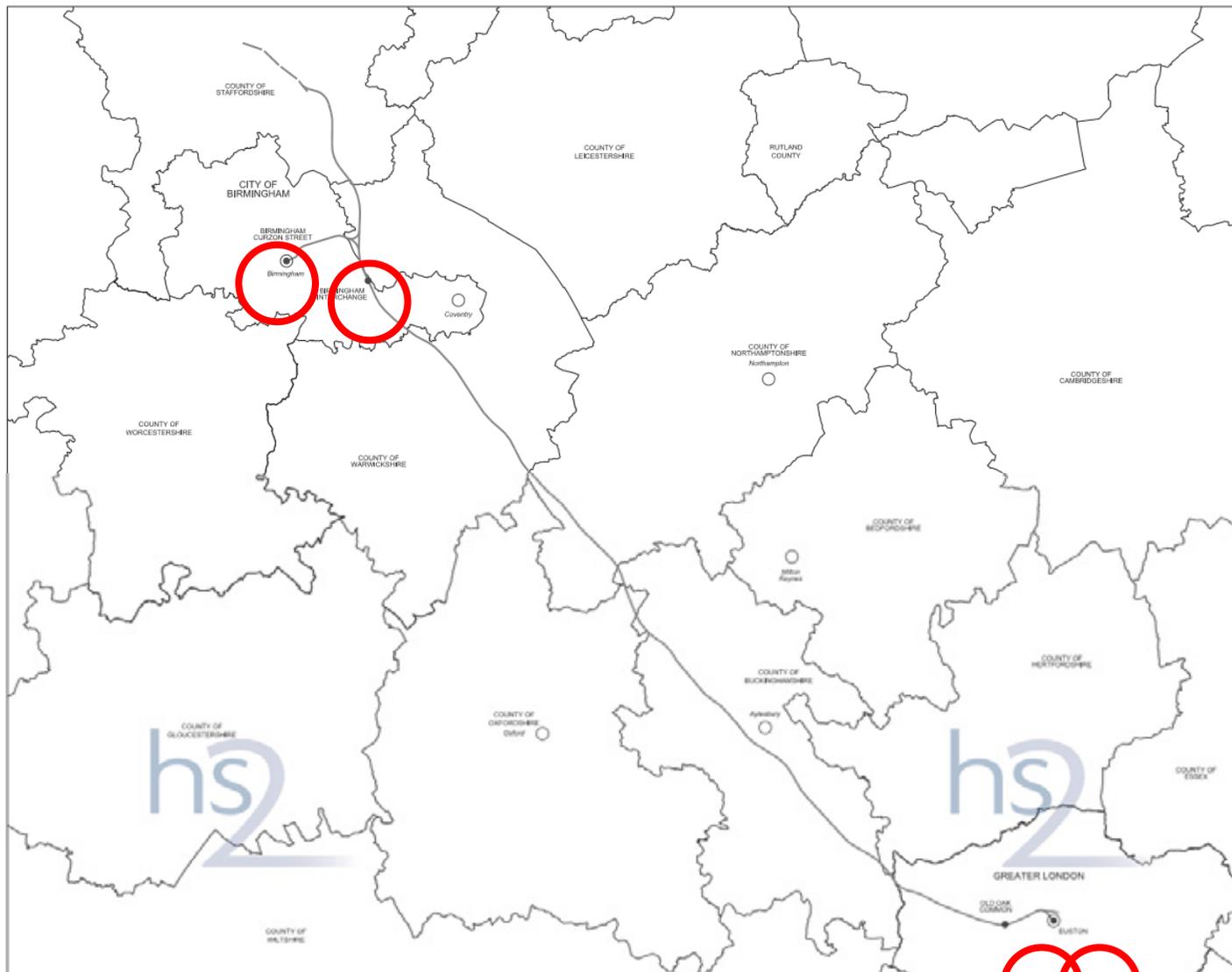
Population Change (all modes)



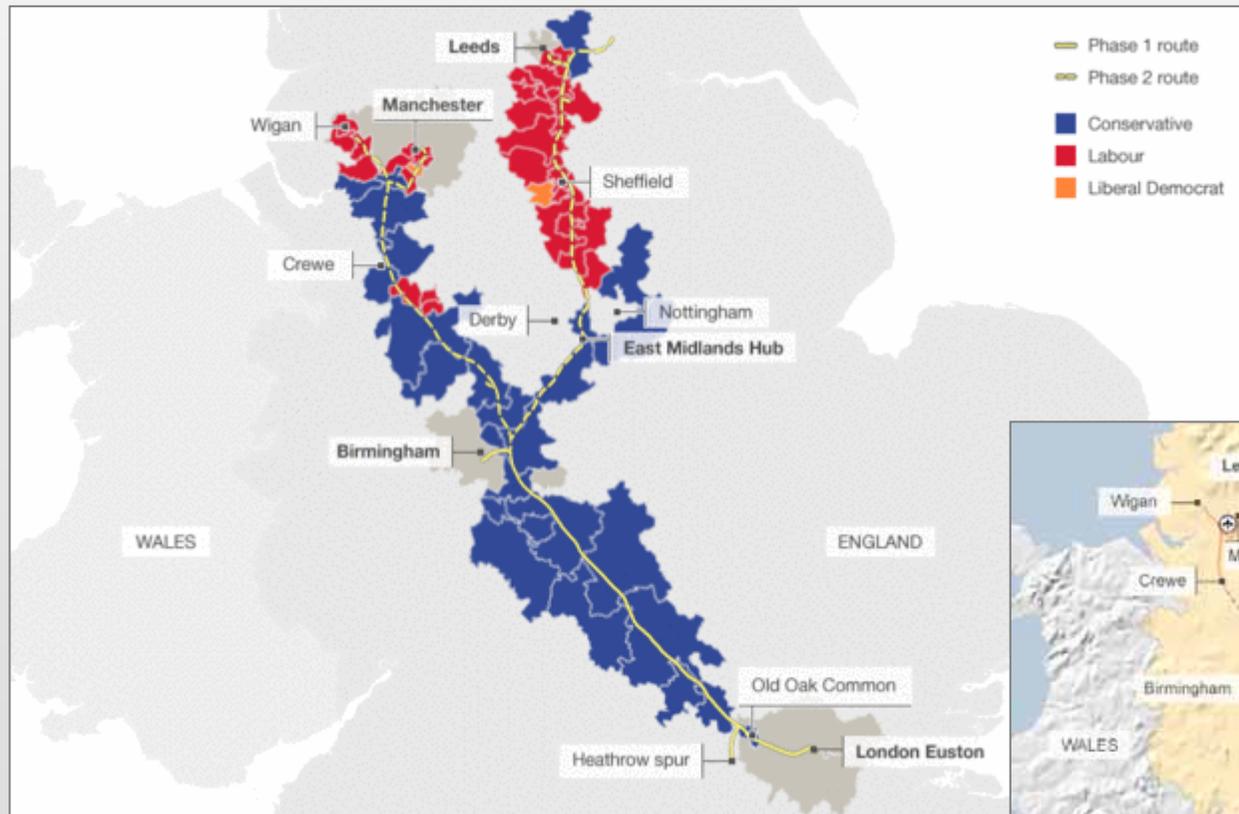
# High Speed Rail



# SCHEME DIAGRAM

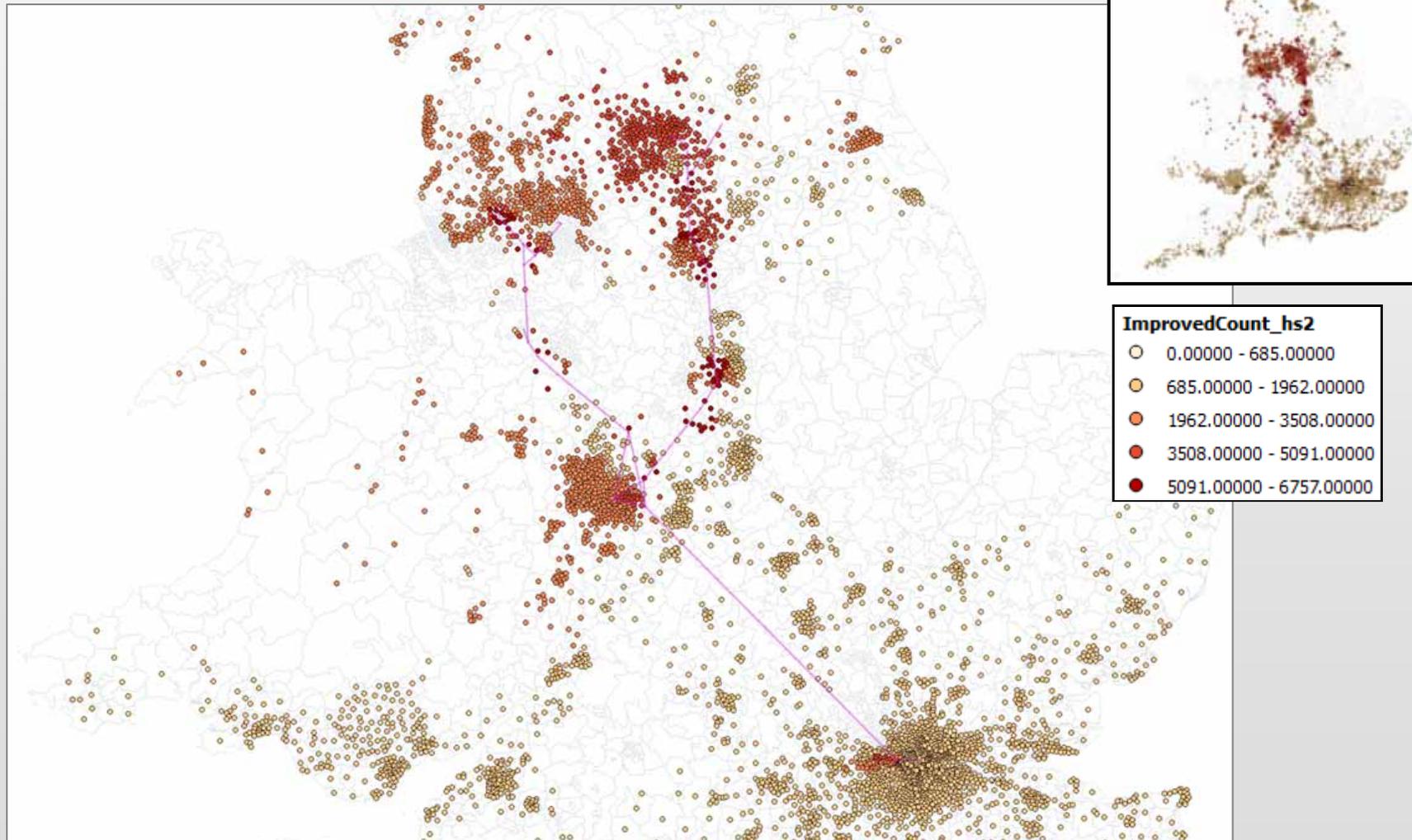


# HS2 Route Maps



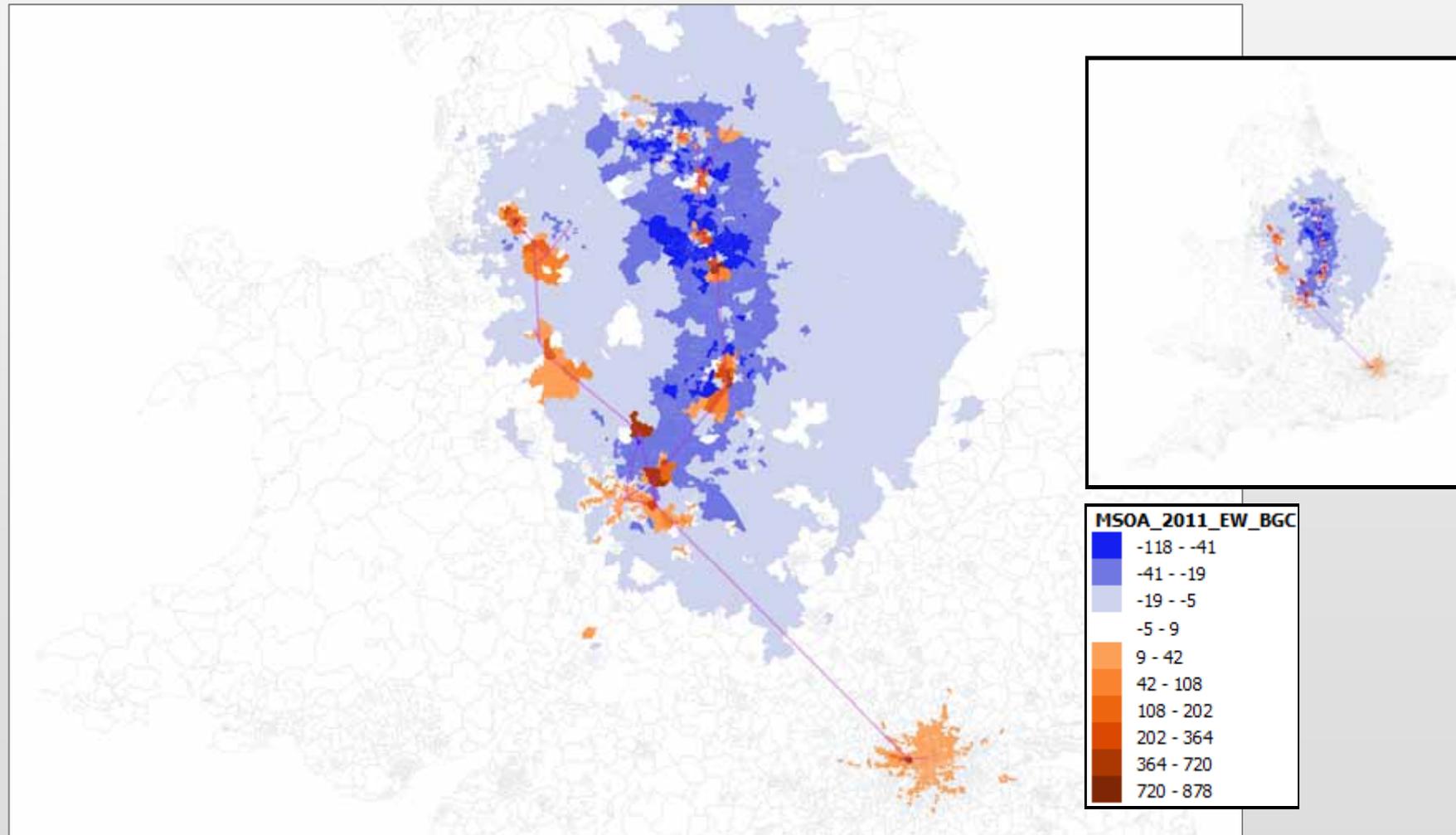
# High Speed 2

Number of improved trips ( $n_i > 685$ )



# High Speed 2

Population change (all modes)



## A Major Project: Third London Airport

(June 1968–December 1970)

*The deliberations of the Roskill Commission on the Third London Airport were distinguished by the very clear and logical process by which recommendations were arrived at. The Commission adopted five cycles, from the definition of a "universe" of possibilities to a short-list of four sites, and then directly to a recommended alternative. One particularly important feature was that the evaluation criteria were determined at the outset of the process and were then used consistently throughout.*

### 11.1. BACKGROUND

The eventual recommendation by the Roskill Commission of Cublington as the site for the Third London Airport in preference to Foulness led to considerable controversy. This controversy, coupled with the fact that the Government eventually decided in favour of Foulness against the Commission's recommendation, has obscured many interesting and original features of the process by which the Commission reached its recommendation. In this chapter we discuss some of the main features of this process. It does not cover the ground of the many critiques of the Commission's work which have mainly concentrated on the treatment of measured items in the Commission's Research Team's evaluation; intangibles in the decision; important issues affected by the decision but outside the Study terms of reference, and on the validity of the Commission's conclusion. In this chapter any reference to these topics is restricted to those cases illustrating a feature of the site selection process itself.

One might say that the setting up of the Commission was a result of public outcry over an inadequate process of site selection. The arguments against the decision to locate the airport at Stansted were largely motivated, and strongly supported, by the fact that the Stansted decision was not shown to be in the general public interest. There was no formal evidence to suggest that the alternative possible sites to Stansted which were considered had been rigorously investigated, with all factors for and against them, in comparison with Stansted, taken into account in the decision. Much of the work behind the selection of Stansted was undertaken in

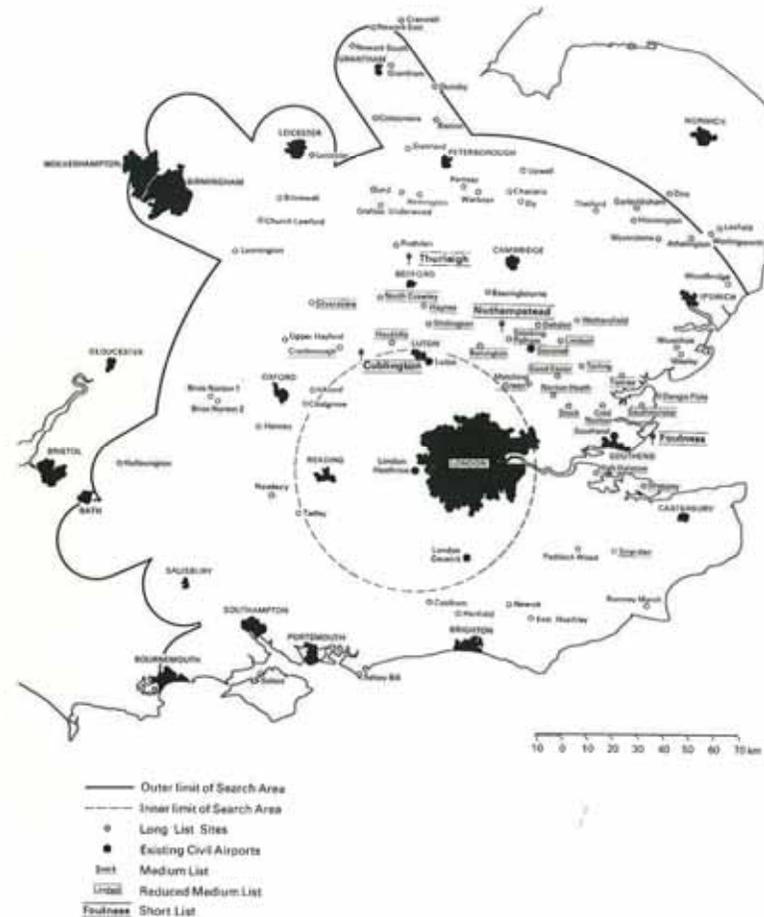


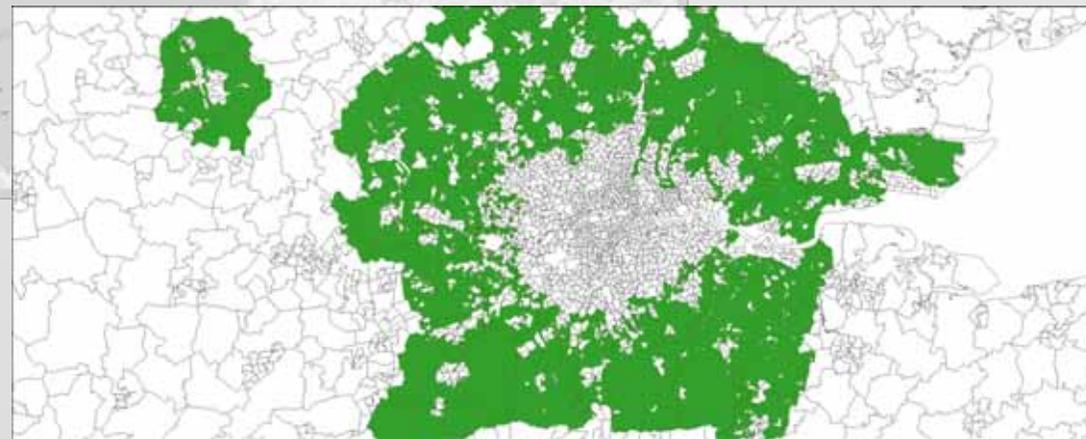
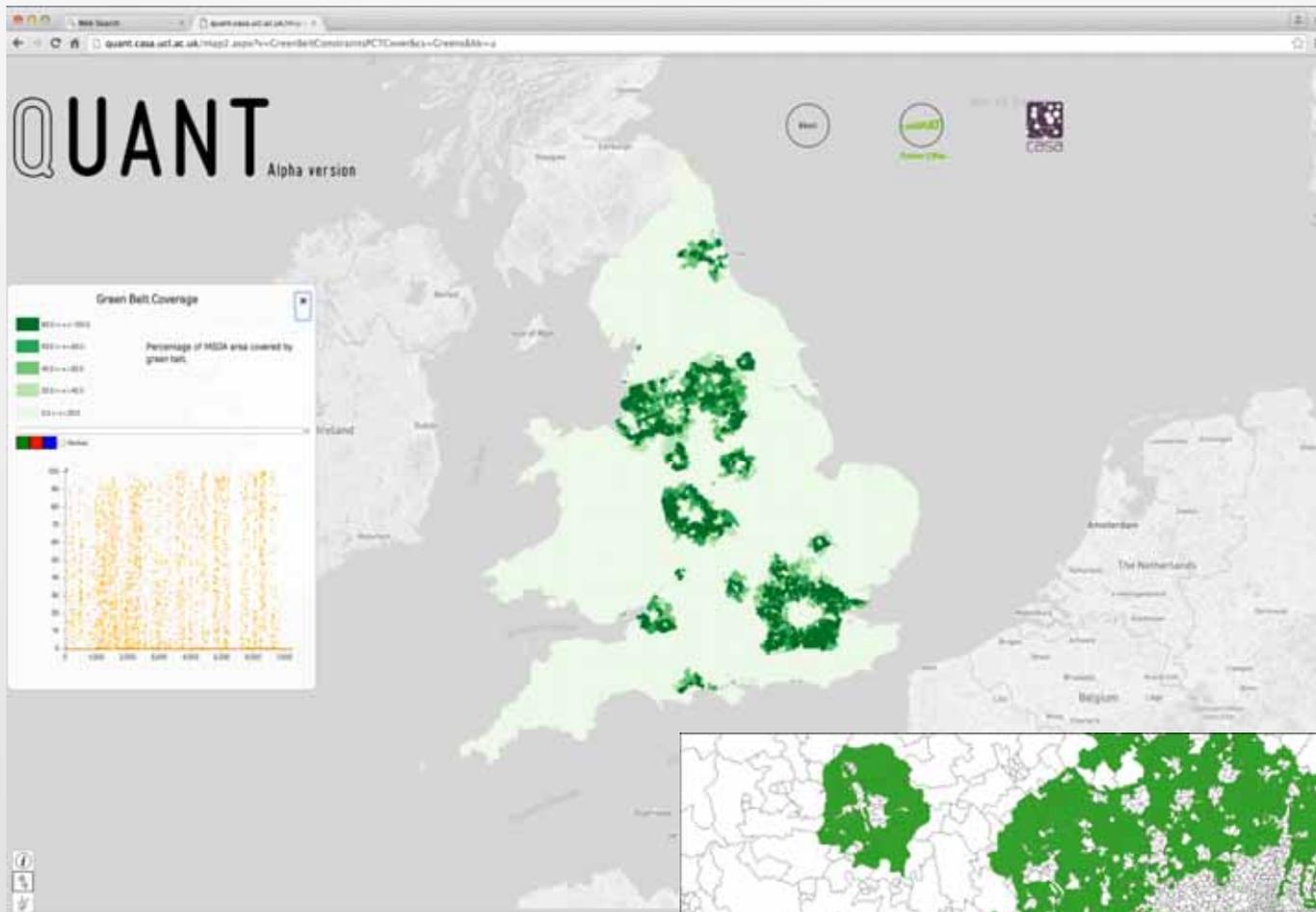
FIG. 11.1. Location of sites. (Source: Commission on the Third London Airport, *Report*, appendix 5, fig. 2, p. 184.)

## The Objectives Used by the Davies Commission in Assessing the Various Options for the Expansion of Heathrow and/or Gatwick

Sift criteria categories	Appraisal objective
Cost	To make efficient use of public funds, where they are required, and ensure that the benefits of schemes clearly outweigh the costs, taking account of social, environmental and economic costs and benefits.
Delivery	To be affordable and financeable, including any public expenditure that may be required and taking account of the needs of airport users.
	To have the equivalent overall capacity of one new runway operational by 2030.
	To actively engage local groups in scheme progression, design and management.
Operational Viability	To enhance individual airport and airports system resilience.

**Table 4.1: The Commission's Appraisal Framework objectives**

Sift criteria categories	Appraisal objective
Strategic Fit	To provide additional capacity that facilitates connectivity in line with the assessment of need.
	To improve the experience of passengers and other users of aviation.
	To maximise the benefits of competition to aviation users and the broader economy.
	To maximise benefits in line with relevant long-term strategies for economic and spatial development.
Economy	To maximise economic benefits and support the competitiveness of the UK economy.
	To promote employment and economic growth in the local area and surrounding region.
	To produce positive outcomes for local communities and the local economy from any surface access that may be required to support the proposal.
Surface Access	To maximise the number of passengers and workforce accessing the airport via sustainable modes of transport.
	To accommodate the needs of other users of transport networks, such as commuters, intercity travellers and freight.
	To enable access to the airport from a wide catchment area.
Environment	To minimise and where possible reduce noise impacts.
	To improve air quality consistent with EU standards and local planning policy requirements.
	To protect and maintain natural habitats and biodiversity.
	To minimise carbon emissions in airport construction and operation.
	To protect the quality of surface and ground waters, use water resources efficiently and minimise flood risk.
	To minimise impacts on existing landscape character and heritage assets.
People	To identify and mitigate any other significant environmental impacts.
	To maintain and where possible improve the quality of life for local residents and the wider population.
	To manage and reduce the effects of housing loss on local communities.
	To reduce or avoid disproportionate impacts on any social group.



# QUANT

Alpha version

Maidenhead

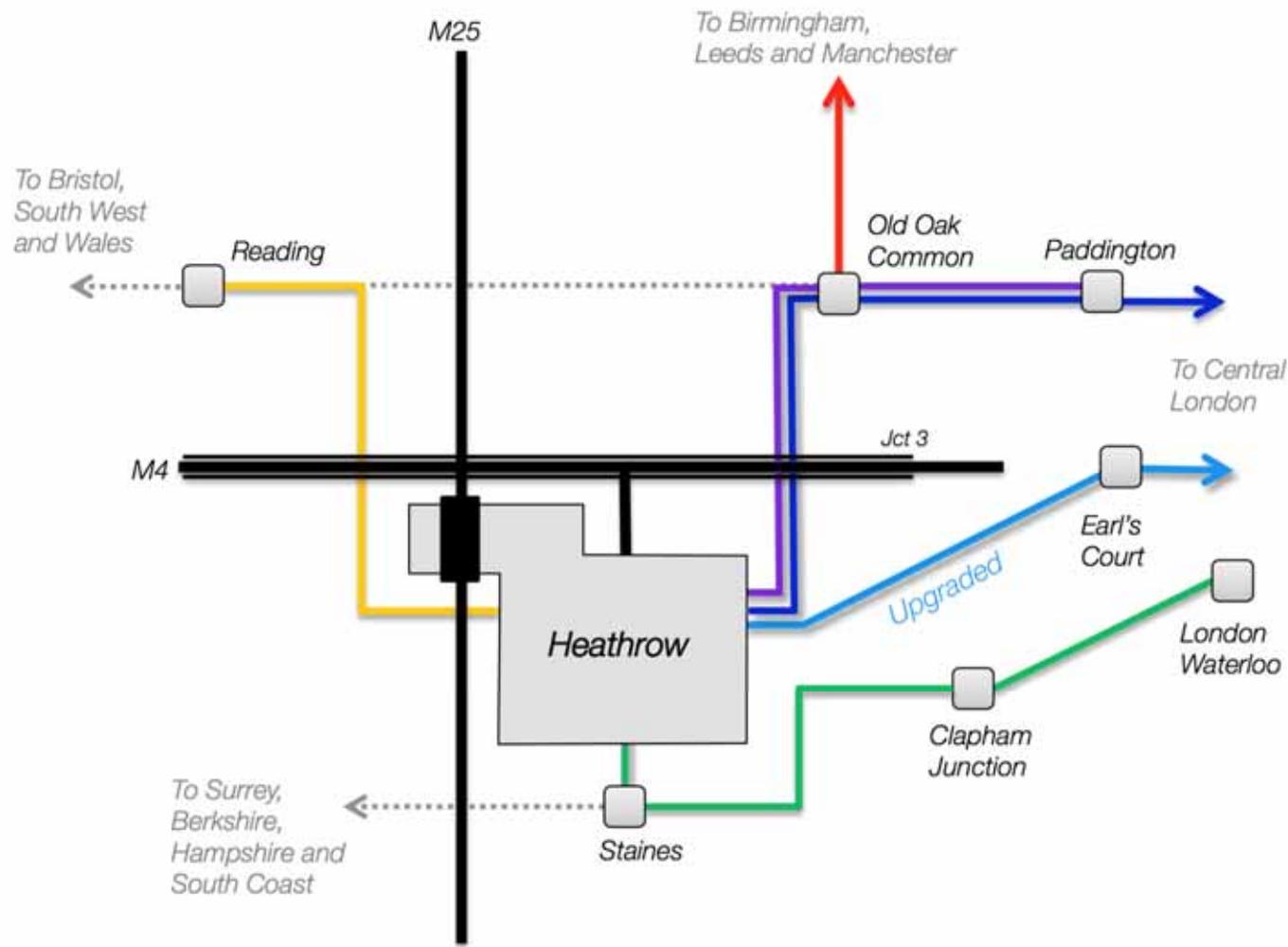
Slough

Windsor



© Mapbox © OpenStreetMap





**KEY**

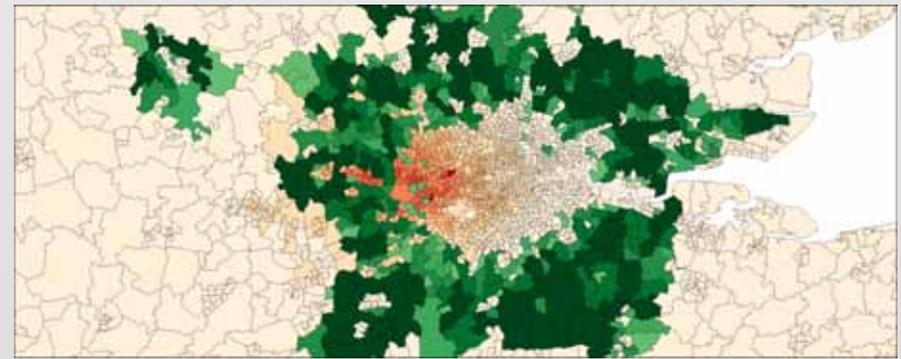
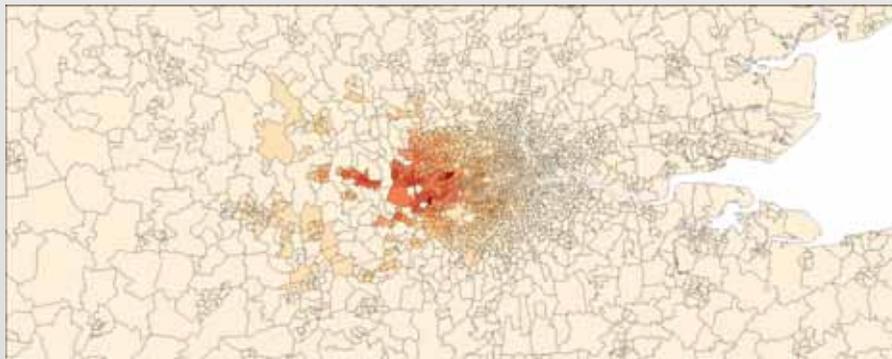
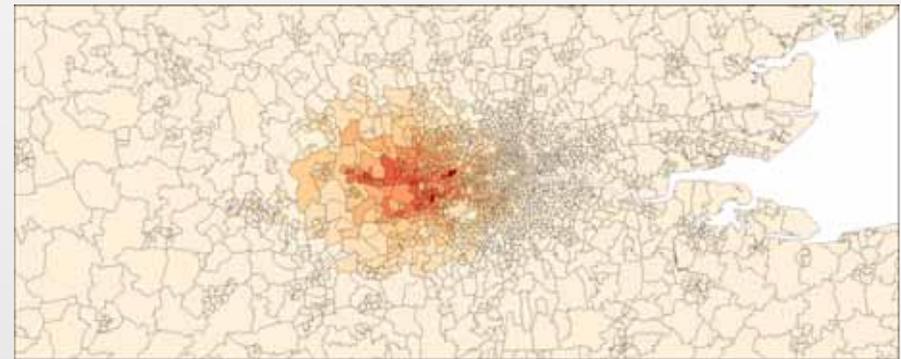
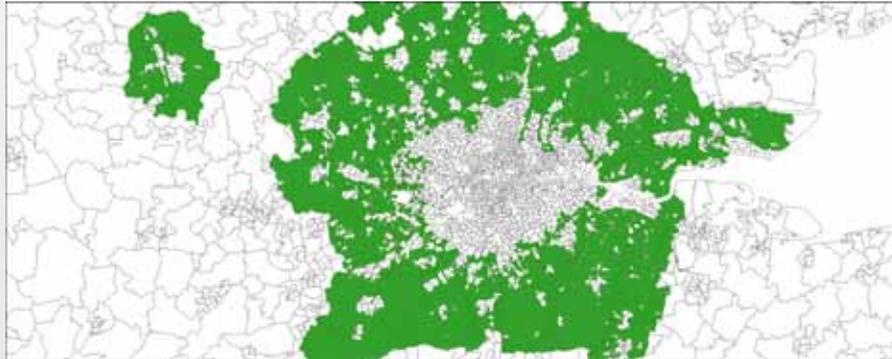
*Highways*

- Standard motorway
- Smart motorway
- Tunnel

*Rail*

- Heathrow Express
- Western Rail Access
- Crossrail
- Piccadilly Line
- Southern Rail Access
- HS2
- Other route

We have Tested the Impact of the Fourth Runway on E&W in terms of Where the Population from an Extra 5000 Jobs will Locate



## Future Urban Models and Use in Planning

- We need a new way of thinking about science in public policy
- It needs to inform, it must be based on conditional prediction – what if scenarios
- It needs to accept the inherent unpredictability of complex systems and this suggest continual action – this is little different from what has always been preached in urban planning – continual review, but the cycles need to be faster
- We must be aware that the systems we are dealing with moving targets of increasing complexity



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That's It, Thanks

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