CogX Data Centric Engineering and the Built Environment

The Alan Turing Institute

casa UCL University College London

Simulating Urban Futures

Digital Twins, Triplets & The Rest

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I have put this on my web site as a PDF and you can get it from

http://spatialcomplexity.blogweb.casa.ucl.ac.uk/files/2020/06/BATTY-CogX-Turing-Talk.pdf

An Outline of the Talk

- Cities and Their Futures?

  High Frequency and Low Frequency Cities. What Are Digital Twins?
- Where Do Digital Twins Come From?
- A Cornucopia of Twins: Maps as Analogies
- Multiple Abstractions: Many Models
- Two Quick Examples: Different Types of Twin

  The High Frequency City: Real Time Simulation

  The Low Frequency City: Long Term Urban Change
- Is the Concept Useful ?

Cities and Their Futures?

High Frequency & Low Frequency Cities. What Are Digital Twins?

- In the past we have largely studied and designed cities for the long term. Our plans we designed for the low frequency city where change is over years and decades, not less
- In the last 20 years, increasing miniaturization of computers has led to a massive embedding of computers, sensors and networks into the built environment.
- Enter the high frequency city – the 24-hour city, the real-time city, generating streams of 'big' data over very short time periods
- In this maelstrom of change, the role of the model has begun to change; the idea of models much closer to the real thing has come onto the agenda – is the digital twin

Where Do Digital Twins Come From?

- Of course we in this audience would immediately say this is a 'model' and ***models are abstractions, simplifications*** of the real thing.
- We throw a lot more away than we keep. In fact arguably the best models are the simplest - but much depends on purpose.
- So how then can we think a model is a twin – this sounds far too close to the thing we are simulating or representing. But as we move from long to short term and from low frequency to high, our models change and perhaps, just perhaps, some of them will get, are getting 'closer' to the real thing.
- This talk is about how close are our models to the original – the real
- And my focus is on models that we build of cities –models are still abstractions, digital not physical but abstractions none-the-less

- So the digital twin cannot be ***a mirror image***, it may be a replica, but it cannot be the same as the original, can it?. There are other features.
- *First* models depend on their ***media*** and if the media is close to the media of the original model, then we might think it is a 'digital twin' – especially if we imagine the system in question is digital.
- *Second* can the digital twin be used for ***predicting a future*** that does not exist? Models might be about only the future, not the present – can a digital twin have this role? If there is no present.
- *Third*: is the digital twin ***reactive*** rather than ***predictive*** and if it is predictive, how close is the prediction to the real system?
- *Fourth*: a digital twin might be a coupling – a relation between the original and digital – ***a transfer of information*** and this is not necessarily so for a model. It may even be a controller of the original system

So Where do Digital Twins Come From?

- The term appears to have been first coined in the early 2000s by Michael Grieves (2014) whose expertise in product design initially rooted the concept in production engineering.
- In this sense, one can see the twin as being very close to the real thing especially as production systems are being continually automated and this automation is largely digital.

A Cornucopia of Twins: Maps as Analogies: A Digression

Let me digress a little because in many fields there are analogies of digital twins. A good story is from Lewis Carroll who in his last work ***Silvie and Bruno Concluded*** (1893) tells of a conversation between himself and a German gentleman about making a map close to the real thing: a digital twin?

The conversation goes like this: between ME and Mein Herr (MH)

ME: 'What a useful thing a pocket-map is!' I remarked.

MH: 'That's another thing we've learned from your Nation', said Mein Herr, 'map-making. But we've carried it much further than you. What do you consider the largest map that would be really useful?'

ME: 'About six inches to the mile'.

MH: 'Only six inches!' exclaimed Mein Herr. 'We very soon got to six yards to the mile. Then we tried a hundred yards to the mile. And then came the grandest idea of all! We actually made a map of the country, on the scale of a mile to the mile!'

ME: 'Have you used it much?' I enquired.

MH: 'It has never been spread out, yet', said Mein Herr: 'the farmers objected: they said it would cover the whole country, and shut out the sunlight! So, we now use the country itself, as its own map, and I assure you it does nearly as well'. (Carroll, 1893 [1982])

This notion of the map being the same as the territory has been explored by others, by Jorges Luis Borges, Gregory Bateson, Joan Robinson, Braudrillard, Gerlenter. Even D. H Lawrence said that "*the map appears to us more real than the land*" (1925)

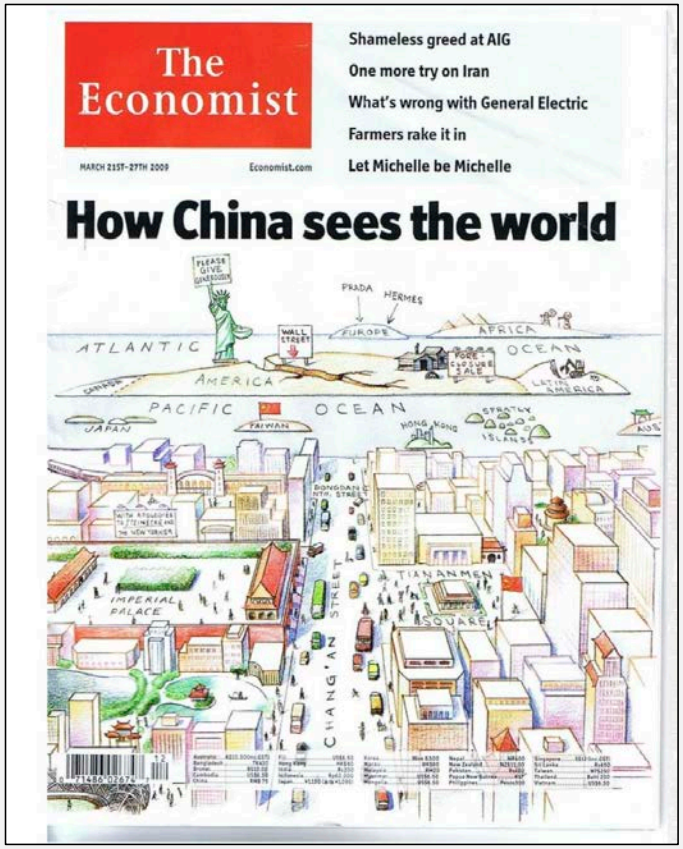
A lot later, Jorge Luis Borges (1946) in his essay '*On Exactitude in Science*' more or less tells the same story of cartographers so obsessed with their art that they decided to produce the most detailed map of their Empire that they could make at a scale of 1 to 1. The next generations less enamoured of cartography than those who made the map had little use for it but Borges concludes by saying

'In the Deserts of the West, still today, there are Tattered Ruins of that Map',

conjuring up images from the movie *The English Patient*. I wonder if the same fate awaits the digital twin: possibly in terms of terminology but the power of simulation and the prospect of getting better and better simulations shows no sign of stopping. The prospects are enticing even if the experience continues to daunt it …… We will see.

To Conclude my Interlude: Maps Based on Our Perceptions





Multiple Abstractions: Many Models

- Let me quote again from a famous book to impress these points about many models, many twins and so on; and indeed in parallel many variants of cities. I have not speculated at all on digital triplets, quads, identical twins – they are all talking points

- While I am throwing out ideas about how close is the map to the territory, let me say recount one of the polemics from Italo Calvino from his 1974 book ***Invisible Cities*** between Kublai Kahn and Marco Polo. One of the stories there goes as follows. I used it in a lecture in Liverpool about 12 years ago, about different models, not unlike the pitch I am giving here. (Model cities, **TPR**, **78** (2))

Many of Calvino's stories are like this:

KK: *'And yet in my mind I have constructed a model city from which all others can be deduced,' Kublai said. 'It contains everything corresponding to the norm. Since the cities that exist diverge in varying degree from the norm, I need only foresee the exceptions to the norm and calculate the most probable combinations'.*

MP: 'I have also thought of a model city from which I can deduce all others', Marco answered. 'It is a city made only of exceptions, exclusions, incongruities, contradictions. If such a city is the most improbable, by reducing the number of abnormal elements, we increase the probability that the city really exists'. Calvino, 1974, 69

Now for Examples: Two Very Different Types of Twin

I am going to look at two very different conceptions of the spatial and physical structure of cities,

- First a model or a representation of a traffic system that needs to be organized as a combination of moving vehicles and passengers that make decision in real time about how and why they travel and how they need to be coordinated: This is a high frequency example.

- Second a model of the low frequency city simulating long term urban growth and change where we are interested in forecasting in a 'what if?' sense the impacts of everything from behavioural change to the economic and spatial impact of new infrastructure, new development.

Real Time Simulation: Passenger Demand, Trains Supply & Flows

Demand by Travellers



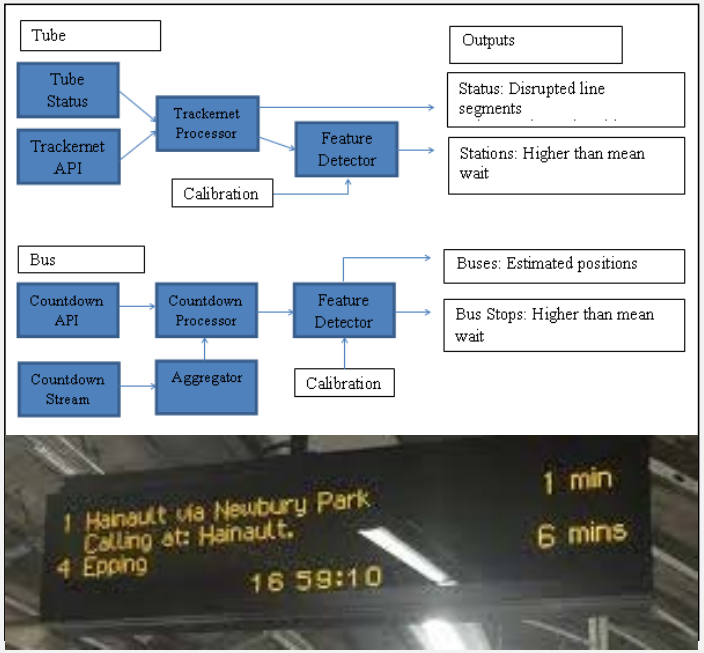




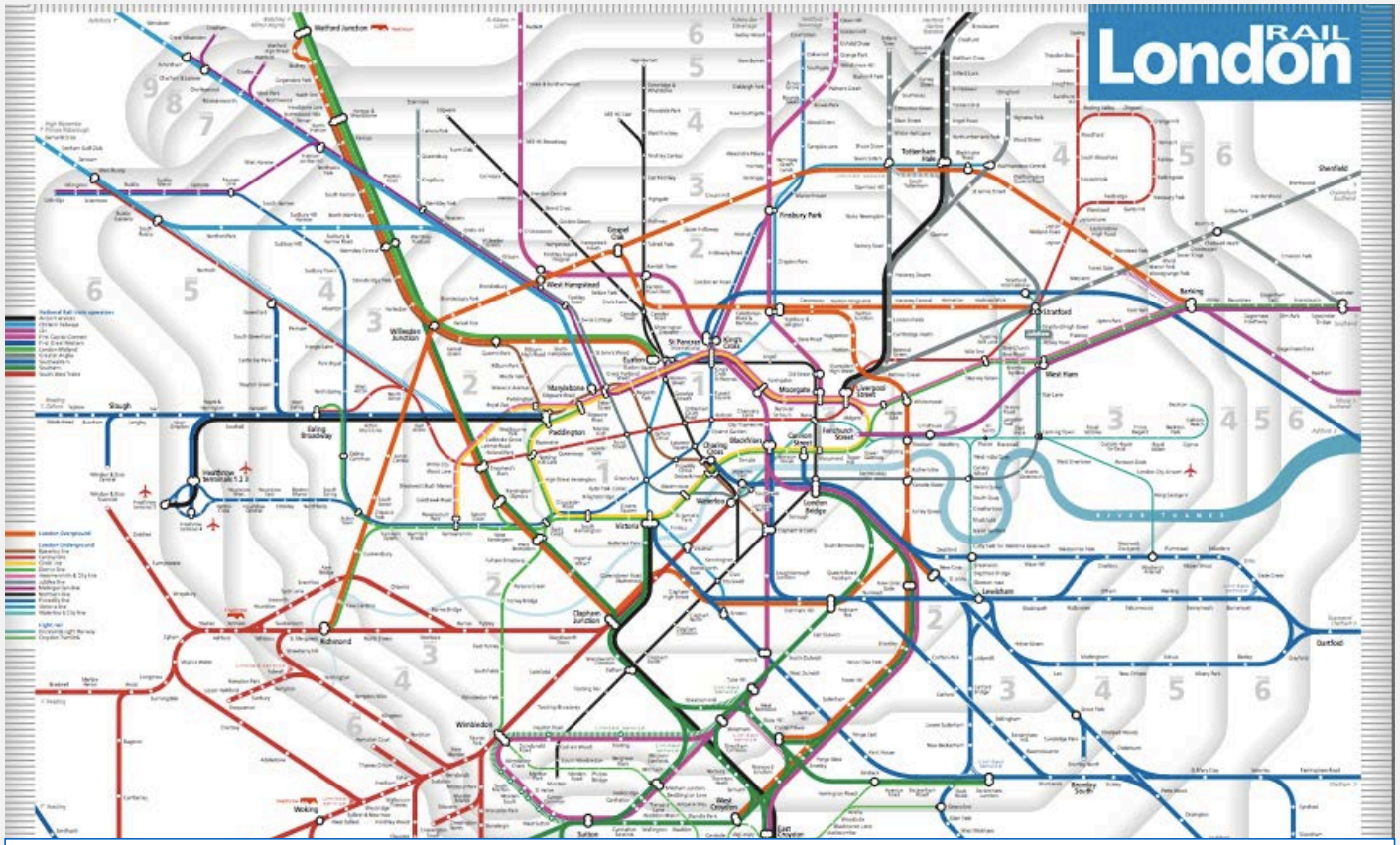




Supply of Trains



How do we match demand & supply without passenger tracking?



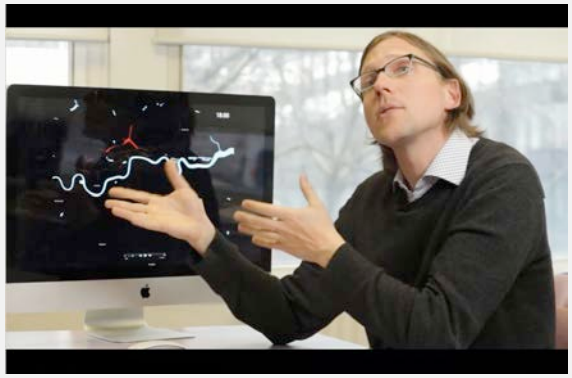
Tube, Overground and National Rail Networks in London where Oyster cards can be used



Passenger Demand for Travel: Flows From Tap-In to Tap-Out Data

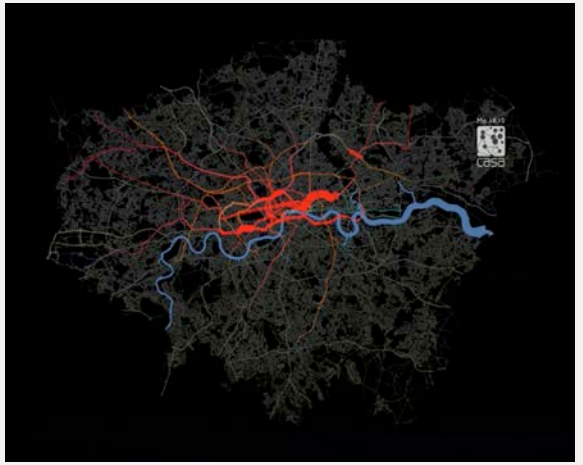

OYSTER GIVES UP PEARLS



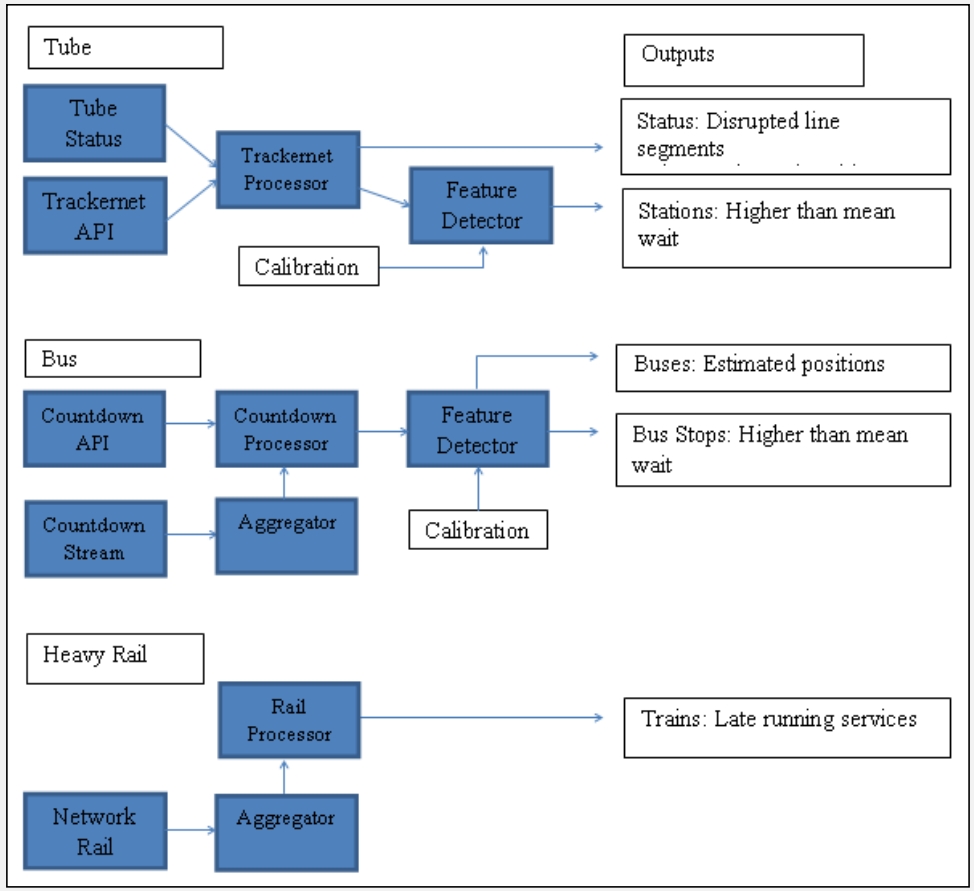


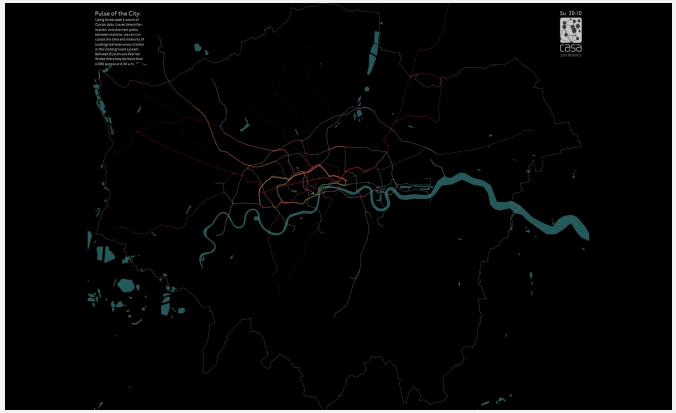




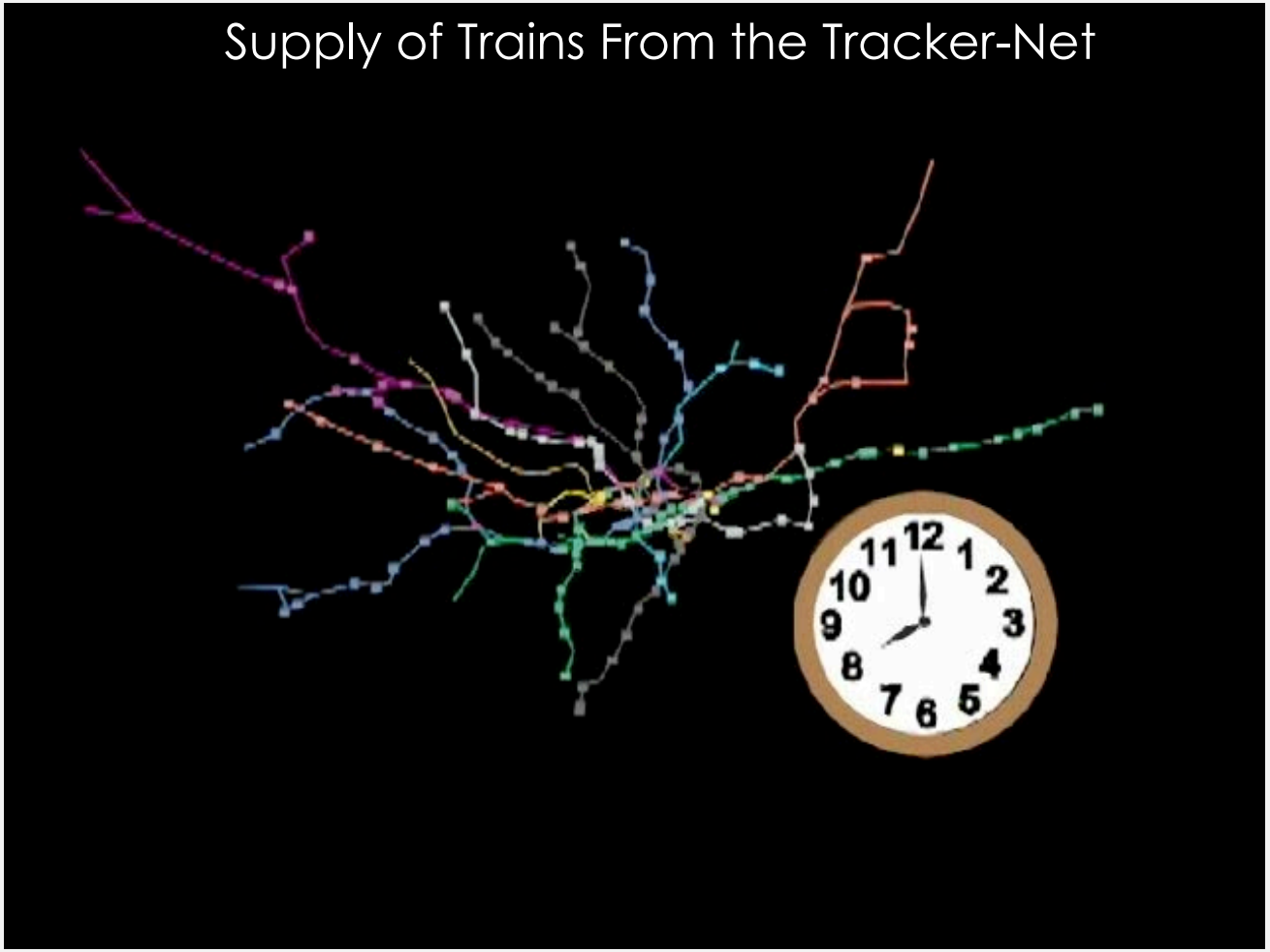


The Public Transport System in Terms of Vehicle Flows and also Passenger Flows from Oyster

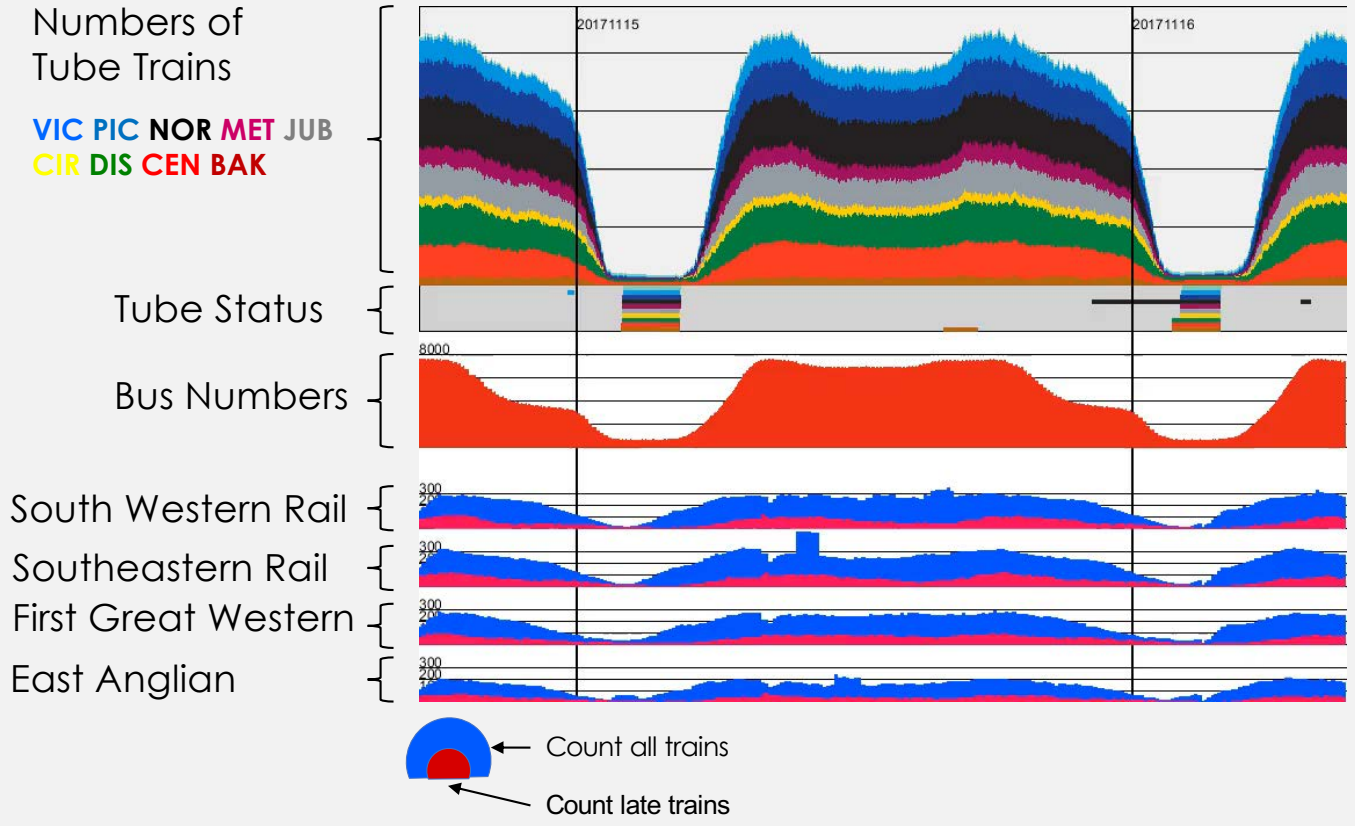







Supply of Trains From the Tracker-Net

Streams of City Data



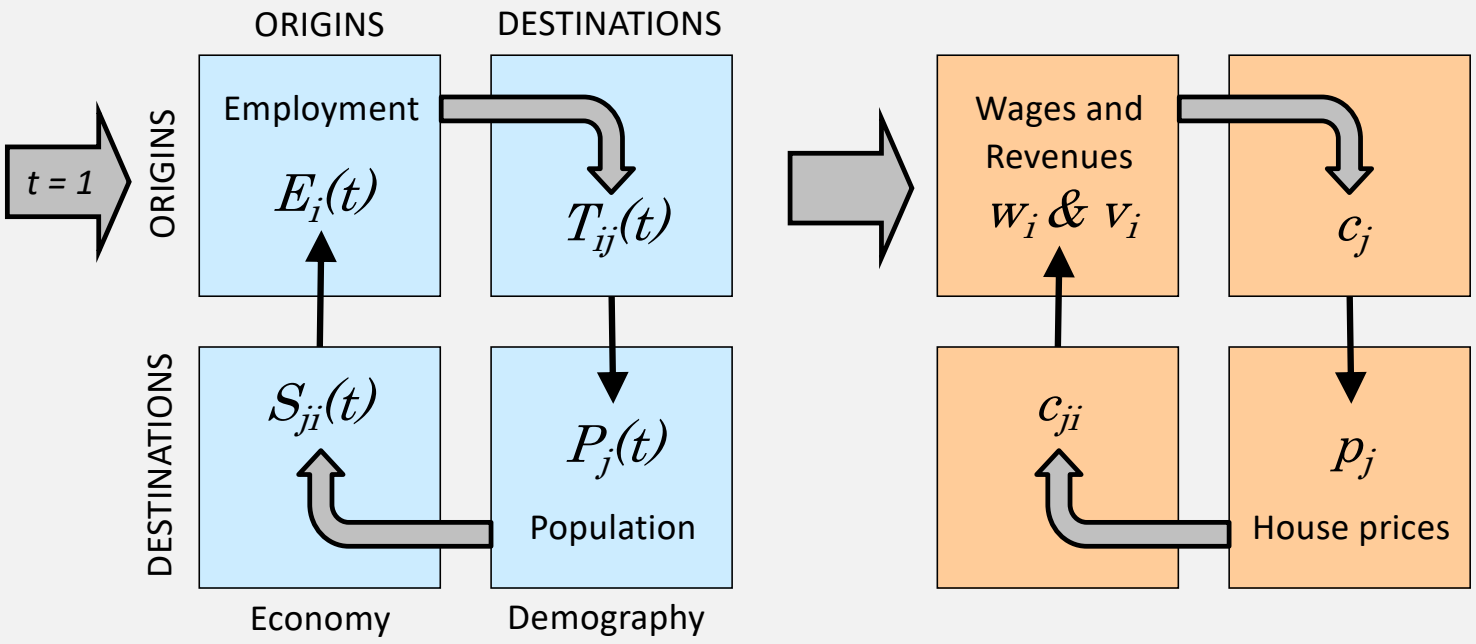


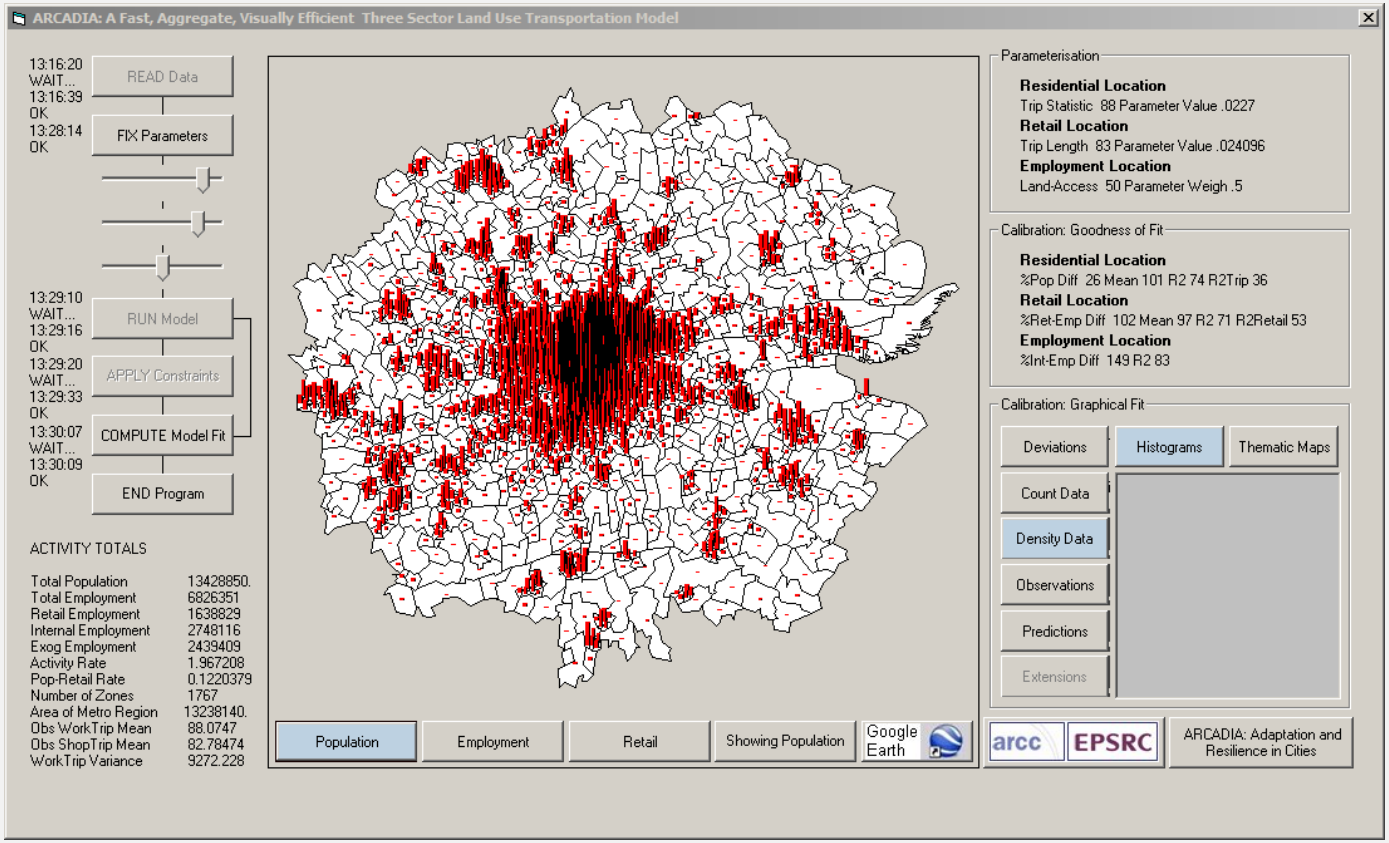
Big Data in 1939

8 March 1939: Some of the four million tickets collected from London Underground passengers are examined in a survey by London Transport to discover the most and least used routes to help future infrastructure development

Long Term Urban Change: The QUANT Model

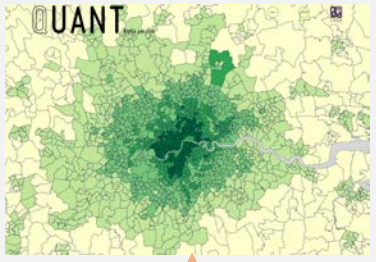
Our model is a LUTI model built sectors that interact using spatial interaction and it is scaled up to Great Britain and it is web-based – all the action is on this kind of implementation, not on the model per se




ARCADIA: A Fast, Aggregate, Visually Efficient Three Sector Land Use Transportation Model
13:16:20 WAIT...
13:16:39 OK
READ Data
13:28:14 OK
FIX Parameters
13:29:10 WAIT...
13:29:16 OK
RUN Model
13:29:20 WAIT...
13:29:33 OK
APPLY Constraints
13:30:07 WAIT...
13:30:09 OK
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 88.0747
Obs ShopTrip Mean 82.78474
WorkTrip Variance 9272.228
Population
Employment
Retail
Showing Population
Google Earth
Parameterisation
Residential Location
Trip Statistic 88 Parameter Value .0227
Retail Location
Trip Length 83 Parameter Value .024096
Employment Location
Land-Access 50 Parameter Weigh .5
Calibration: Goodness of Fit
Residential Location
%Pop Diff 26 Mean 101 R2 74 R2Trip 36
Retail Location
%Ret-Emp Diff 102 Mean 97 R2 71 R2Retail 53
Employment Location
%Int-Emp Diff 149 R2 83
Calibration: Graphical Fit
Deviations
Histograms
Thematic Maps
Count Data
Density Data
Observations
Predictions
Extensions
arcc
EPSRC
ARCADIA: Adaptation and Resilience in Cities



Client & Server Architecture



Colour Scale

MapBox GL JS (modified)

Unity? MapTube?

HTML

Spatial

Aspatial

Web Site

MSOA Vector Tiler

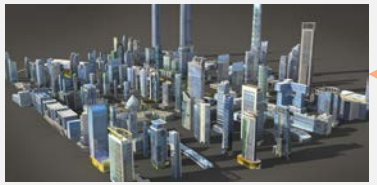
Web Services WCF

Pages

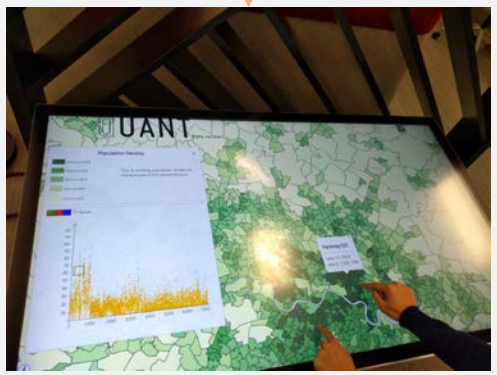
MSOA

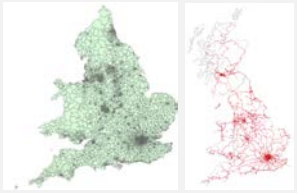
QUANT Model

DATA



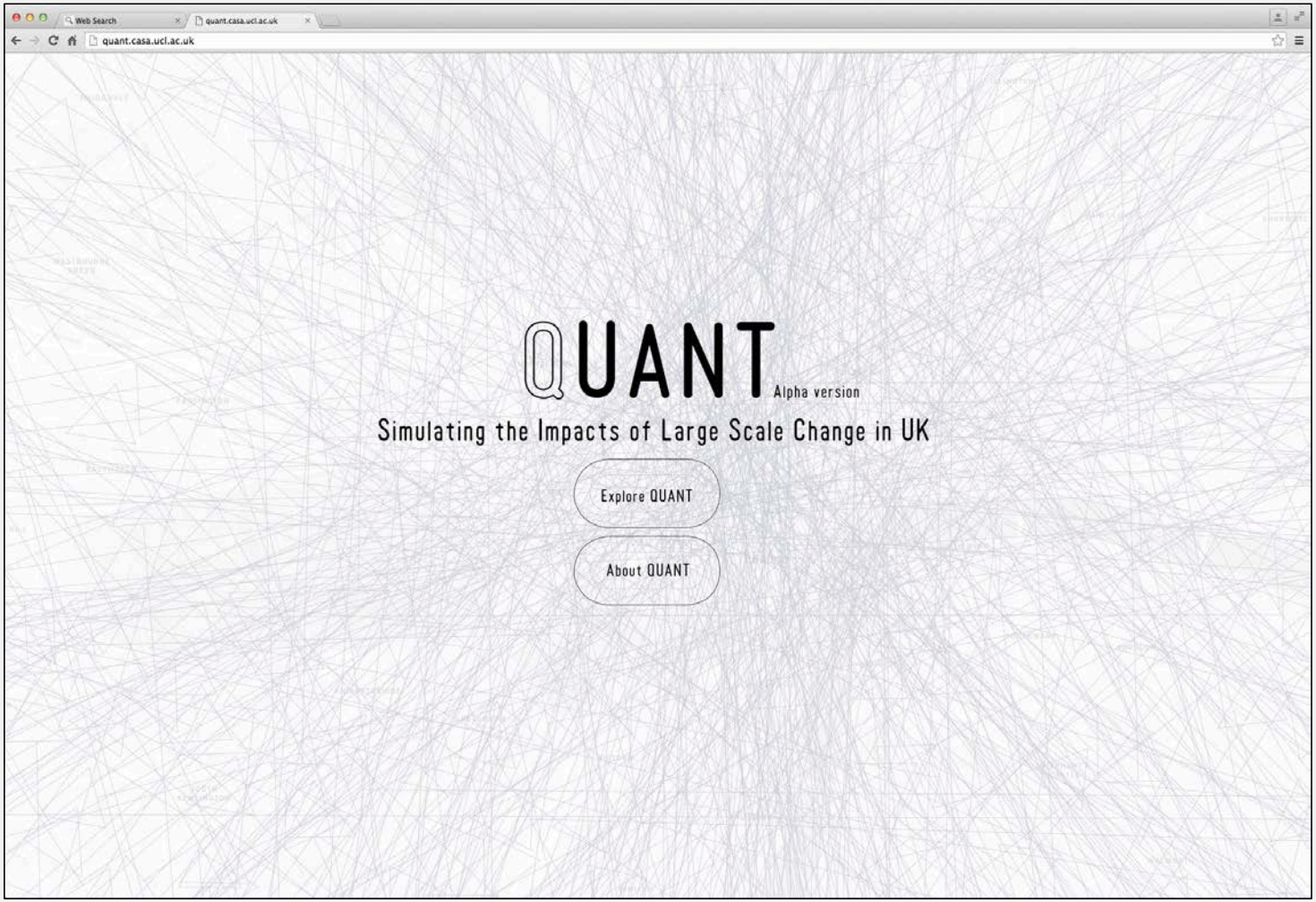
3D Visualisations





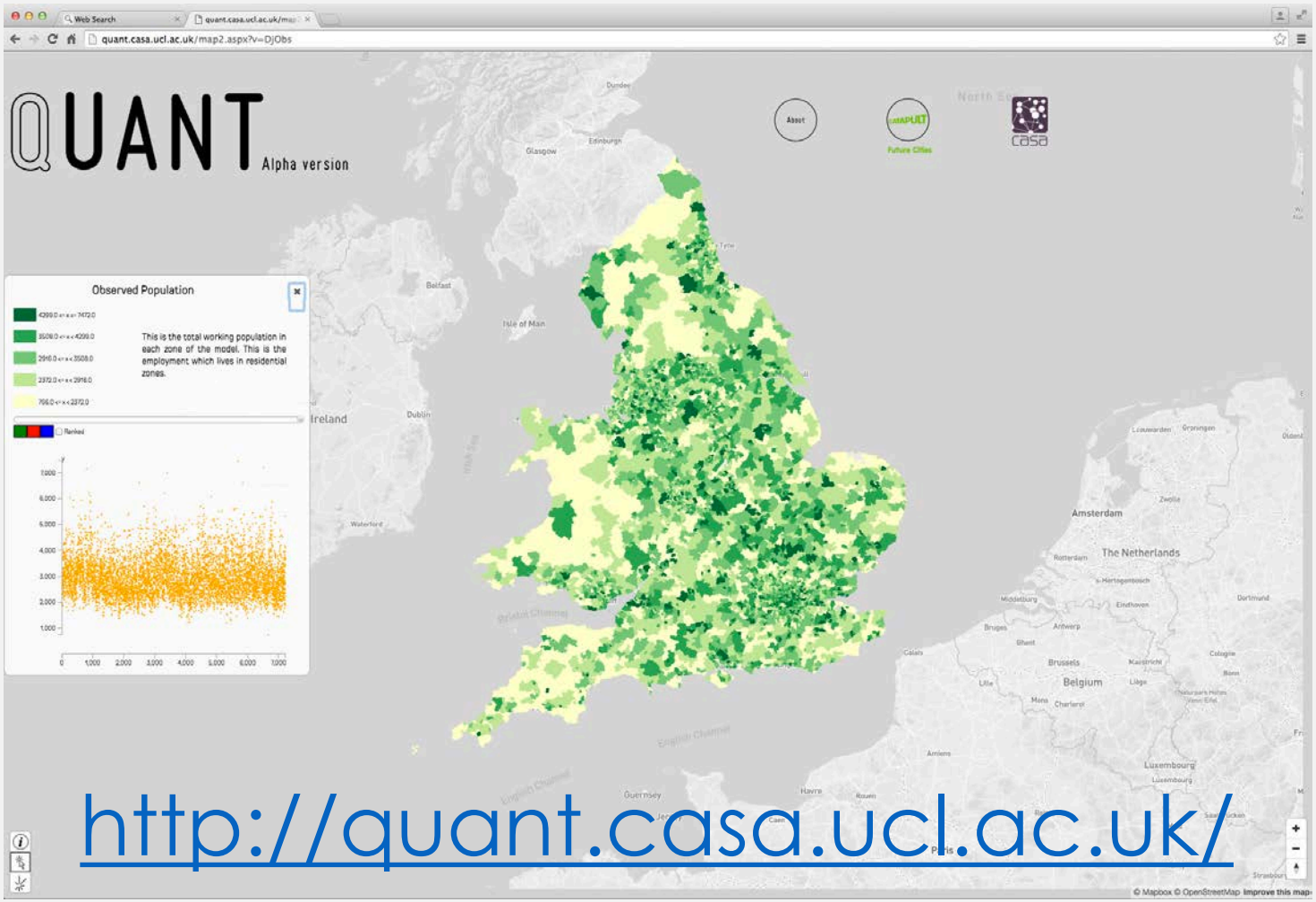
Server

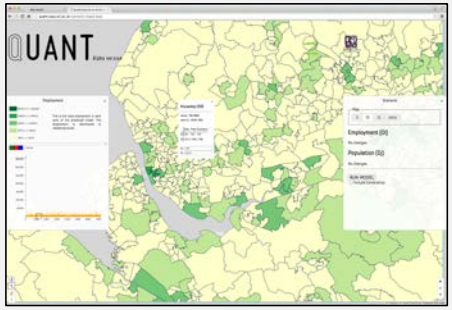
Client-side

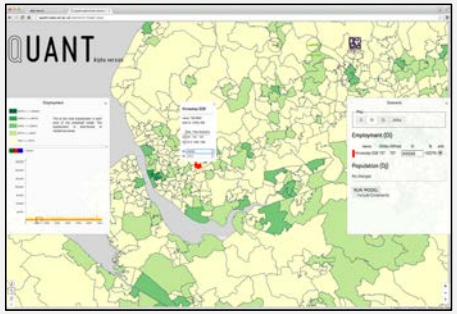

Web Search
quant.casa.ucl.ac.uk
quant.casa.ucl.ac.uk
QUANT
Alpha version
Simulating the Impacts of Large Scale Change in UK
Explore QUANT
About QUANT

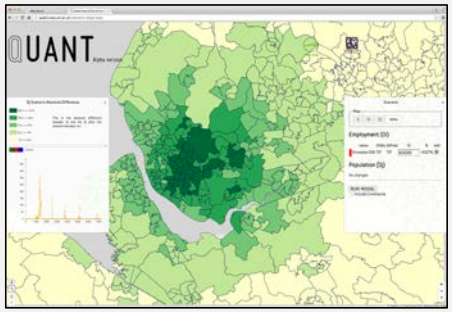


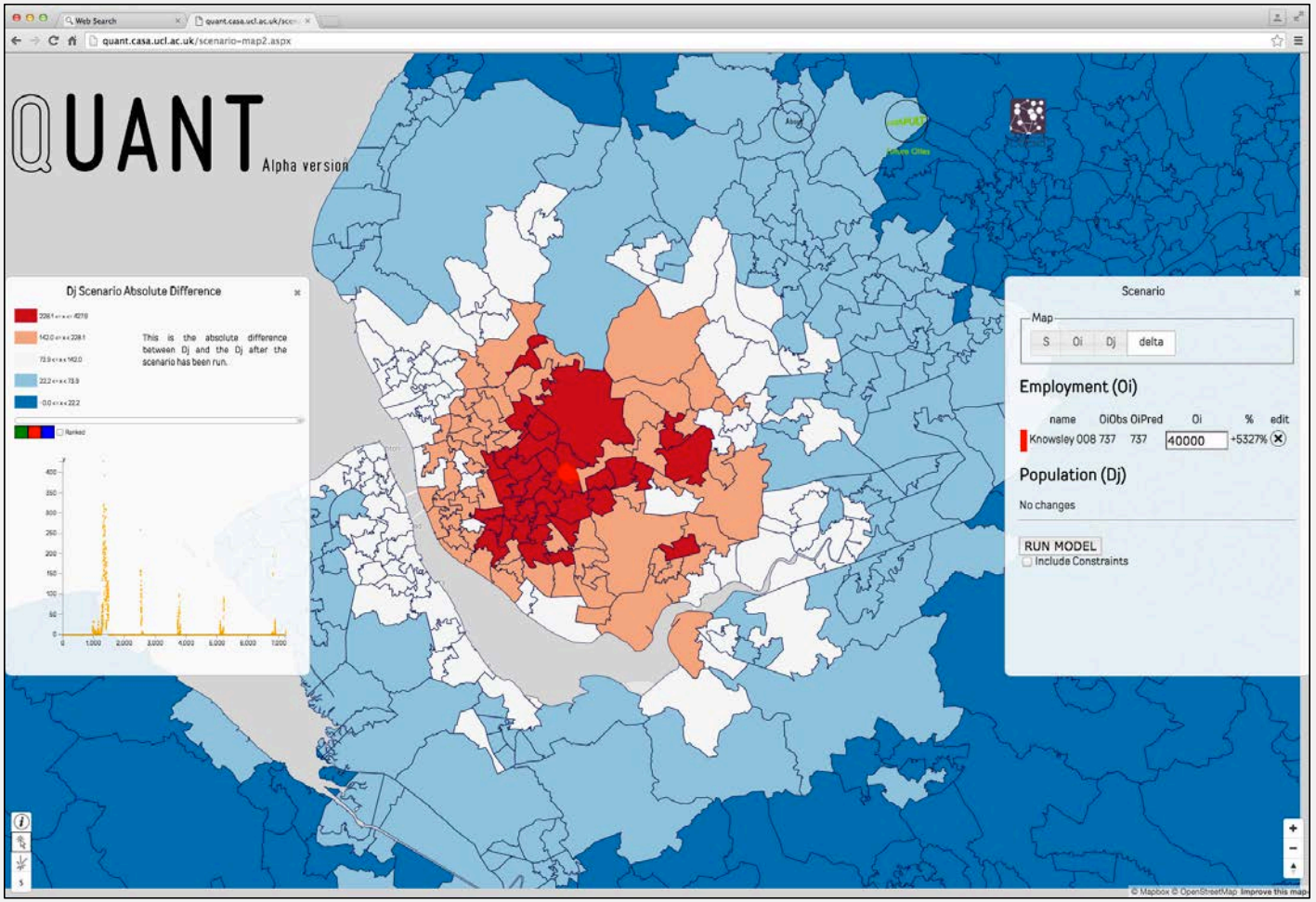
Simulating Urban Futures


QUANT
Alpha version
quant.casa.ucl.ac.uk/map2.aspx?v=DjObs
Observed Population
This is the total working population in each zone of the model. This is the employment which lives in residential zones.
Ranked
Amsterdam
The Netherlands
Belgium
Luxembourg
Ireland
Dublin
Belfast
Glasgow
Edinburgh
http://quant.casa.ucl.ac.uk/







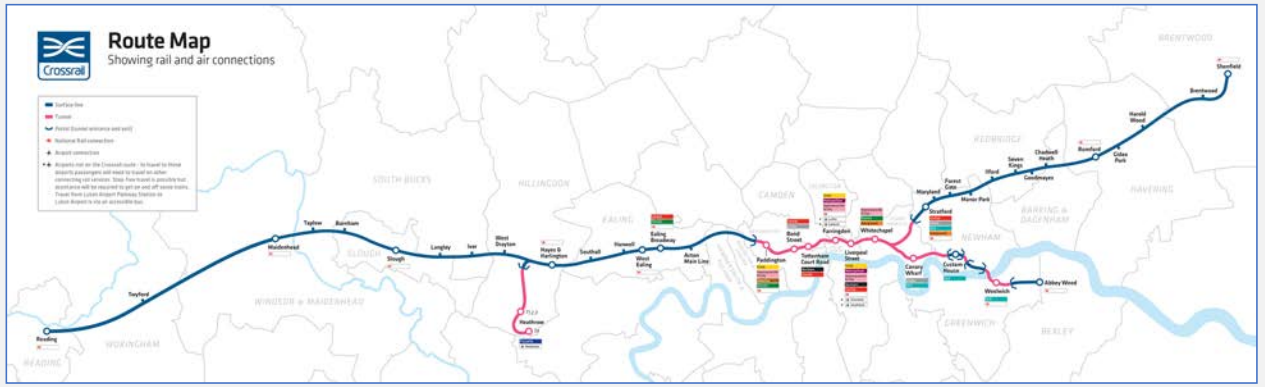


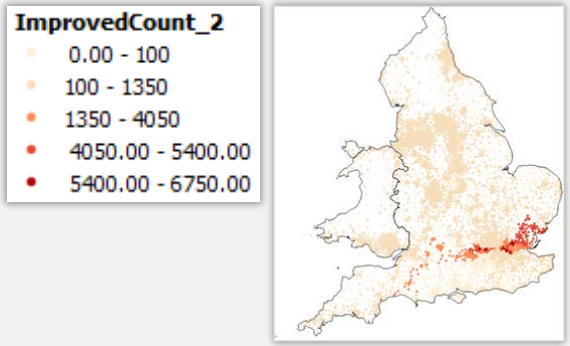
Simulating Urban Futures

A Typical Transport Example: Crossrail

Reading, Heathrow, Shenfield, Abbey Wood

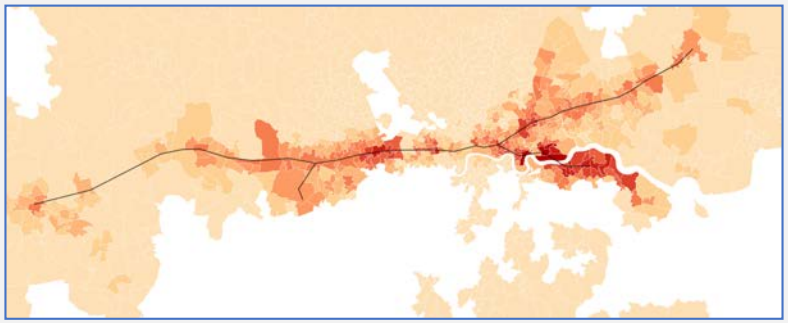


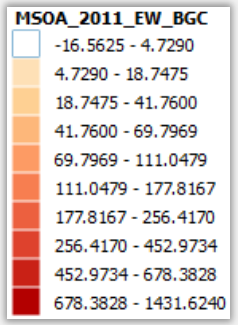




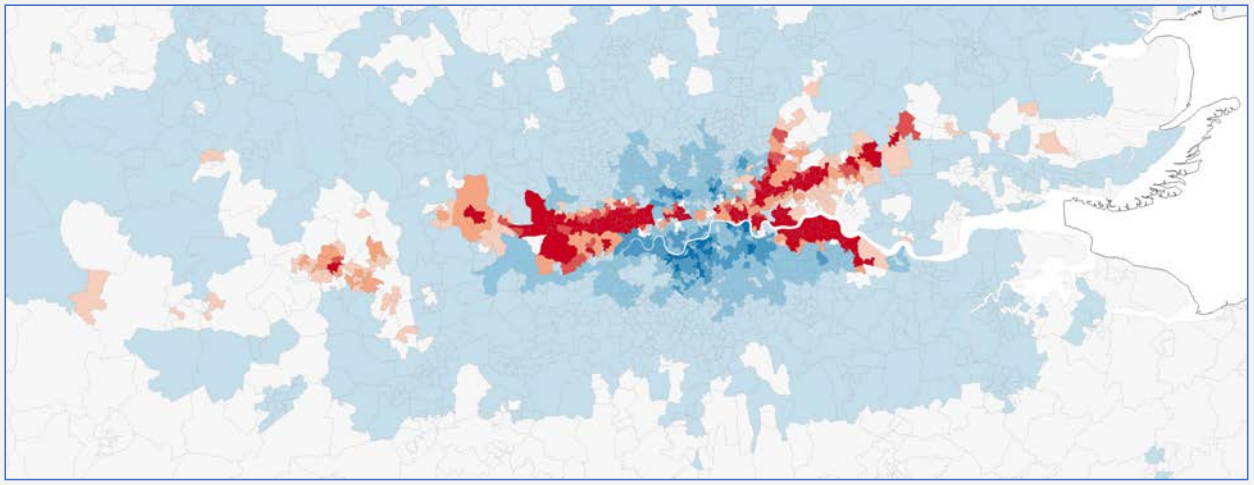


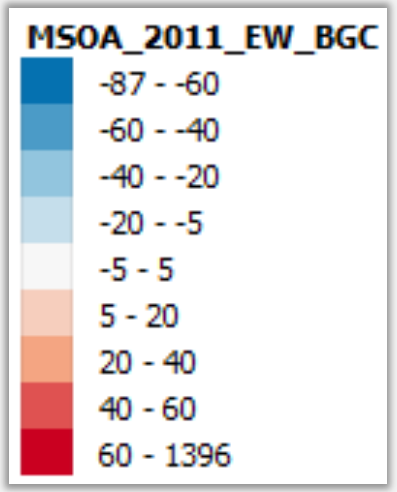
Population change (rail mode only

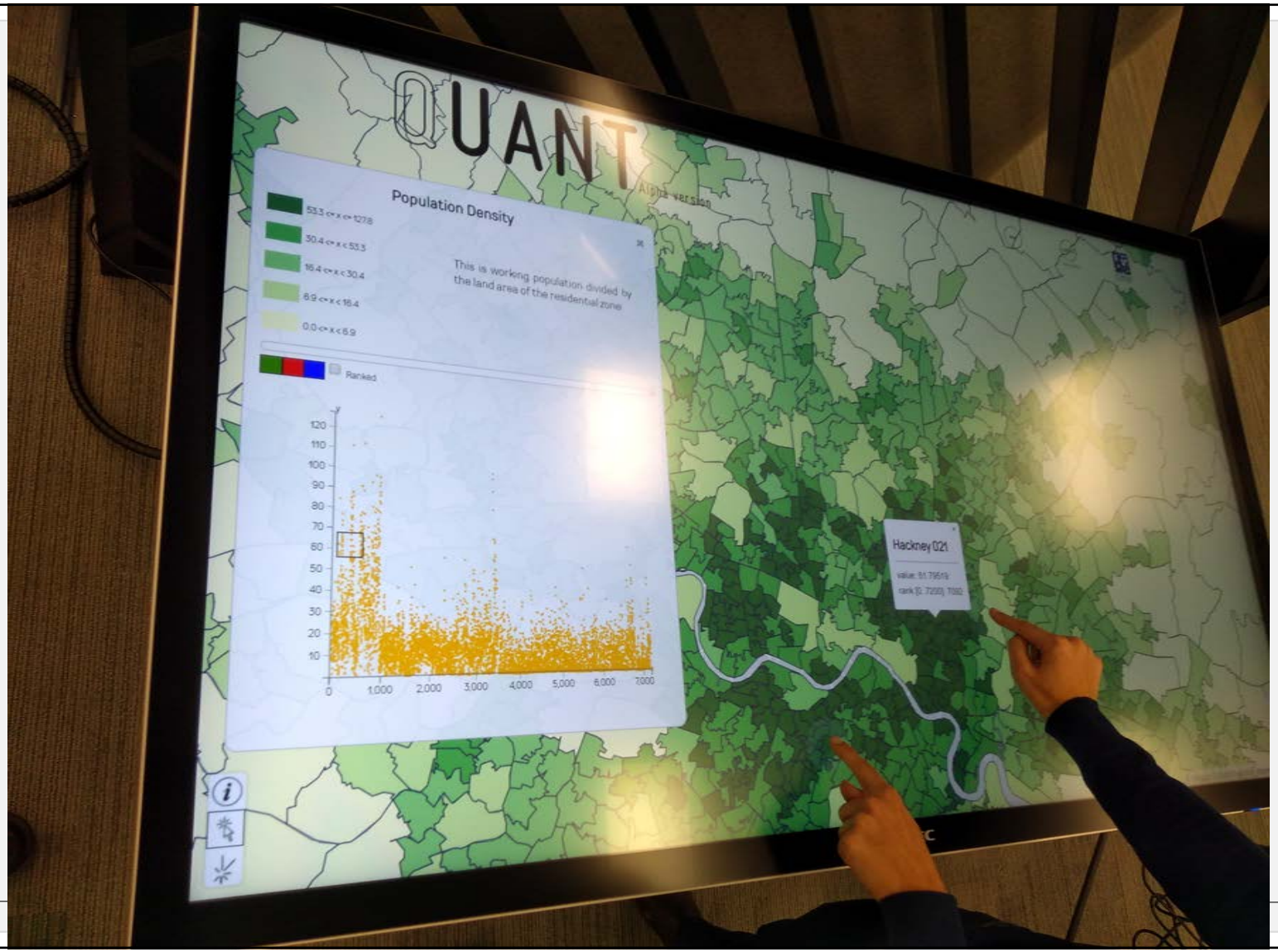




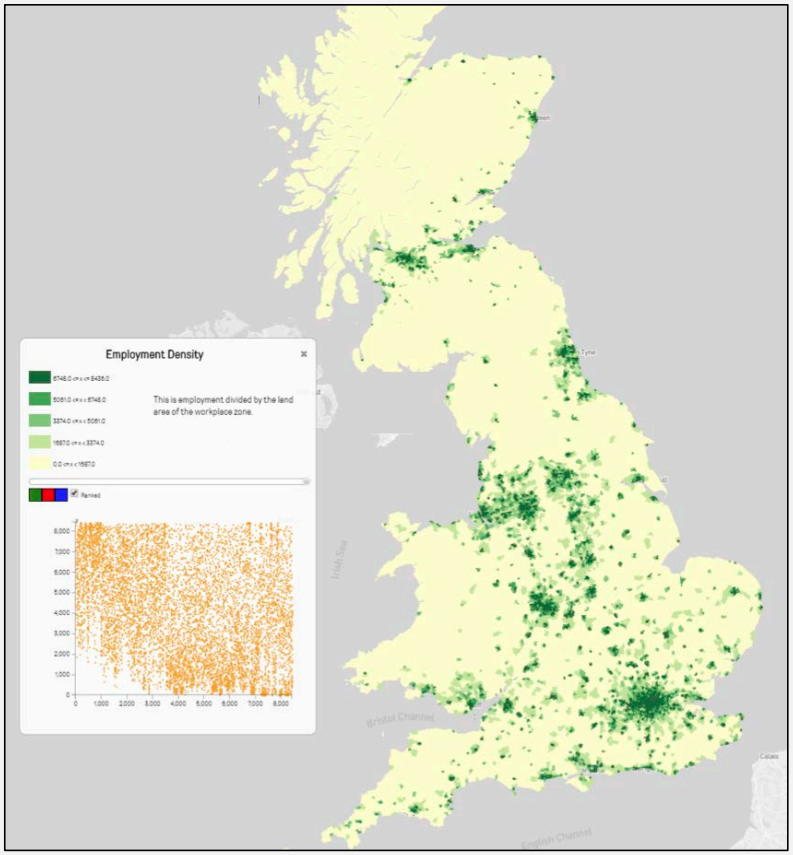




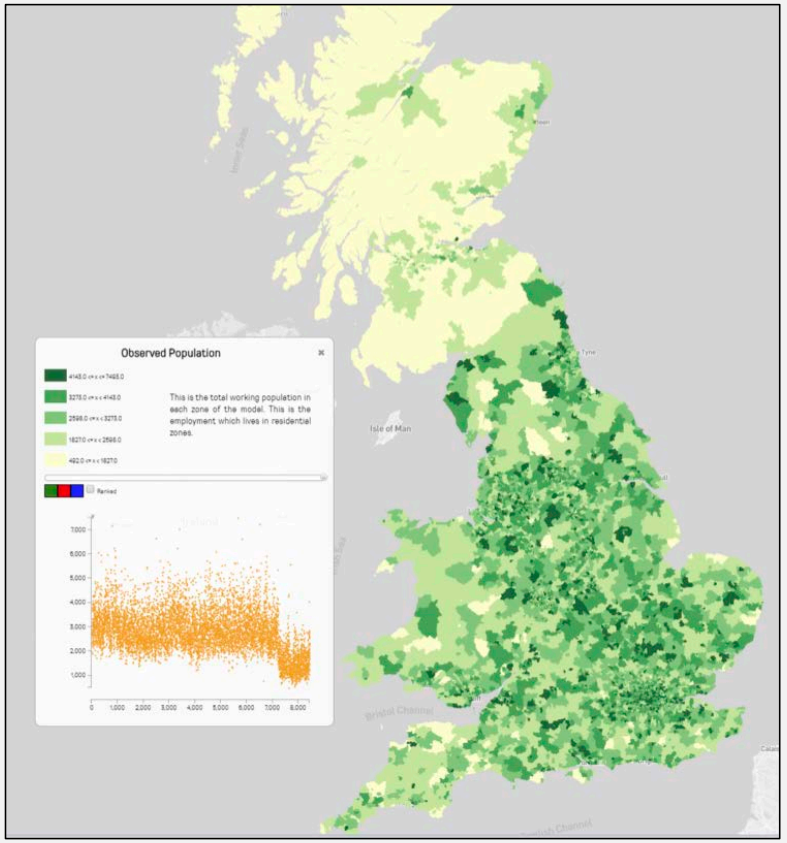



QUANT
Alpha version
Population Density
This is working population divided by the land area of the residential zone
Ranked
Hackney 021

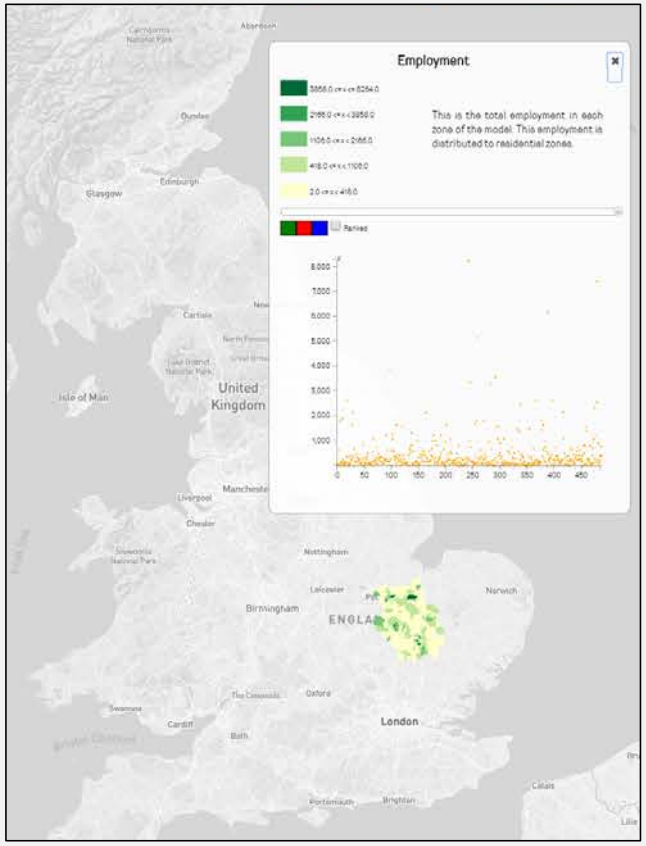
Employment Density

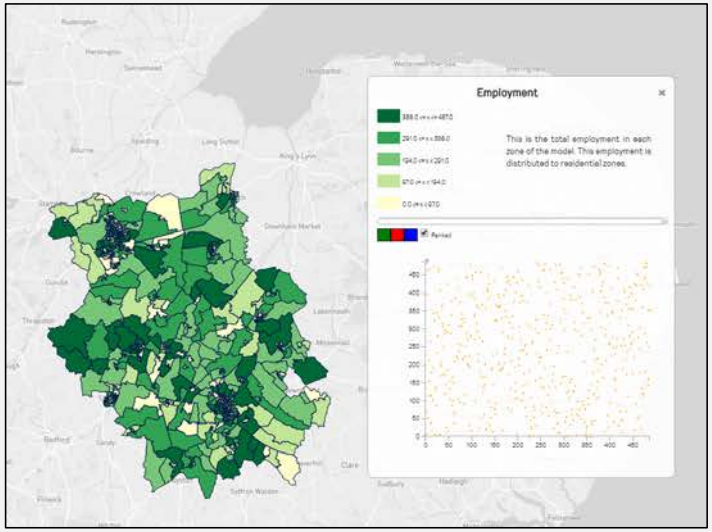


Population Counts



QUANT CAMBRIDGESHIRE
(Cambridge, SouthCam, EastCam, Fenland, Peterborough, Huntingdonshire)





487 LSOAs → 97 MSOAs
We modified the original QUANT model to work at two different geographical scales: MSOA & LSOA and to work with data from two different sources: LUISA & Census

Is the Concept of the Digital Twin Useful ?

- I leave you to judge. Like many things, Yes & No. It forces us to think about how cities are changing, how models are proliferating. ***How do we deal with many models of the same problem?***

- It forces us to think about what cities really are about in terms of new technologies, which is of course is part of the wider debate about what cities are and ***how cities are being transformed by new technologies***.

- It forces us to think about what a model really is and the extent to which we can link many models together for one system but also ***how we can think of many models and many different conceptions of the same system at the same time***.

Thanks

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Editorial

B Urban Analytics and City Science

Digital twins

Environment and Planning B: Urban Analytics and City Science
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Editorial

B Urban Analytics and City Science

A map is not the territory, or is it?

EPB: Urban Analytics and City Science
2019, Vol. 46(4) 599–602
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