Modelling a New Normal

Social Distancing's Impact on Land Use

Michael Batty
Centre for Advanced Spatial Analysis
CASA-UCL

18 June, Thursday | 4.00pm - 4.40pm

m.batty@ucl.ac.uk
@jmichaelbatty

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/Singapore-Batty-Final.pdf

Of from the CLC Webinar Site

An Outline of the Talk

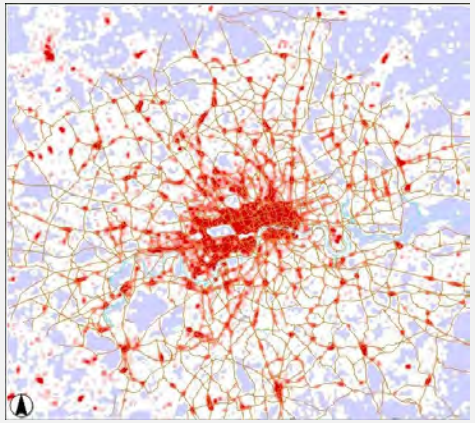
- Disruptive Events: The Network Analogy: Post Pandemic Cities
- Tobler's Law: How Near Can We Get To One Another
- The Very Large Scale, the Very Small Scale & Coupling Models
- Different Varieties of Urban Model
  - *Very Fine Scale: Contact at the Urban Design Scale*
  - *Building Very Large Scale Models of National Systems*
  - *Long Term Urban Change: The QUANT Model*
- Scenarios for Long Range Travel Determined by Short Range Contact
- Where Do We Go From Here?

Disruptive Events: The Network Analogy: Post Pandemic Cities

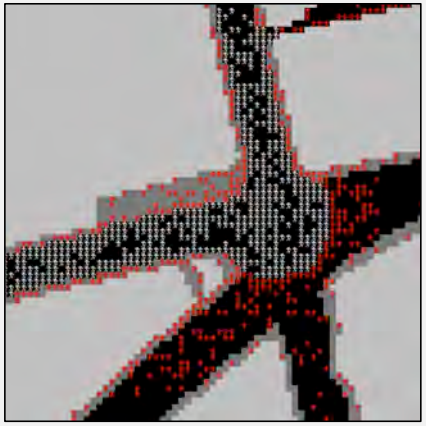
- Our model are based on the city as network. We can see ***disruption*** as breaks in the network links or the closure of nodes, and the cascading events that are generated from such actions.
- But nothing could have prepared us for a set of events that close down entire parts of our networks – virtually everything.
- In the UK, the ***Lockdown*** has led to a drop to 80% of people working from home, a decline of 20% in GDP in April alone, the UK government funding some 30% of all employment up to the average wage. The scale of the change is enormous.
- Bringing the economy back and ***Out Of Lockdown*** is now the issue and also putting in place a new set of rules as to how we move at every scale. We have little idea about how the virus is transmitted.

- ***Distance and where and how we move are critical to this whole question.***
- Most of our models are based in key questions of distance – how far we can travel for what cost and for how long
- Before the industrial revolution, generally the maximum distance walked to work was no more than about 6 miles a day
- Most of our economy is now structured in big cities for travelling about ***one hour a day on average***, and this is accomplished generally by motorized transport; by individual car travel or by mass transit
- If we suddenly have to change the density of how we use vehicles in which we travel, this will have enormous implications for how far we can travel and at what capacity. We will not be able to travel the same distances.
- And this also impacts on how we move locally within small spaces.

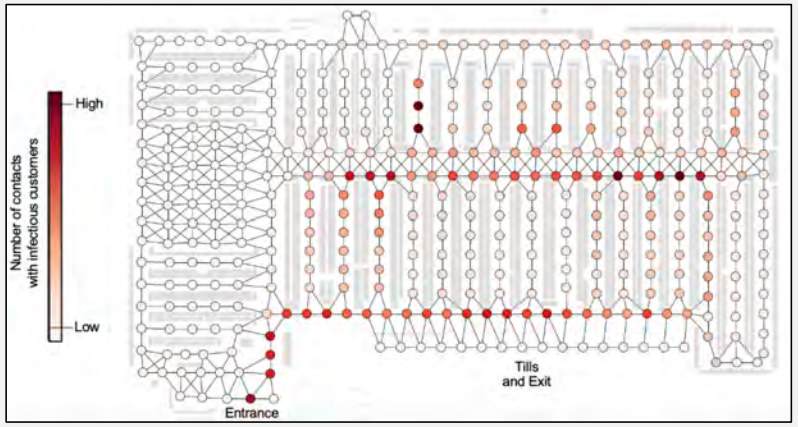
- One of the features of how we might adapt to the current pandemic is in terms of density, spacing in crowds, and cost of travel across all scales – from global travel using airlines, to the most local shopping.
- Let me just throw onto the canvas some pictures of how spacing is being affected – through keeping apart so the probability of transmitting the virus is at a minimum



retail locations in a big city – London



a parade around a street route



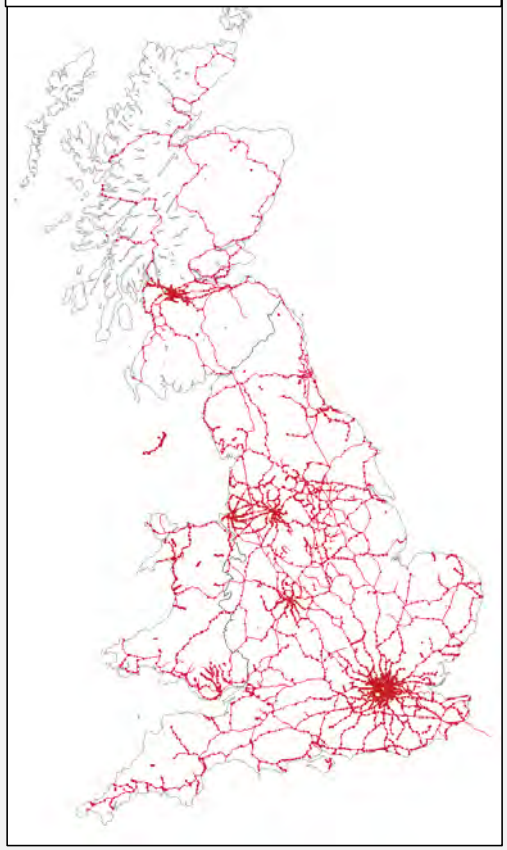
one-way systems for organizing shoppers in a supermarket

- Before I begin to suggest how our models might be adapted – or how and why we might need completely new models, let me say something about scale. Social distancing to keep people apart is as critical at very large scales as at very small scales
- We need to note that to travel and move over very large scales – over large distances, we usually use some form of mass transit. I know we can move locally using cars and occasionally make long driving trips but in general if I want to come to Singapore, I need some form of mass transit and this means locally whatever the mode I need the capacity. If I cannot social distance, then I cannot travel.
- This means our national and international systems are going to be dramatically affected –more so than local systems because the more costly the travel and the farther we go, the greater the sunk costs in fixed capacity. Capacities cannot easily be changed – reduced - and hence the systems may not longer be viable.

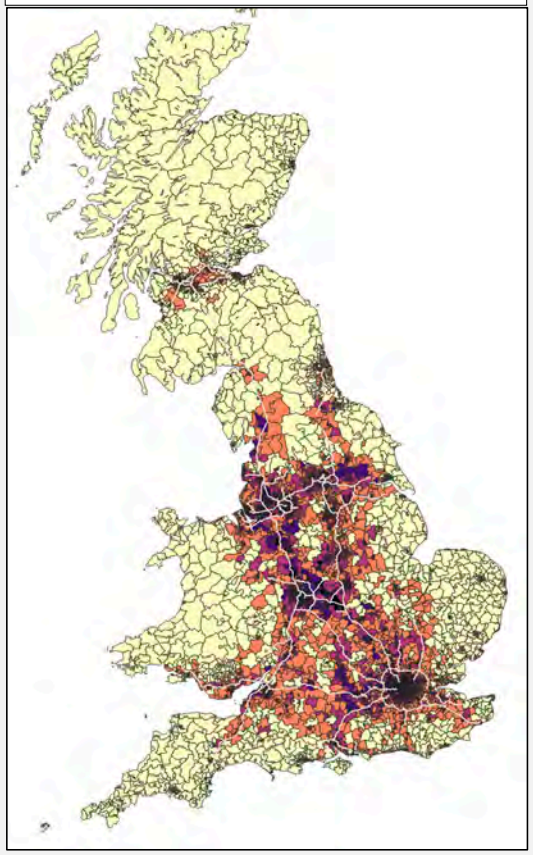
- And at the global scale where local capacity matters

Road, v=3.5M, e=8.4M

Rail, v=3165, e=10,269



Social distancing



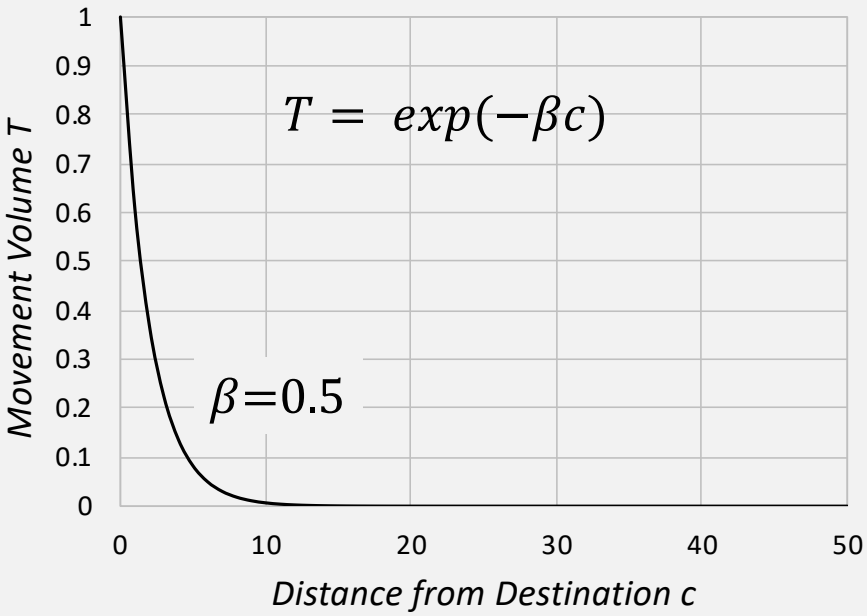
Tobler's Law: How Near Can We Get To One Another

- Waldo Tobler in a famous paper in 1970 said in quite an off-the-cuff type of way: " …everything is related to everything else, but near things are more related than distant things."[1]
- This of course is the famous inverse distance law, in Newtonian physics, the inverse square law.
- If you look at any location as a destination, the model or law assumes that the flow from any distant point to the destination, drops off the the power of distance or cost. This function is often assumed to be a power law or a negative exponential. It applies across many scales

$$T \sim exp(-\beta c)$$

[1] Tobler W. (1970) A computer movie simulating urban growth in the Detroit region, ***Economic Geography***, **46** (Sup), 234–240.

- Here is the basic idea. The area under the curve is the total flow of people who visit the destination which is at distance 0



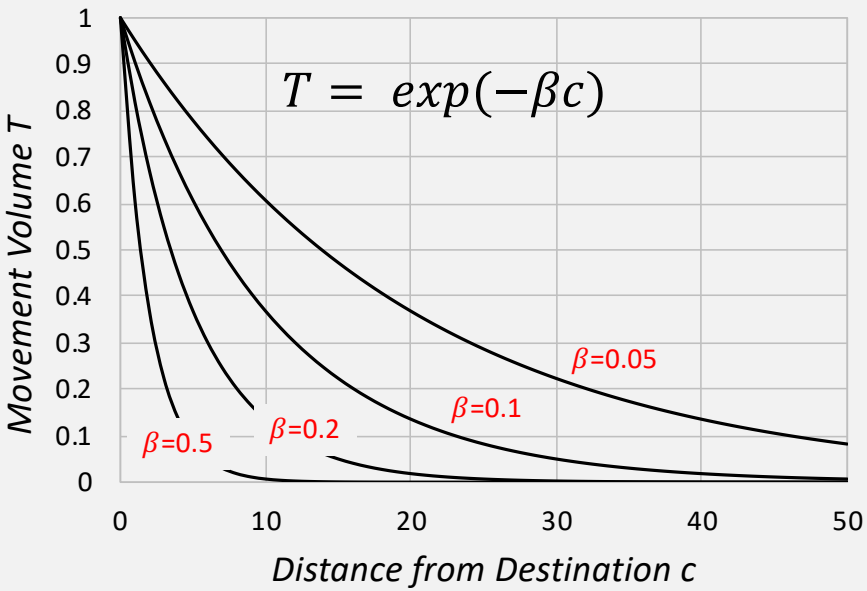
To get this, we add up all the flows under the curve as

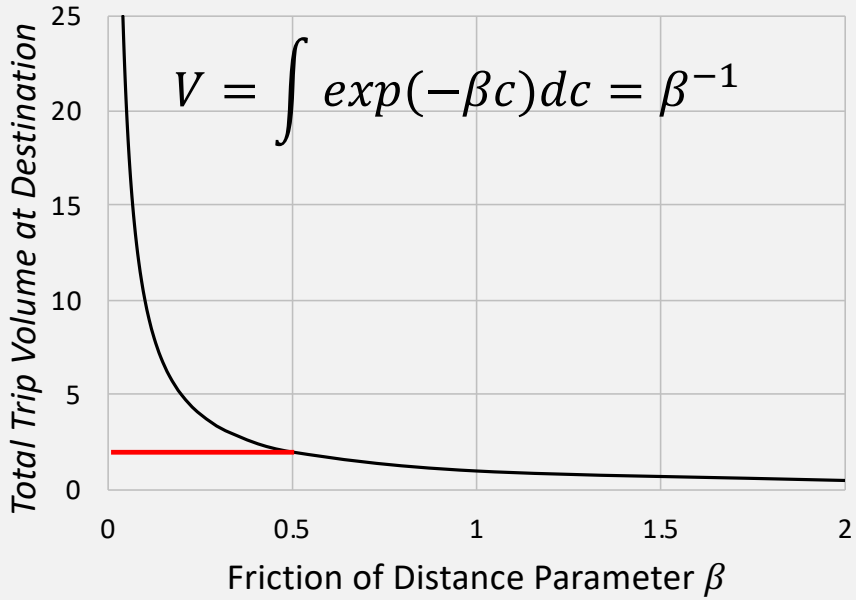
$$V = \int exp(-\beta c)dc = \beta^{-1} = 2$$

and this gives us in this example a total of 2 when β=0.5

- If we decrease the friction of distance – lower the paramete β we get more and more trips

- We can show this as follows and then we can plot a curve on the right of the volume generated for each parameter





- We now need to examine what happens when thee volumes get to a destination

- Now imagine we have a volume of 25 which is determined by a friction of distance parameter $\beta=0.05$ Assume this volume is people. Then in principle each person can have an interaction with everyone else at that point or location. That is, the set of potential interactions is

$$Interactions = V^2 \sim (\beta^{-1})^2 = \beta^{-2}$$

- And for $\beta=0.05$, we have 625 interactions and a proportion, say ρ of these would lead to infections.

- Now we might be able to measure this but *so little is known about the virus transmission* that anything we can now say would be an heroic guess. If the infection probability were let us say 10% per unit time interval of spending time at the location, $\rho=0.1$, then the total number of infections would be something like $\rho^2 V(V-1)$.

- For the example involved, this would imply some 6 infections per trip period. In fact, if we assumed that a 2 meter rule to keep people apart from transmitting the virus, then the actual infections would be lower as not everyone can physically pack into the space involved.

- So to summarize, we need to examine all our models with respect to the flow from the wider hinterland and how the volumes of trip makers interact at the point location.

- We also need to qualify all this with respect to the capacity of the systems used to transport the flows to the locations and the capacity of the location with respect to local interactions.

- Thus in modelling the pandemic, we not only need to alter our large scale models but we need to integrate them with the small scale. This is something we have little or no experience of doing this.

The Very Large Scale, the Very Small Scale & Coupling Models

- In fact, we have an interaction between scales where people move using machine technologies and scales where people move using their natural motion.
- We have different models for different scales and usually these are applied separately to each scale. But think about it. In the case of the pandemic because we get it when we meet people or surfaces where the virus is deposited at the most local scale, then the most local scale occurs at all scales, from airline travel to trains to shopping.
- We thus need models that are integrated between scales. If we figure out how to model people moving to in a metropolitan area, when they get to a place we need to then model how they move locally because the diseases is prevalent everywhere

- We also need to look at capacity. If we have to keep apart at the local level, this imposes ***capacity limits***, in small spaces where we transact most of our business but even in terms of travel we must self-distance inside vehicles moving at high speeds, over long distances.

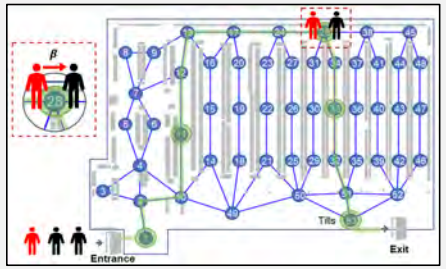
- Most of our models of the pandemic are not spatial – although the whole thing is about contact, the models in general assume that contact is not very important – it is hard to deal with of course

- Let me explain briefly the standard Kermack–McKendrick in 1927. It is dead simple really - you have a population and someone gets infected and then they infect others according to their R number – eventually everyone gets infected and there are no susceptibles left so the epidemic dies out. Some might die but the infection is usually time limited. It is this type of model that we need to make spatial, or variants of it. It gets complicated if we don't become immune

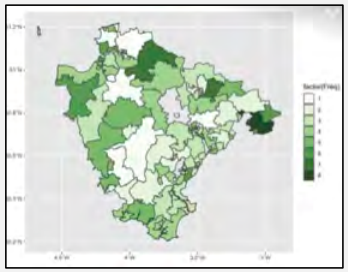
Different Varieties of Urban Model

Let me tell you quickly about the models I going to demonstrate as I don't know how much time I will have – and Zoom technology can be exhausting

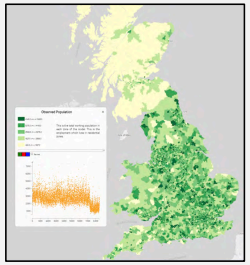
- *Very Fine Scale: Contact at the Urban Design Scale*
- *Building Very Large Scale Models of National Systems*
- *Long Term Urban Change The QUANT Model*



Figuring out social distancing in supermarkets



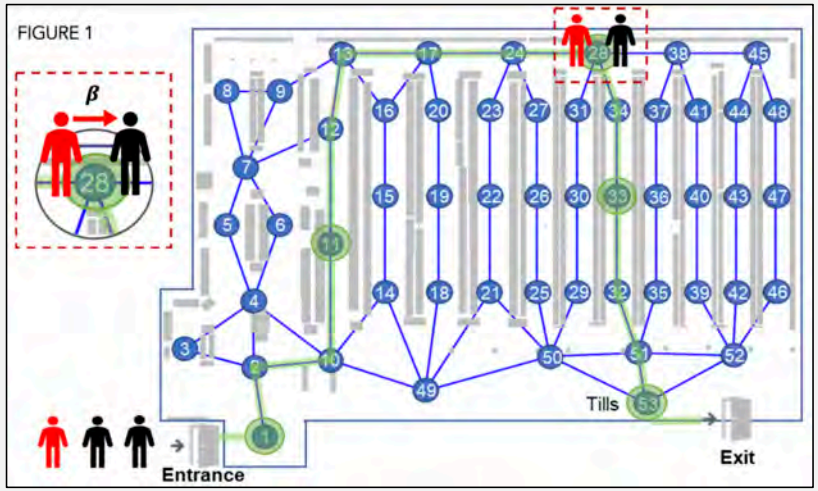
Spatial epidemic modelling in Devon using spatial interactions

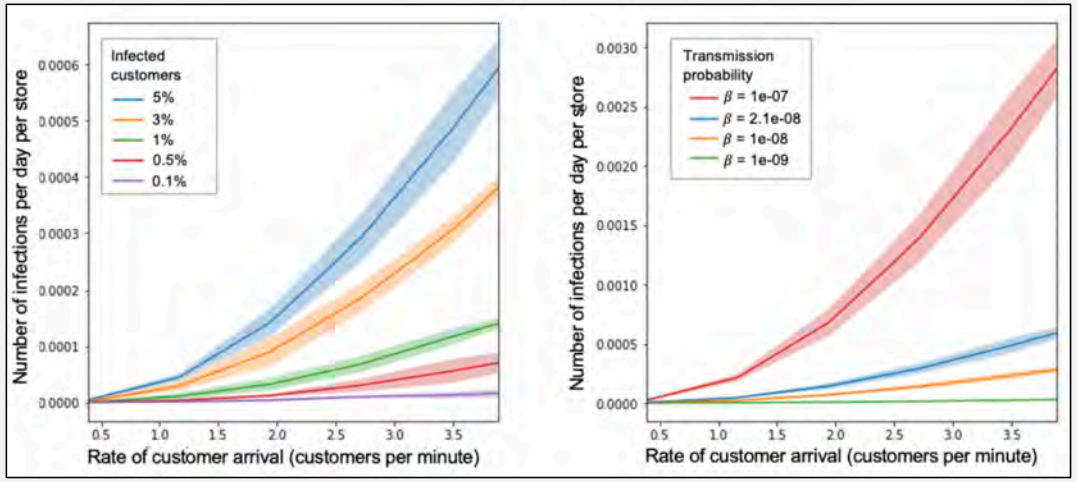


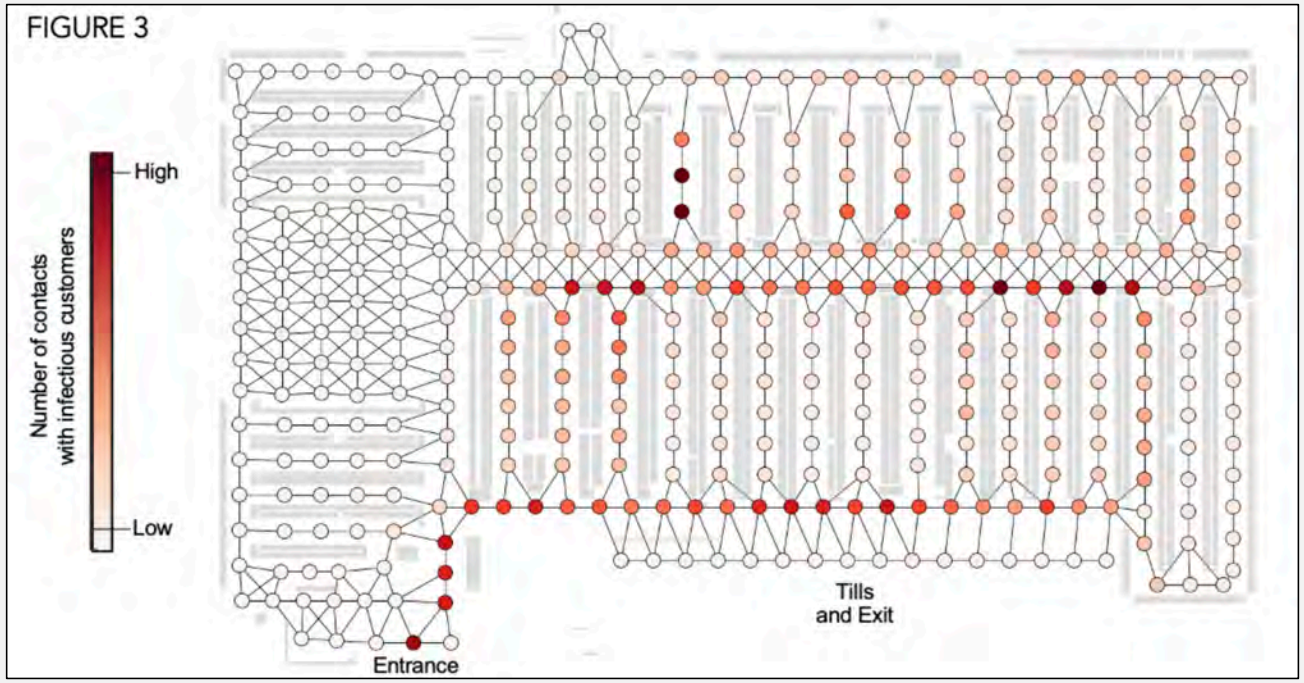
LUTI model QUANT for England, Scotland and Wales to Assess Impacts in Large Scale Transport Movements

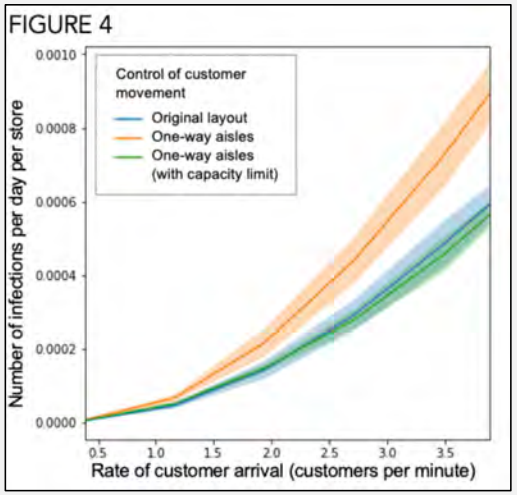
Very Fine Scale: Contact at the Urban Design Scale: Supermarket Models

One of the key elements relating to contact is in retail environments and some of the simplest are supermarkets where purchase are routine and this social distancing is relatively easy to figure out, if not ensure, at least understand what needs to be done. Here is the basic layout







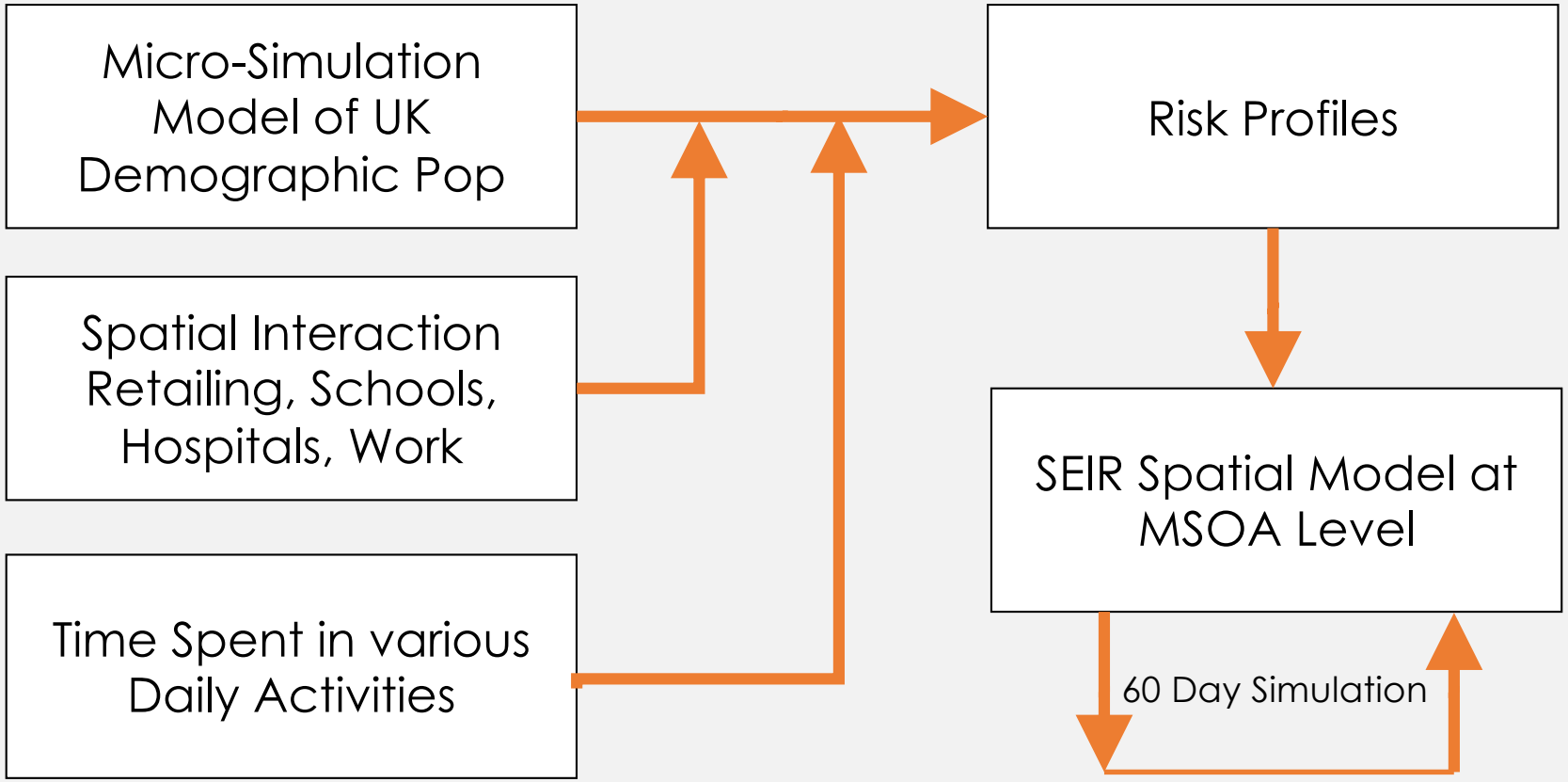


Essentially queuing and rates of arrival as well as volumes of customers increase super-linearly infection rates while transmission rates are linear in effect. We need to figure out how all this local geometry affects infection

Building Very Large Scale Models of National Systems

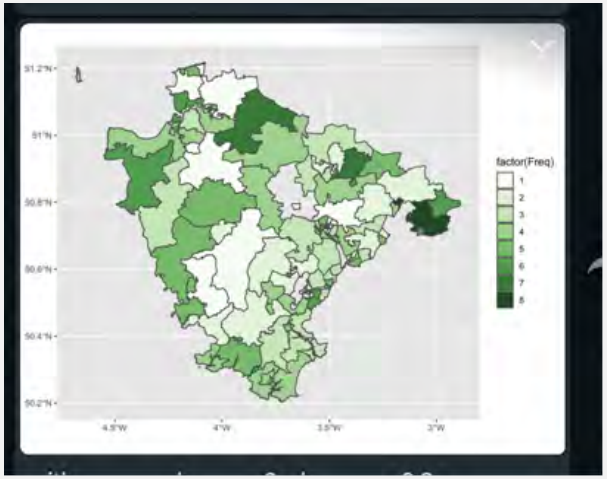
- We are building a national model of the spatial pandemic which is open sources, available on Github which synthesizes a microsimulation model of the UK Demography called SPENSER from Leeds, retail, schools and hospitals spatial interaction models from CASA, journey to work models from the Martin Centre Cambridge, and Epidemiological SEIR model from Exeter

- This model essentially feeds the epidemiological model with demography and spatial interactions and generates risk profiles which determine infections amongst the wider susceptible population, These risk factors are spatial at the usual scale we use in the UK which is the MSOA which has an average of about 7000 persons in each (over the whole country). The model is currently validated & working for Devon.

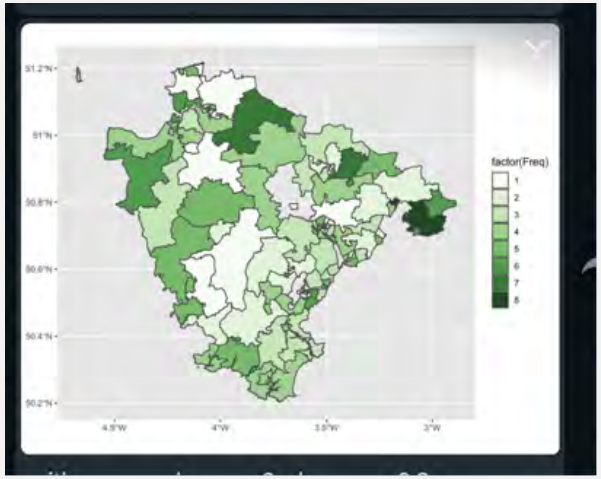


Modelling a New Normal

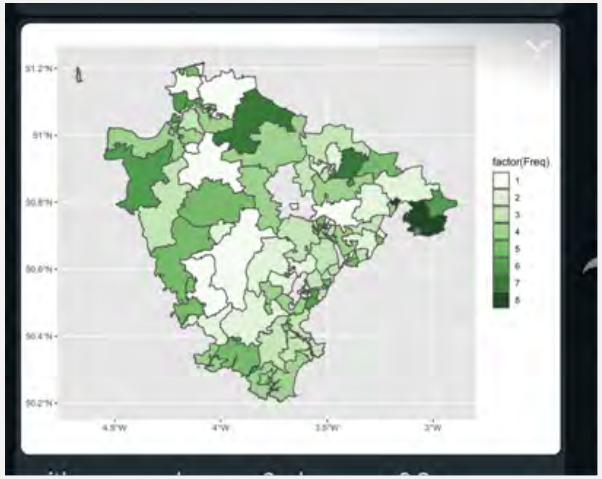
Infections

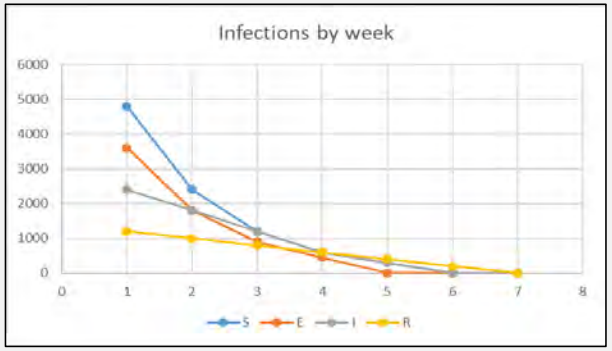


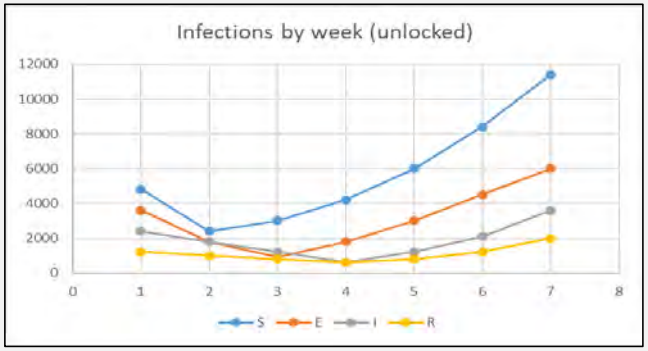
Observed Mortalities



Predicted Mortalities

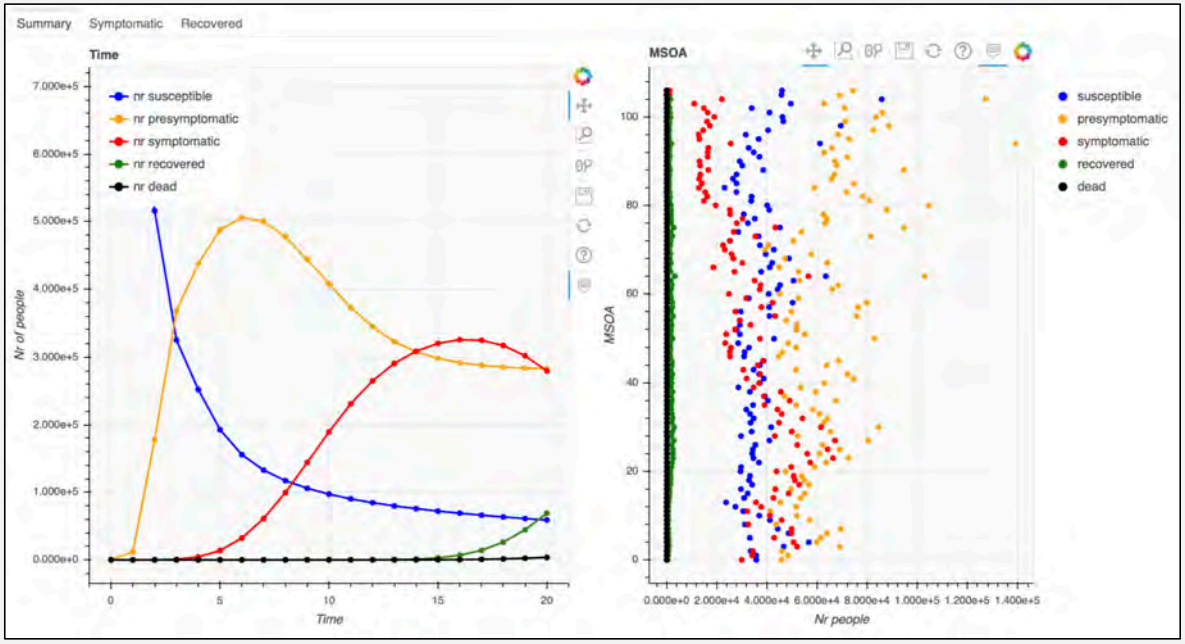


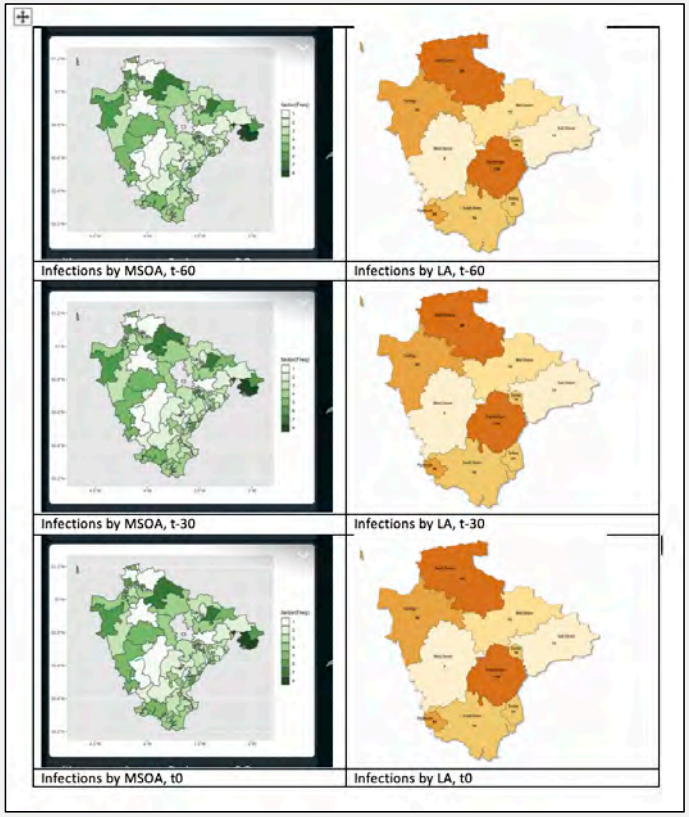




Modelling a New Normal

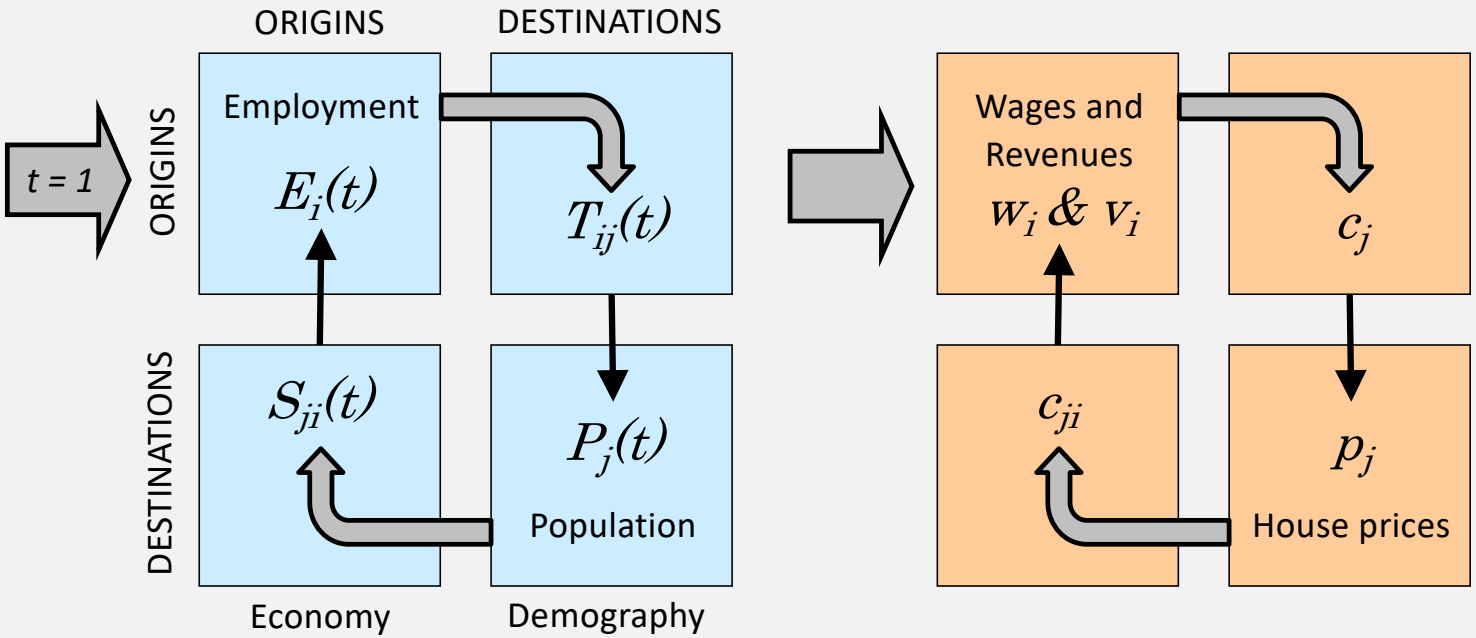
The 60 Day Simulation

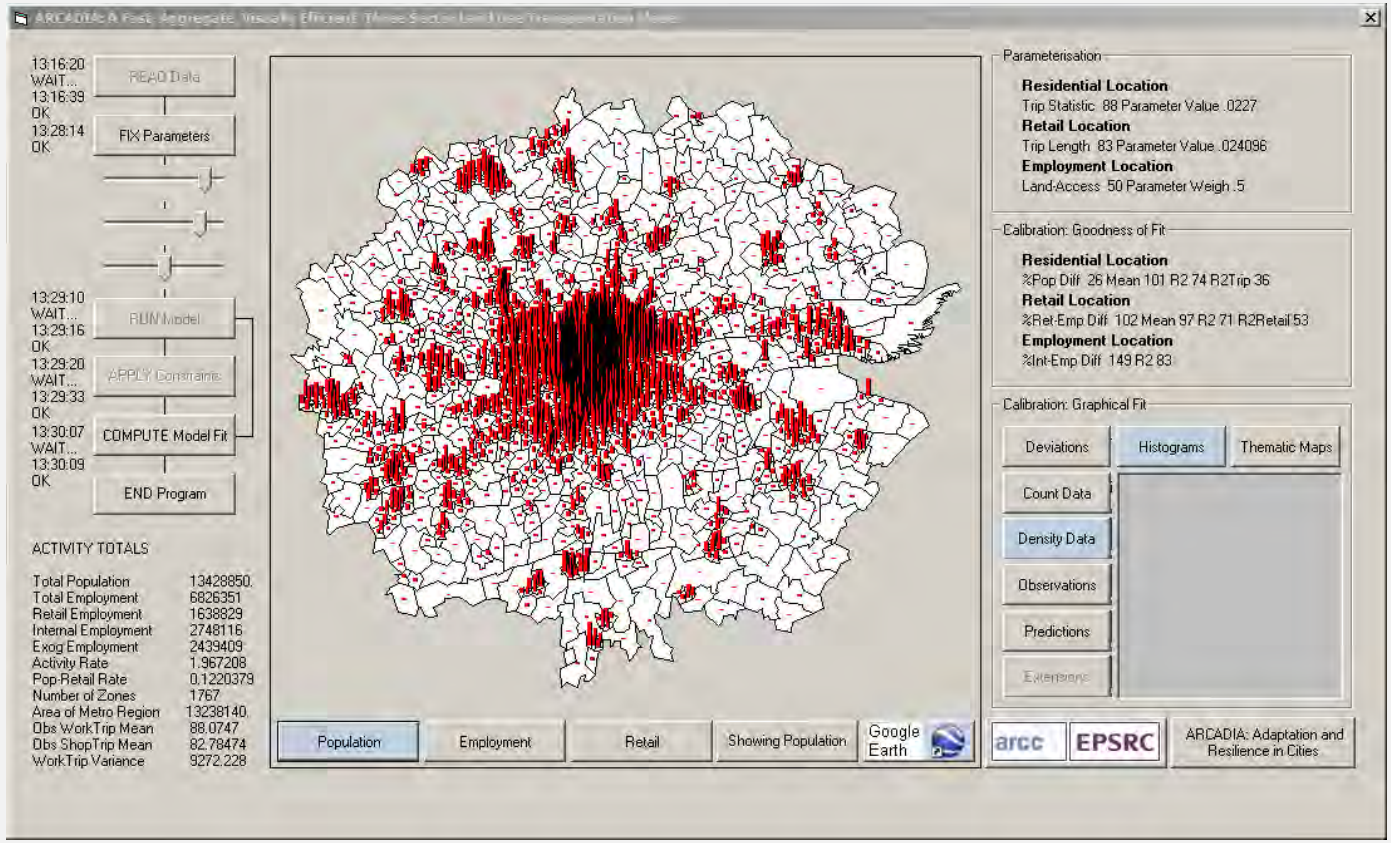




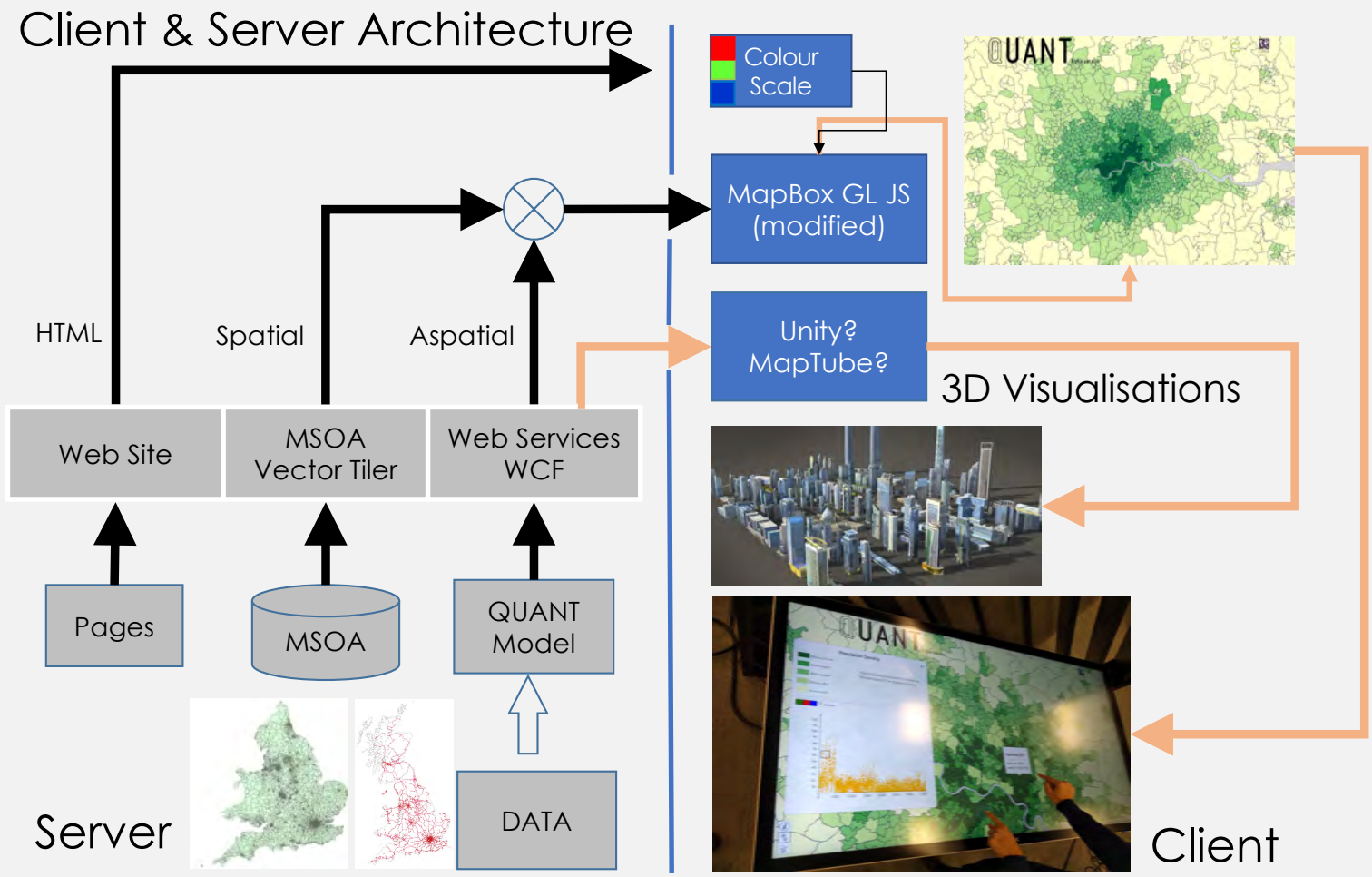
Long Term Urban Change: The QUANT Model

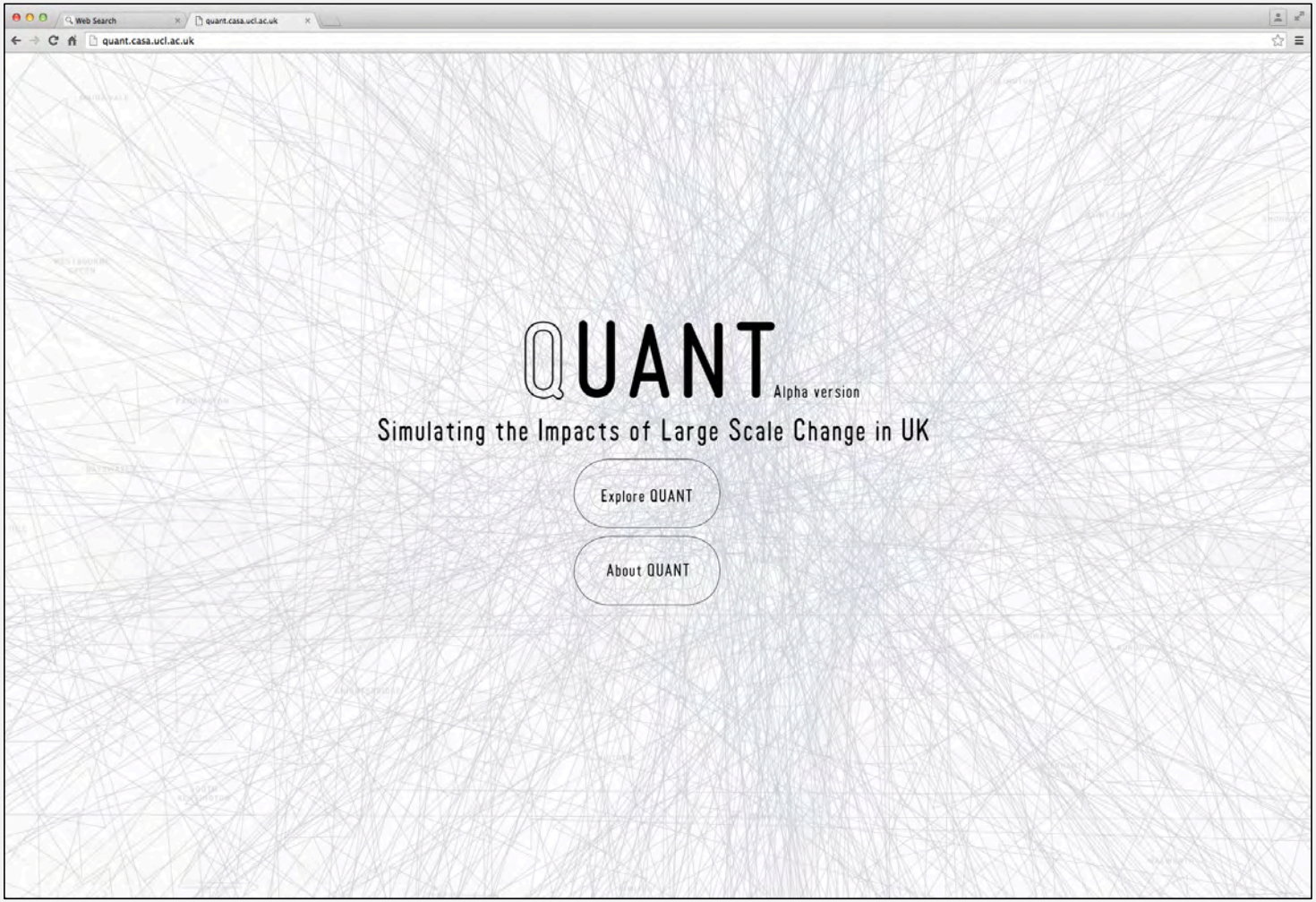
This is a LUTI model built on different sectors that depend on one another through their spatial interaction. It is scaled to Great Britain (E, W and S), is web-based, runs in real time, & enables scenarios to be tested on the fly.





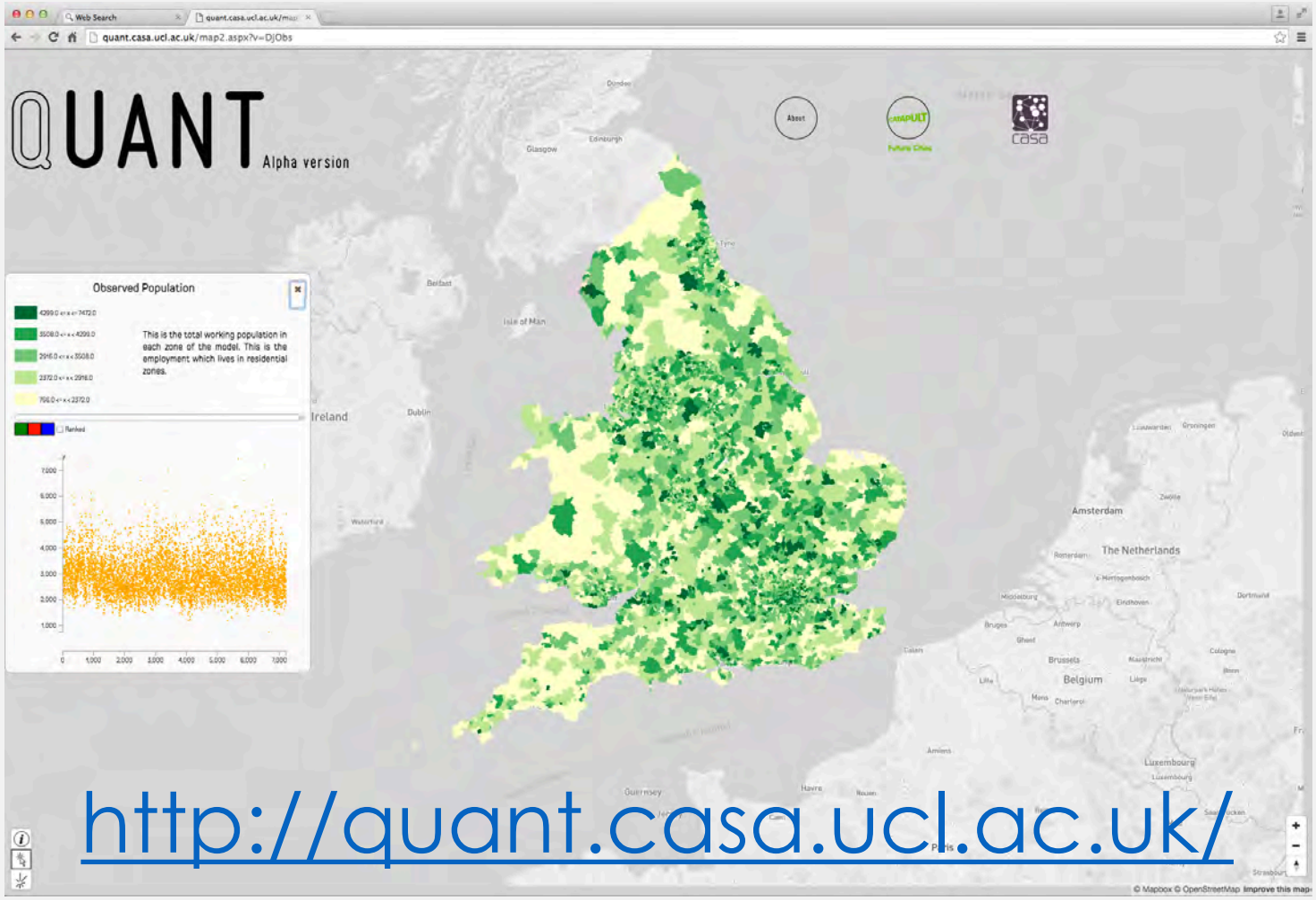
Modelling a New Normal


Client & Server Architecture
Colour Scale
QUANT
MapBox GL JS (modified)
HTML
Spatial
Aspatial
Unity? MapTube?
3D Visualisations
Web Site
MSOA Vector Tiler
Web Services WCF
Pages
MSOA
QUANT Model
DATA
Server
Client

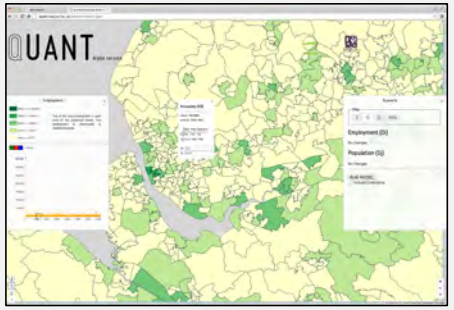


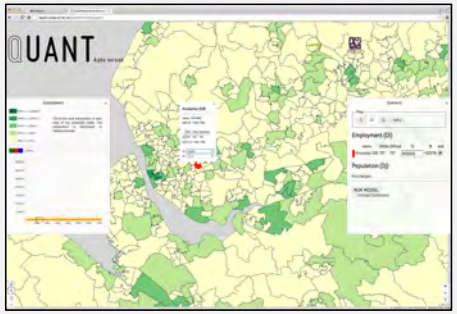
Modelling a New Normal

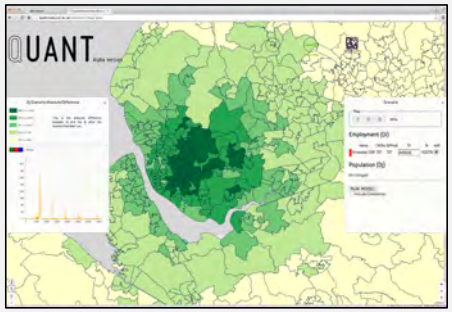
Modelling a New Normal

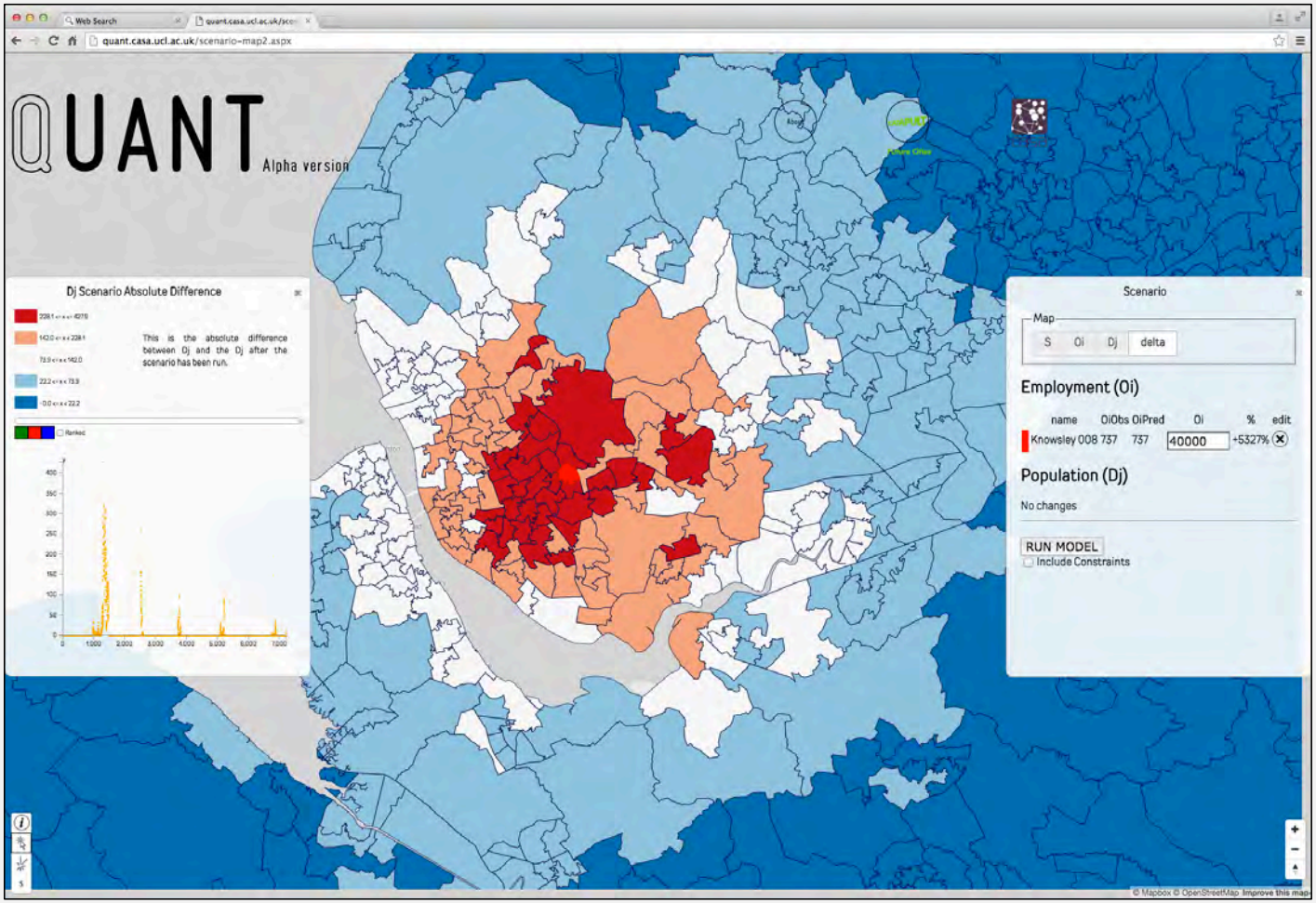


http://quant.casa.ucl.ac.uk/



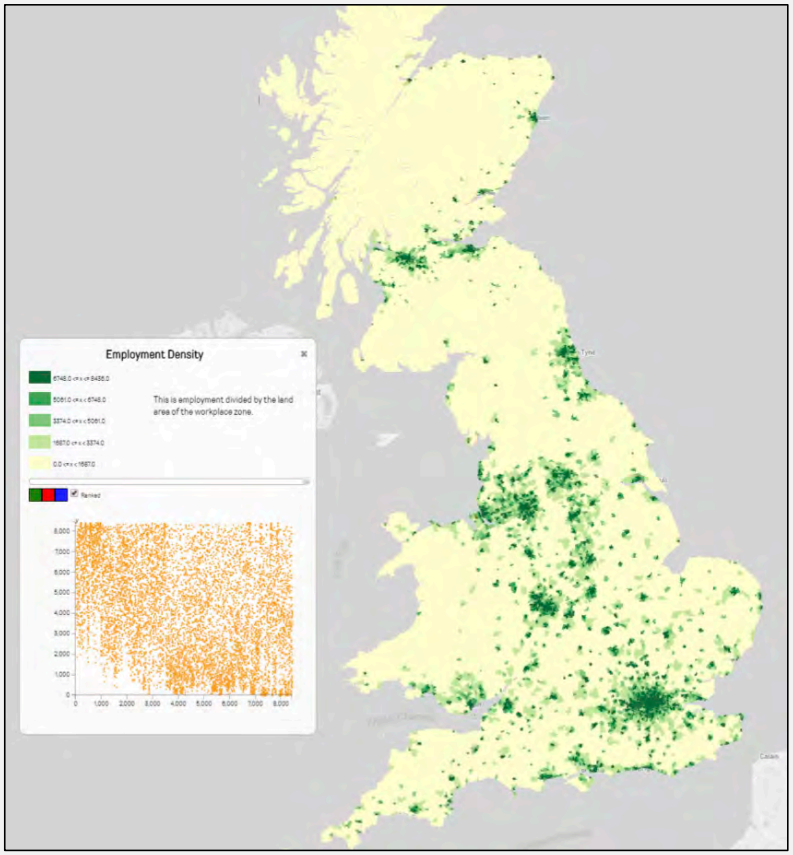




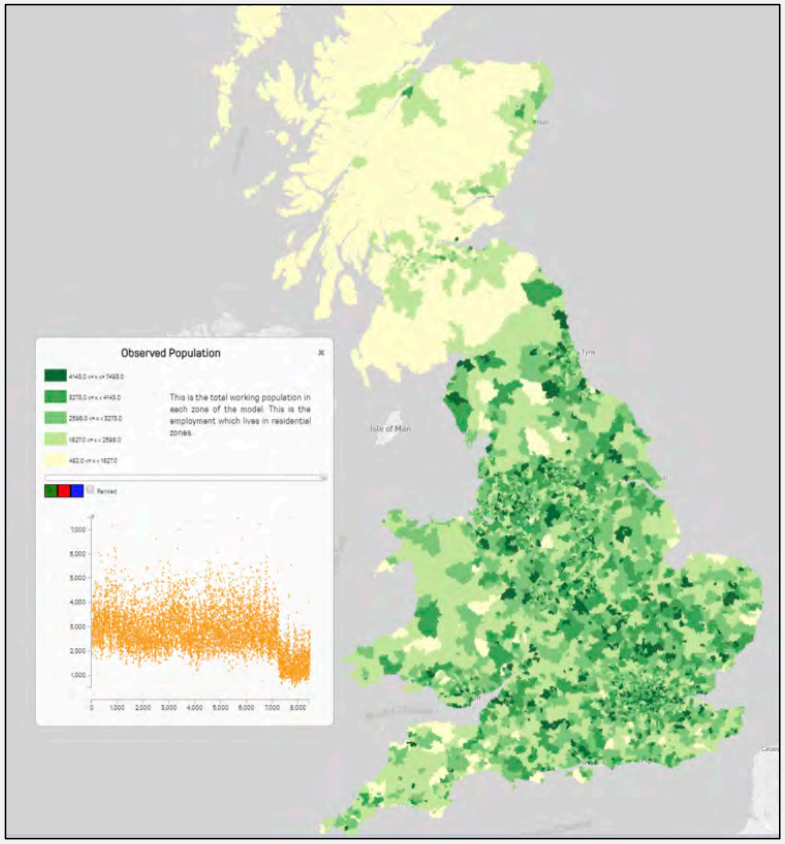


Modelling a New Normal

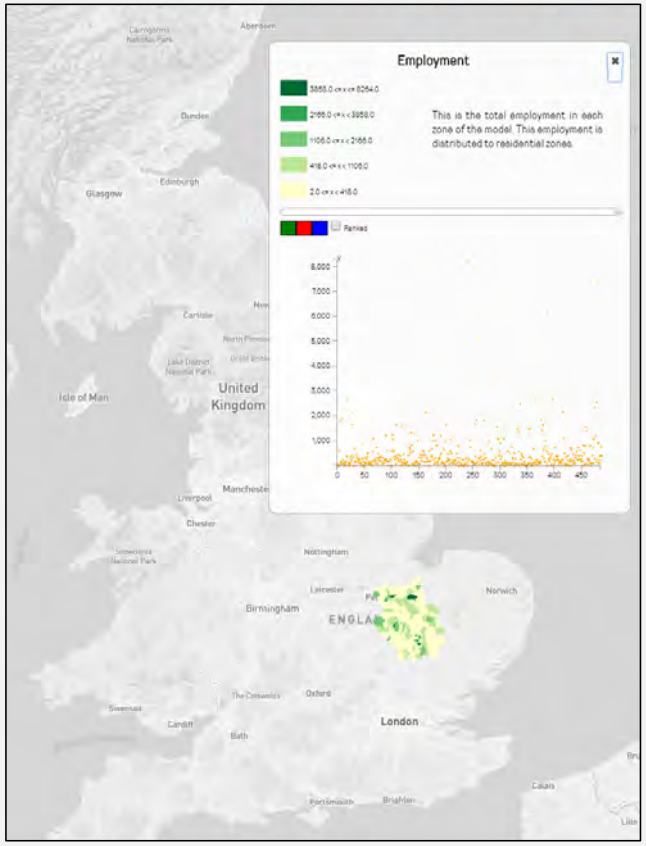
Employment Density

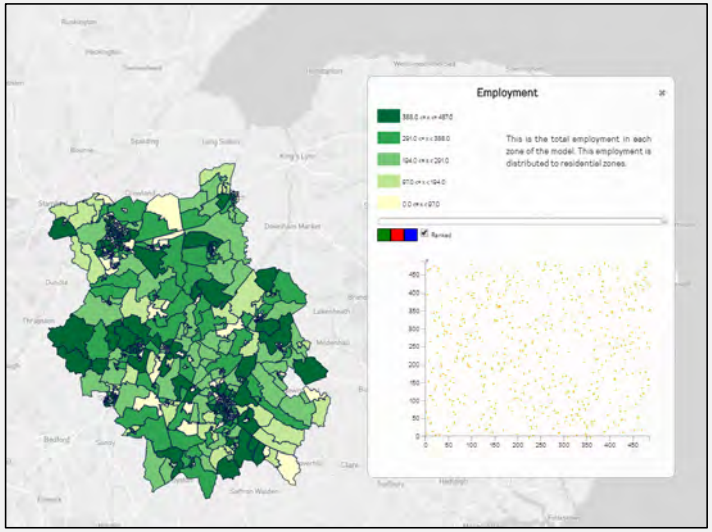


Population Counts



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

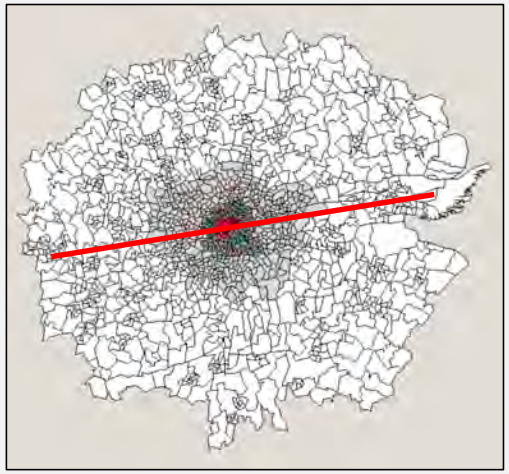
Scenarios for Long Range Travel Determined by Short Range Contact

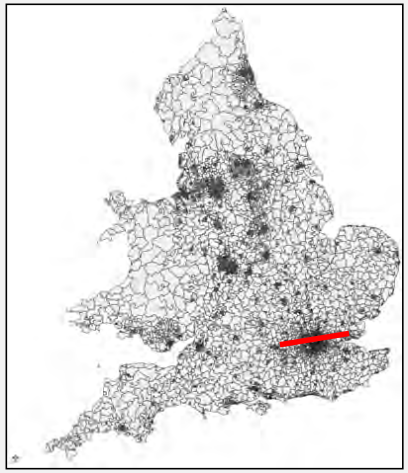
There are many infrastructure projects in the UK that can be tested using this model but many of them will now be under scrutiny –

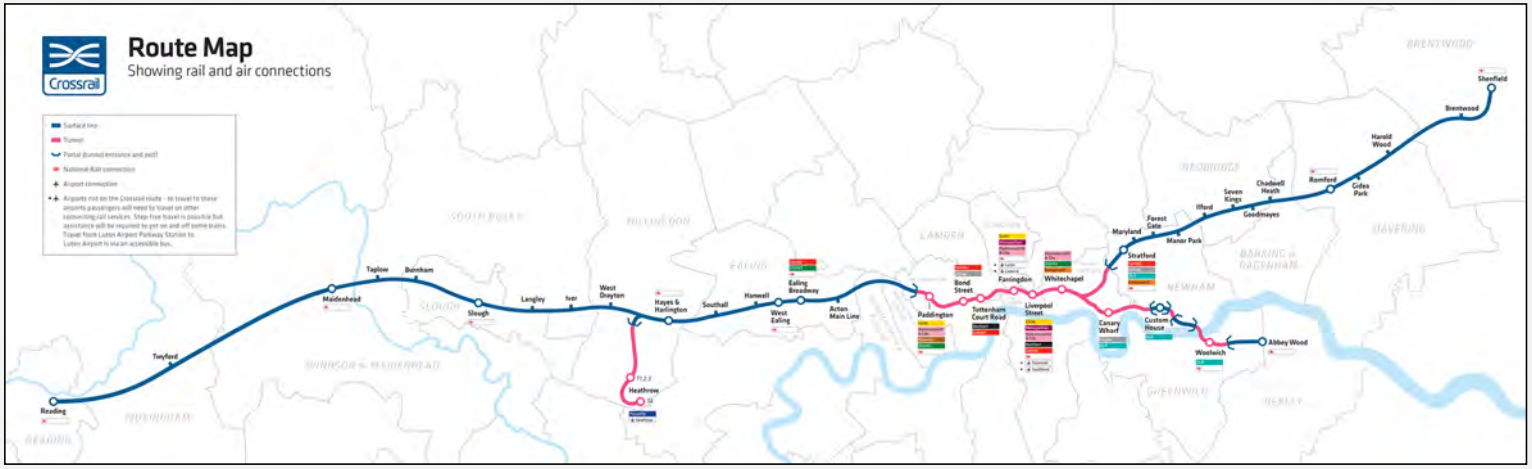
- one that is almost complete is ***Crossrail*** – the high speed tube line under London linking east and west. We will look at this.
- Then we will briefly look at how high speed rail takes passengers from the road network and how this leads to ***reduction in carbon emissions***
- But also we will look at the ***Impact of social distancing on Network Rail*** – which leads to the suppression of accessibility and volume on national and suburban rail

Crossrail

Reading, Heathrow, Shenfield, Abbey Wood

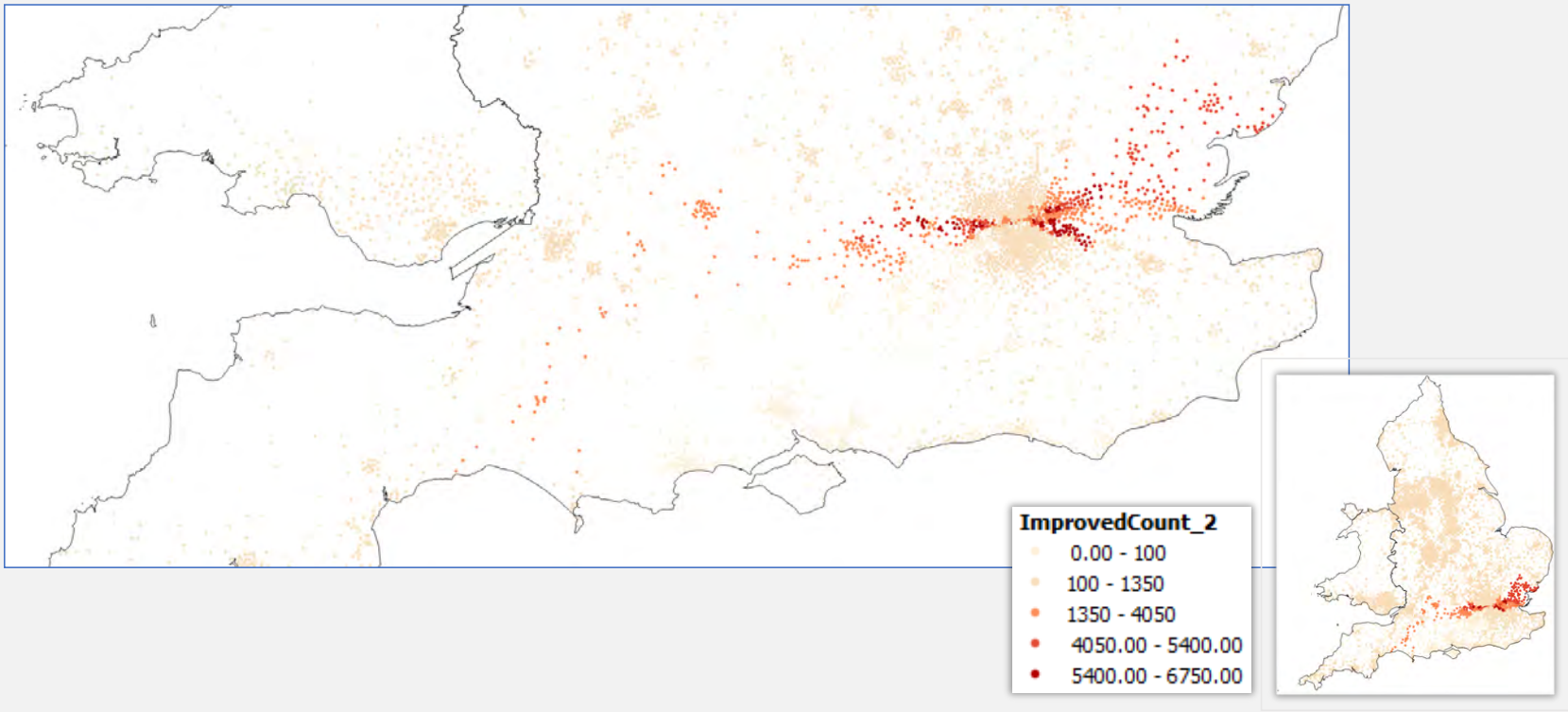






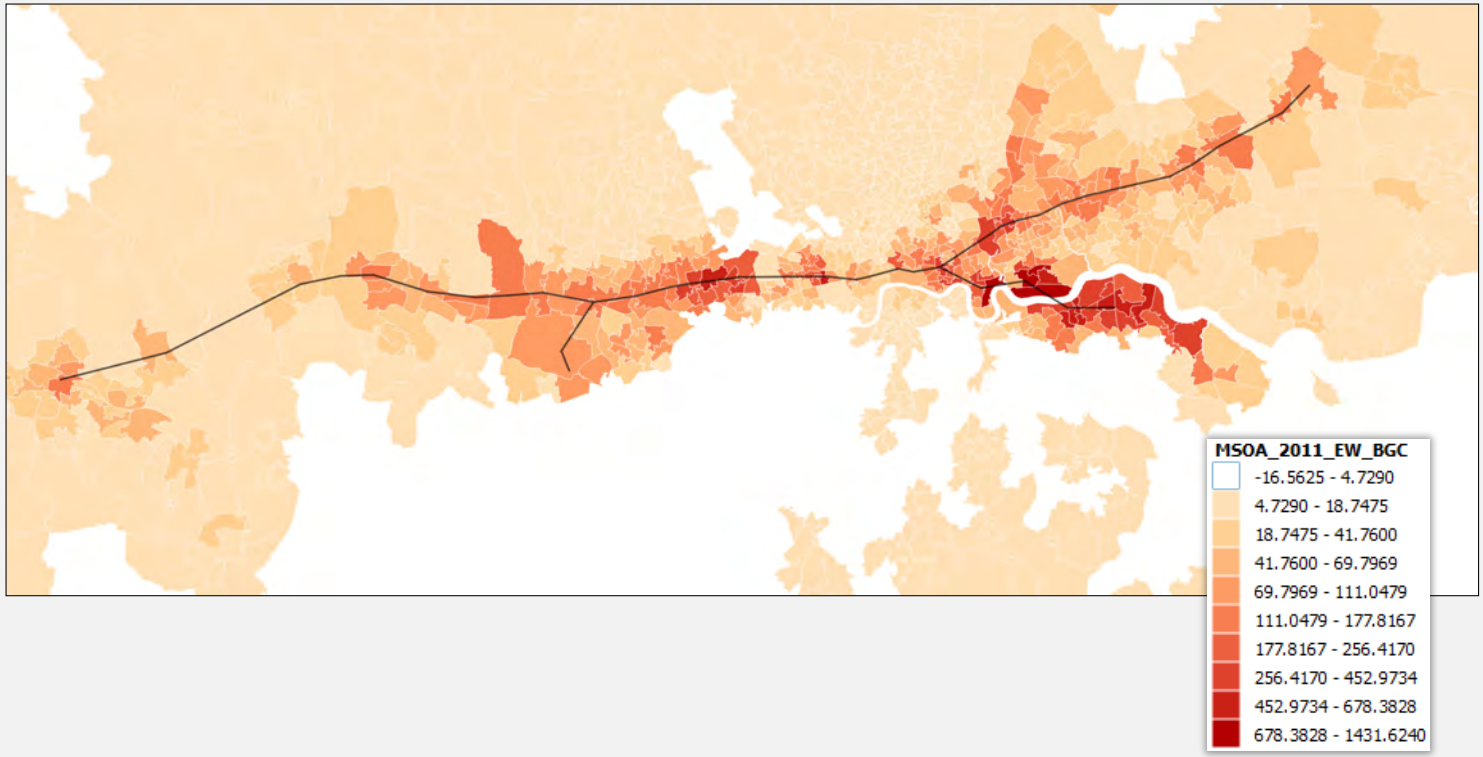
Crossrail

Number of Improved Journeys (n_i)



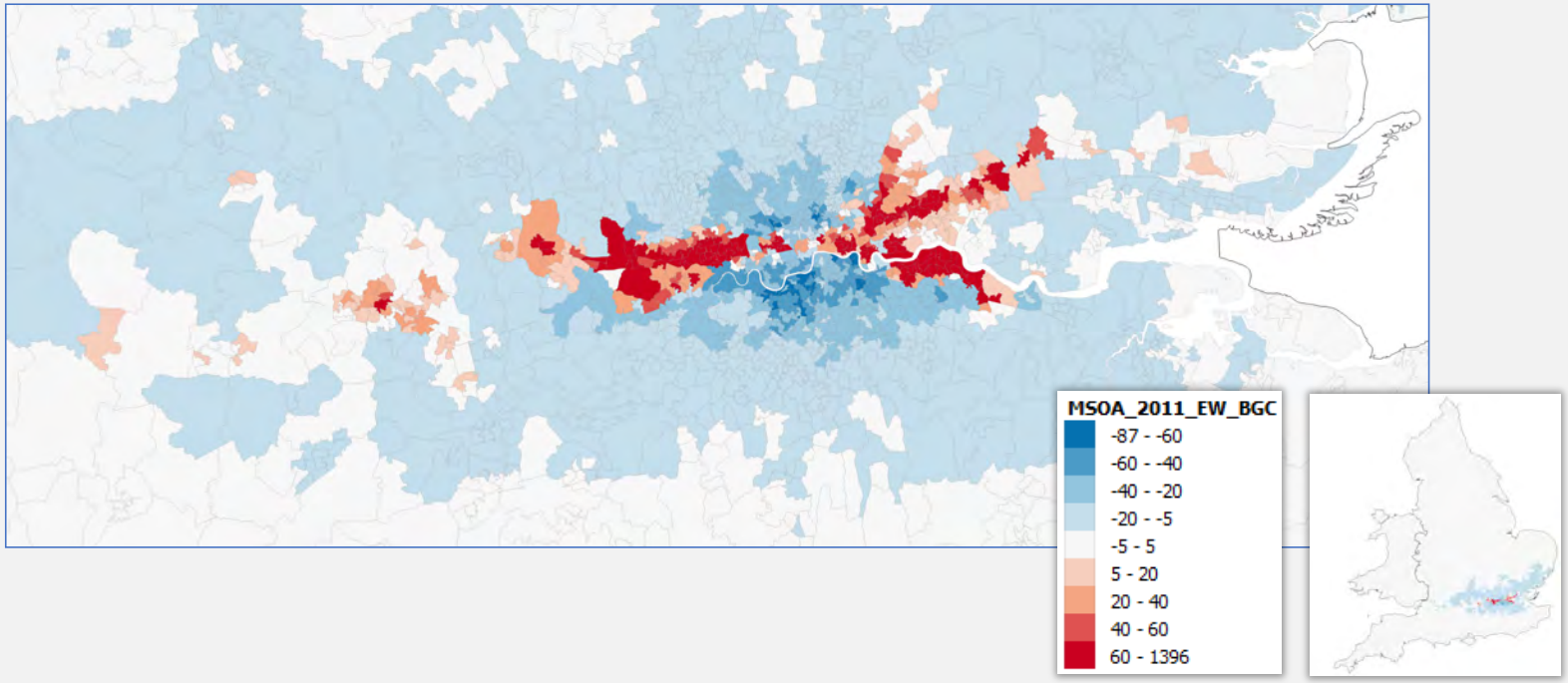
Crossrail

Population change (rail mode only)

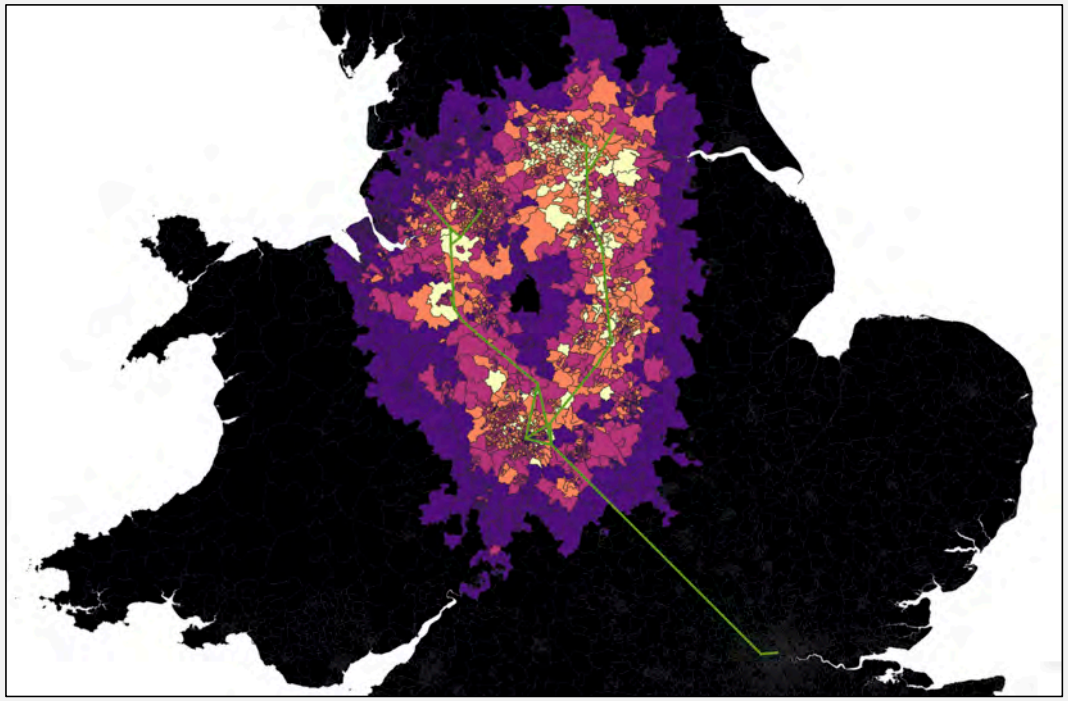


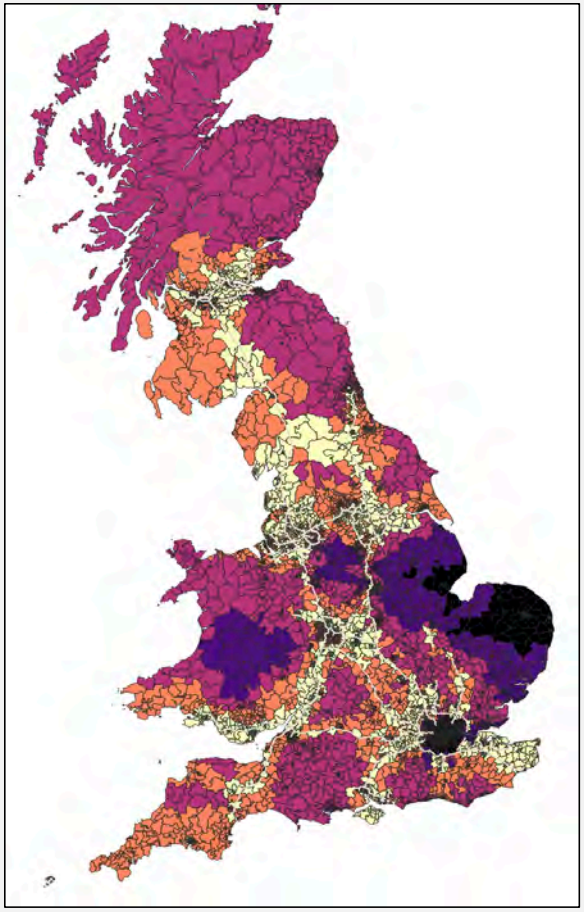
Crossrail

Population Change (all modes)



Impact of High Speed Rail and Reduction of Carbon Emissions





Keeping Rail to a Capacity of 15% for Social Distancing

$$T_{ij}^{k} = O_i \frac{D_j^{obs} \exp(-\beta^k d_{ij}^k)}{\sum_k \sum_j D_j^{obs} \exp(-\beta^k d_{ij}^k)}$$

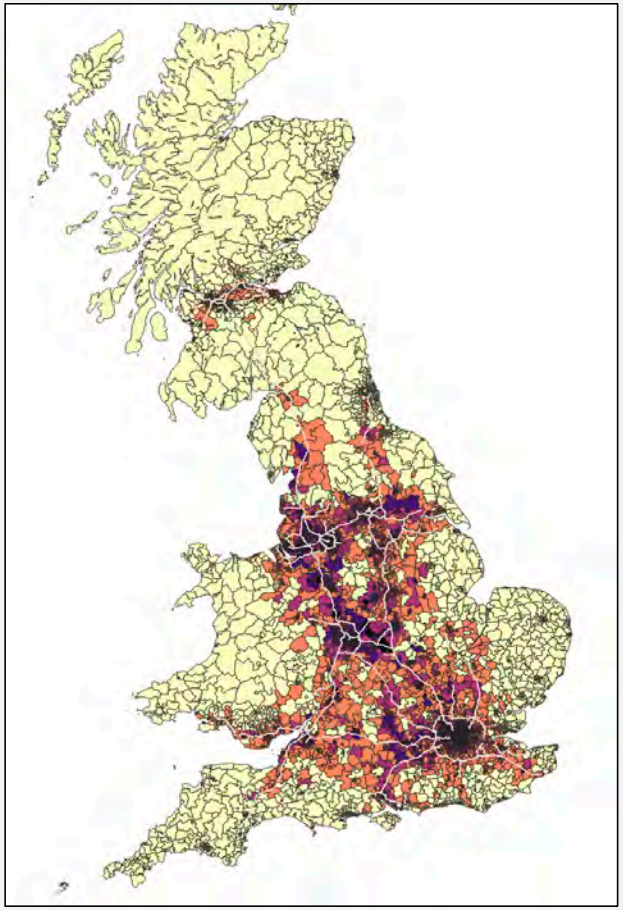
$k = 1,\ k = 2,\ k = 3$

$road, rail, bus$

Check

to see if total trips by rail are less than 15%
If not, we increase the travel cost on the rail
We essentially add a small value to d_{ij}^k and
Reiterate with new distance on rail

Ultimately we get the system balanced with massive gridlock on the highways and dramatic decreases in overall road accessibility across the urban areas of the country



Where Do We Go From Here?

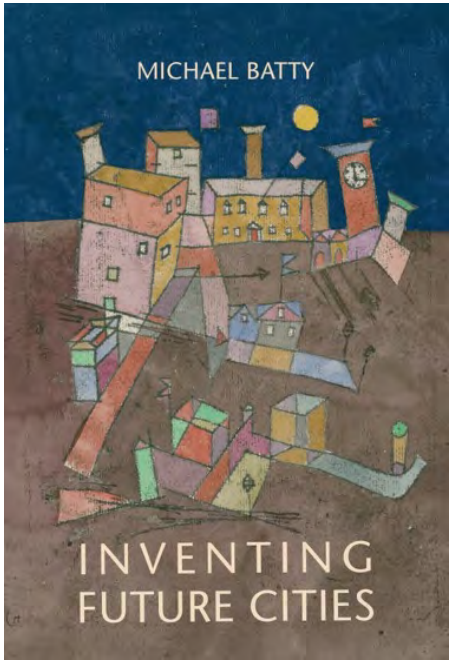
- We need to modify our models to do figure out how models embrace locational patterns at every scale – we cannot explain global without local because the whole pandemic is driven from the local scale.
- We need to add many new attributes to our model so we can extend the story to many things that we do not yet model
- We need to figure out how new kinds of electronic networks support physical networks and vice versa and how the diffusion of ideas and infections correlate with one another
- We need to modify the whole question of distance and geometry in models to take account of the new normal – new ways in which we may have to self distance for many years to come or for as long as it takes but this will change our view of space in cities anyway.

Thanks

Michael Batty
Centre for Advanced Spatial Analysis
CASA-UCL

www.complexcity.info
www.ucl.ac.uk/bartlett/casa/

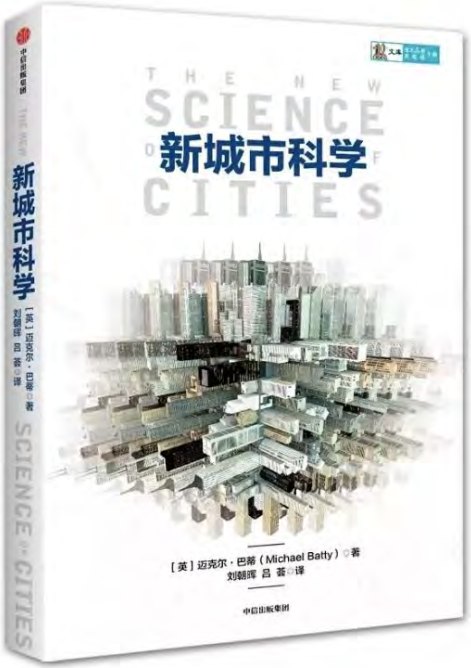
m.batty@ucl.ac.uk
@jmichaelbatty



MIT Press, 2018

Translated 2020

创造未来城市



Translated 2019

WeChat