KING'S College LONDON

CUSP Centre for Urban Science & Progress
Series Seminar (10)

casa UCL University College London

The New Normal

Embedding Social Distancing into Urban Models

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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/CUSP-Batty.pdf

Or from the CLC Webinar Site

An Outline of the Talk

- Disruptive Events: Post Pandemic Cities
- Tobler's Law: How Near Can We Get To One Another: The Inverse Distance Hypothesis: Newton's Law, A Little Bit of Theory
- 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?

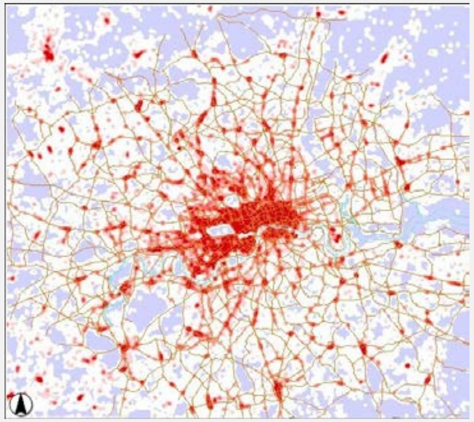
Disruptive Events: Post Pandemic Cities

- Many urban models developed during the last 30-40 years have tried to incorporate rapid and unanticipated change in our models. The paradigm of what cities are has changed from cities-in-equilibrium to those that are far-from-equilibrium. Discontinuity has become key
- 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.
- 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.

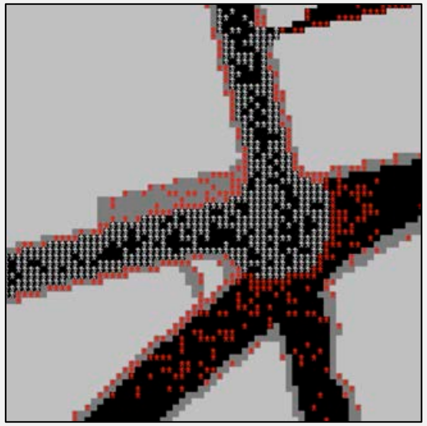
- How can we embed these massive changes into our models? And what kinds of things in cities. Distance and where and how we move are critical to this whole question and lie at the basis of all our models
- Most of our models are based on ***key questions of distance*** – how far can we travel for what 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, and ***how many people can we pack into small spaces***, this will have enormous implications for how far we travel and at what capacity. We will not be able to travel the same distances.

- In terms of the form and function of cities, we need to grapple again with the whole question of centralization and decentralization
- ***Sprawl*** versus ***the compact city***. The last 250 years: migrating to cities, out of cities and then back to cities – walking, trains, then cars, then more walking
- The Pandemic makes us walk more but also makes us take to our cars and avoid mass transit – this is a new paradox
- These are big questions and we could speculate on these for ever without coming to any conclusions about what is best or what is possible
- We cannot predict the future – that is impossible – only reflect on the pandemic – no one was able to predict where and when and how
- ***But what we can do is see how our models might be adapted …?????***

- 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.

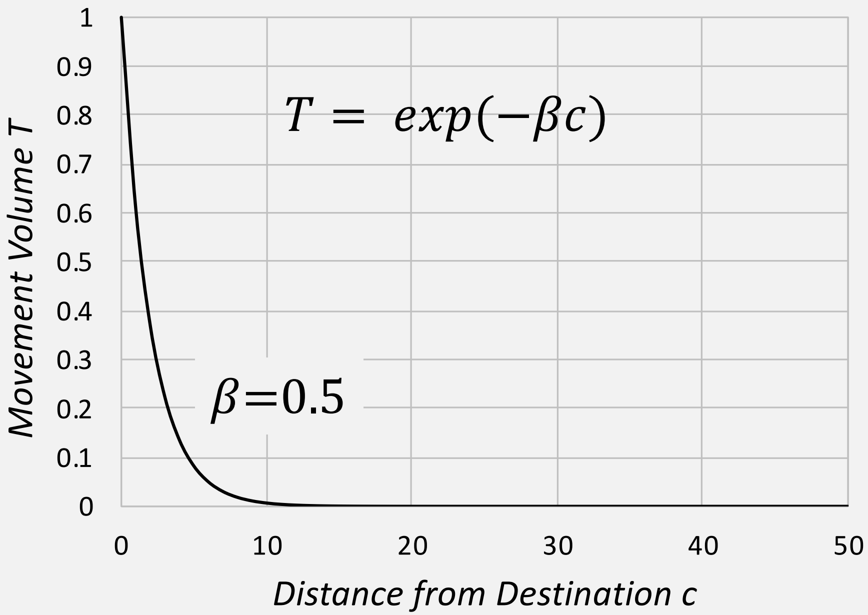
Tobler's Law: How Near Can We Get To One Another

- 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



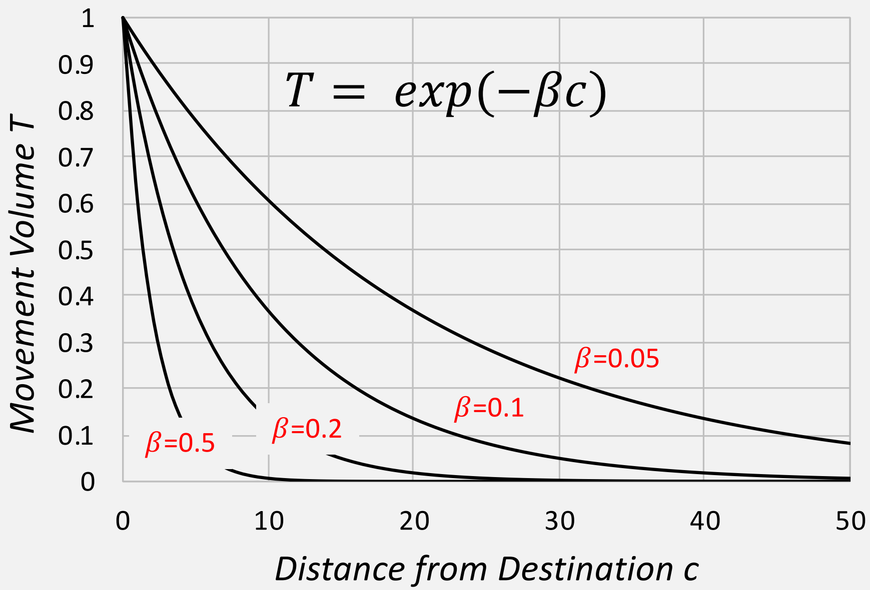
To get this, we add up all the flows under the curve as

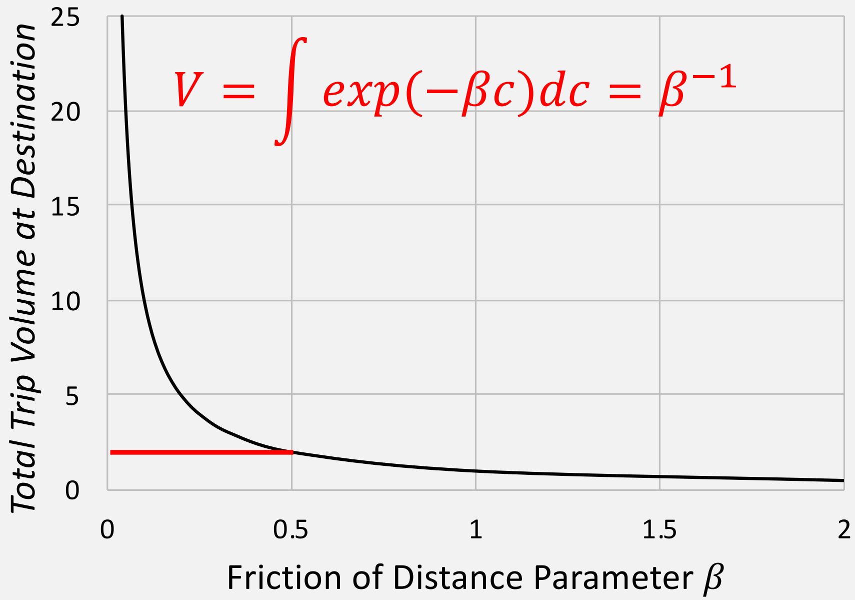
$$V = \int exp(-\beta c)dc = \beta^{-1} = 2$$

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

- If we decrease the friction of distance – lower the parameter 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 these 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

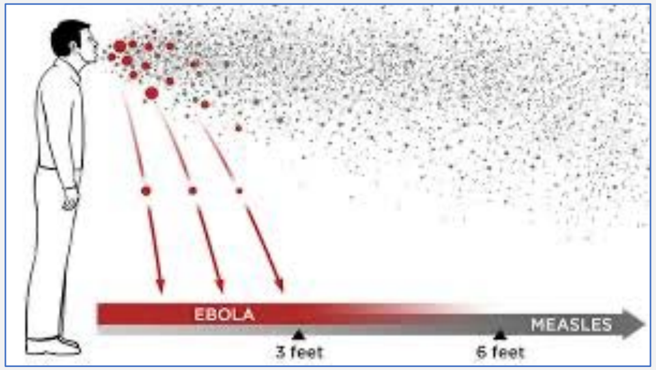
$$Interactions = V^2 \sim (\beta^{-1})^2 = \beta^{-2}$$

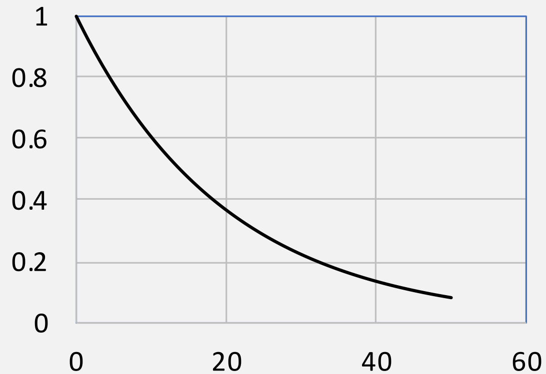
- And for $\beta=0.05$, we have 625 interactions and a proportion, say ρ of these would lead to infections.

- 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.

- Then we need to figure out how this is affected by the virus transmission and much of this depends on the load and the speed of transmission which essentially is simulated again using Newton's law. If infected when we cough, the virus spreads as





$$V \sim exp(-\lambda d)$$

& then

Dispersion

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

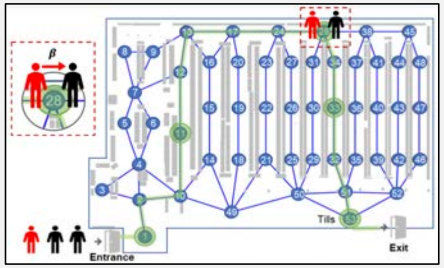
- How we put all these flow systems together to get a good estimate of infection is tricky and we need still to add capacity constraints but we also need to integrate between scales. If we model people moving to in a metropolitan area, when they get to a place we need to then model how they move locally
- 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

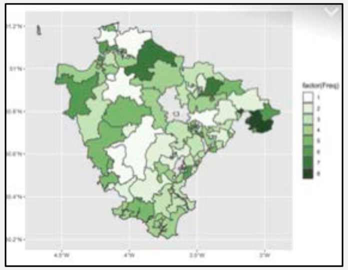
Different Varieties of Urban Model

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

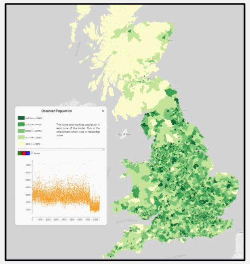
- *Very Fine Scale: Contact at the Urban Design Scale*
- *Building Very Large Scale Models of National Systems*
- *Long Term Urban Change The QUANT Model*



Figuring out social distancing in supermarkets



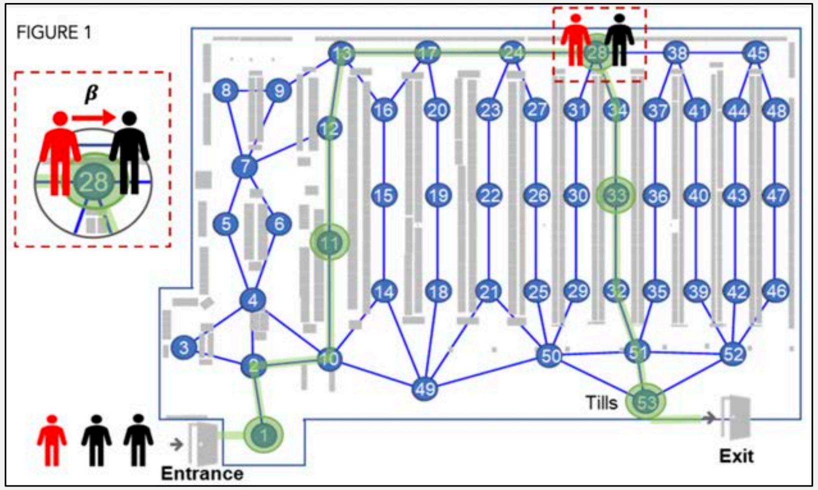
Spatial epidemic modelling in Devon using spatial interactions



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



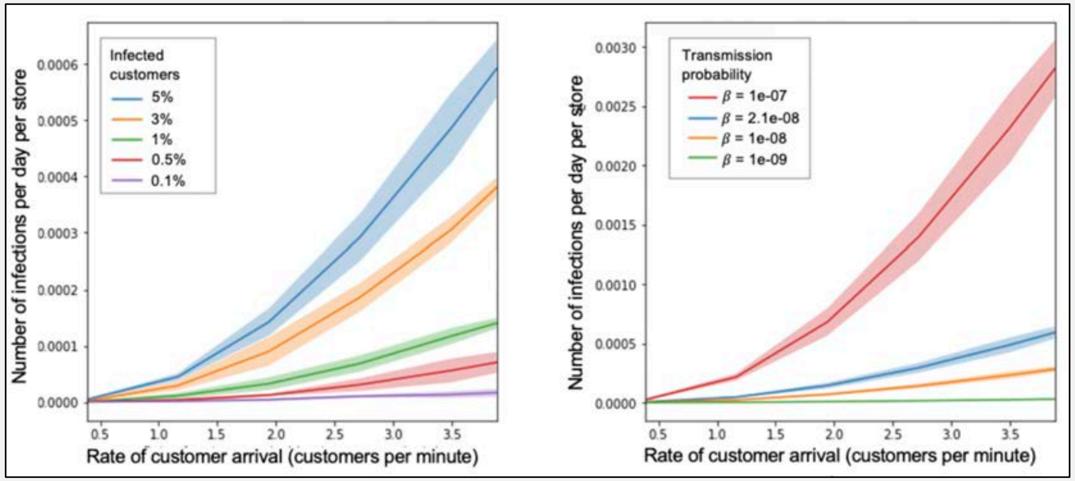


FIGURE 3

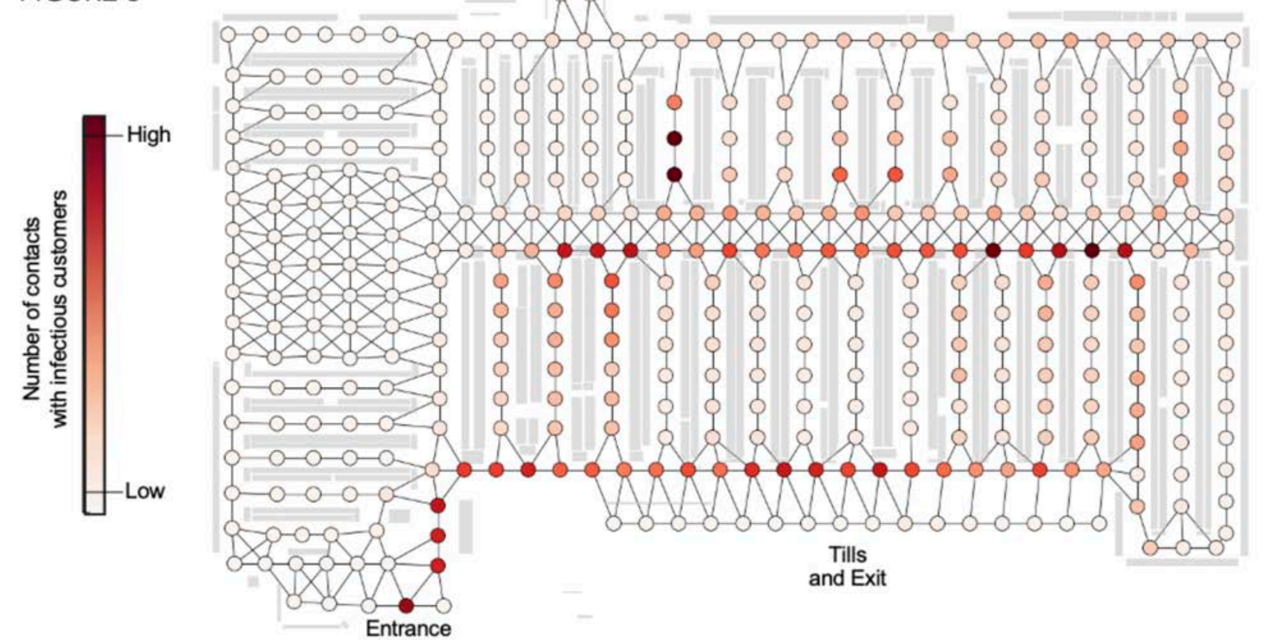
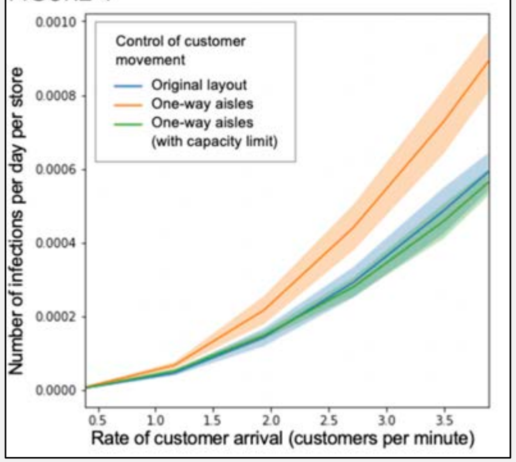


FIGURE 4

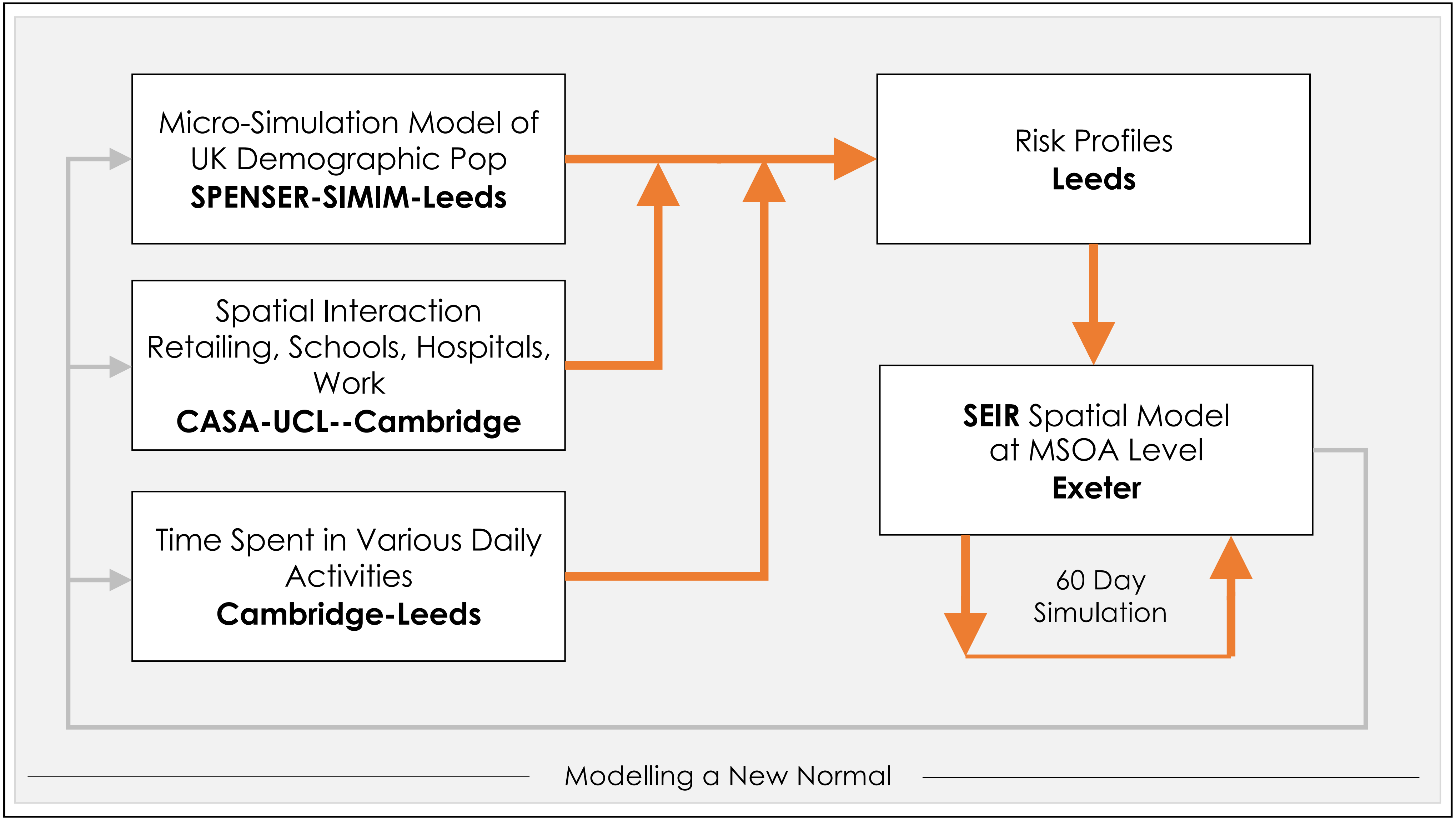


Essentially queuing and rates of arrival as well as volumes of customers increase super-linearly infection rates while transmission rates are linear in effect. We need to figure out how all this local geometry affects infection

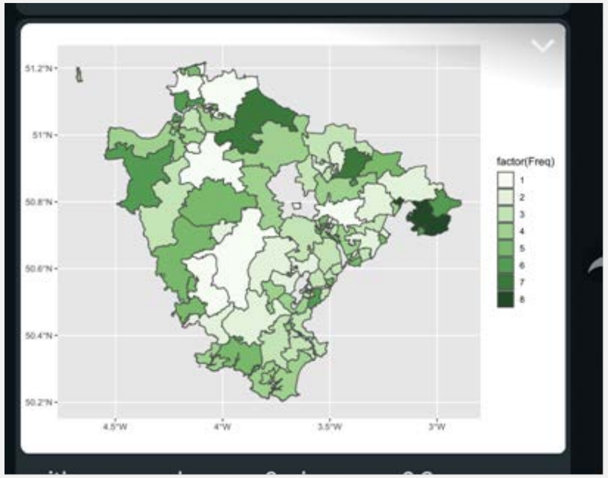
Building Very Large Scale Models of National Systems

- 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. What SEIR models are.

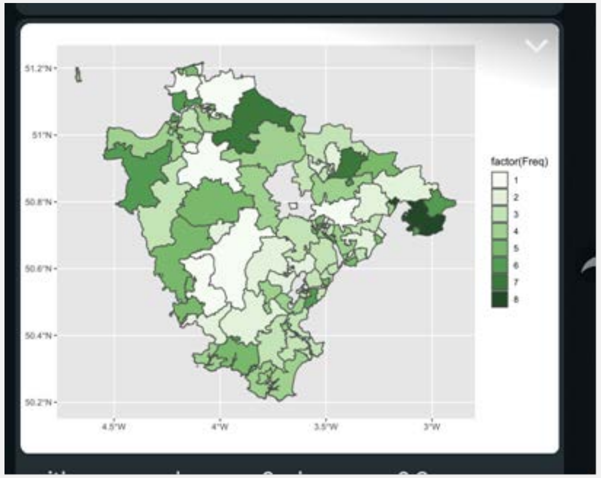
- This model essentially feeds the epidemiological model with demography and spatial interactions and generates risk profiles which determine infections amongst the wider susceptible population, These risk factors are spatial at the usual scale we use in the UK which is the MSOA which has an average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


Micro-Simulation Model of UK Demographic Pop
SPENSER-SIMIM-Leeds
Spatial Interaction Retailing, Schools, Hospitals, Work
CASA-UCL--Cambridge
Time Spent in Various Daily Activities
Cambridge-Leeds
Risk Profiles
Leeds
SEIR Spatial Model at MSOA Level
Exeter
60 Day Simulation
Modelling a New Normal

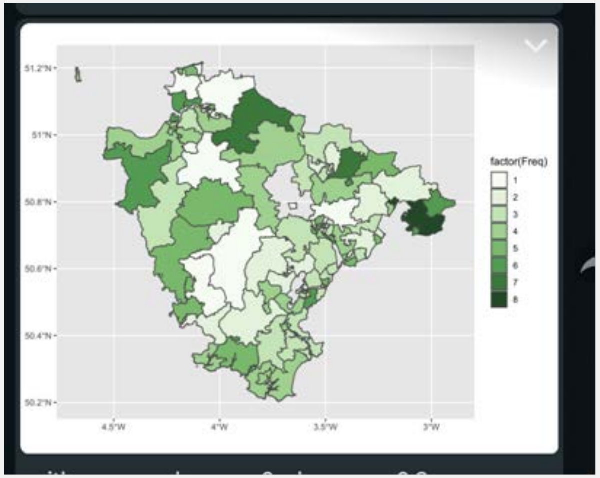
Infections

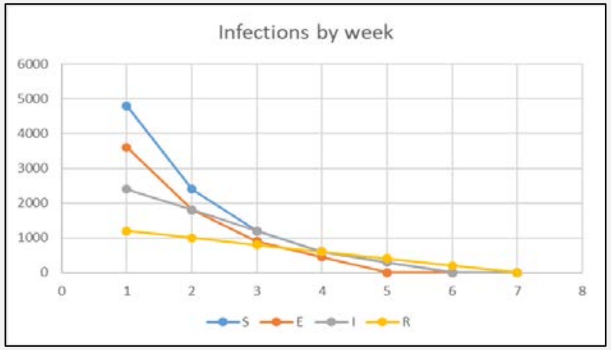


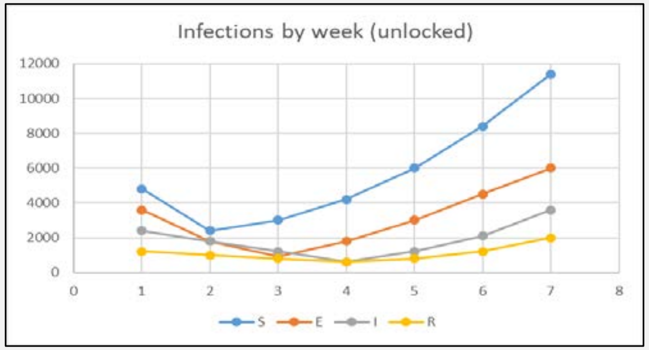
Observed Mortalities



Predicted Mortalities

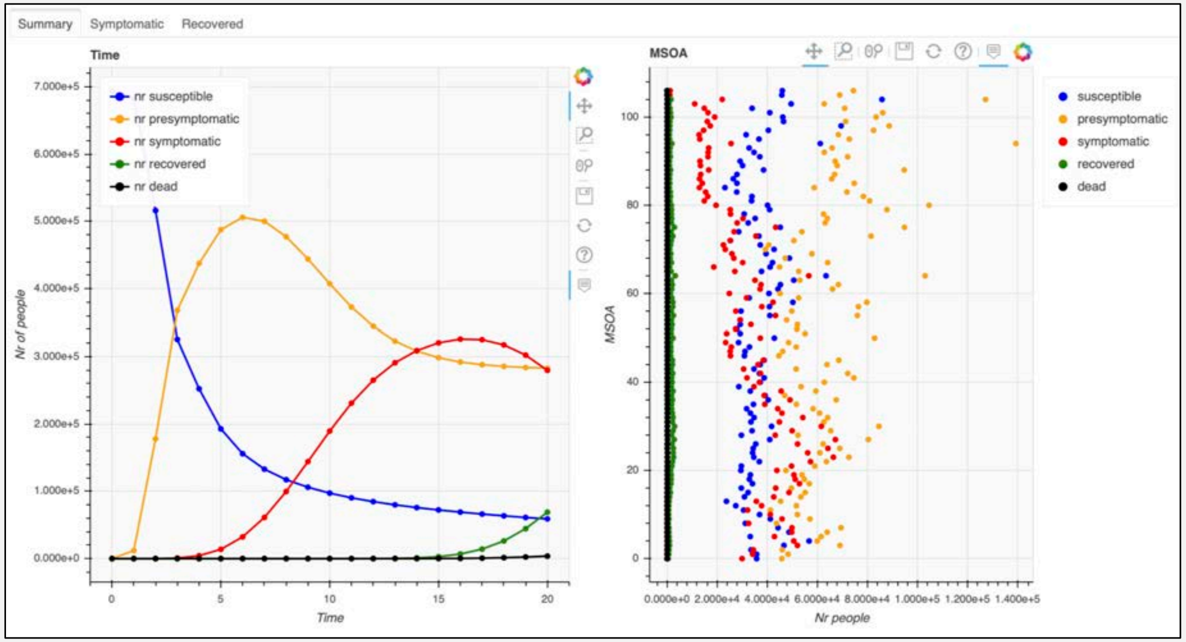


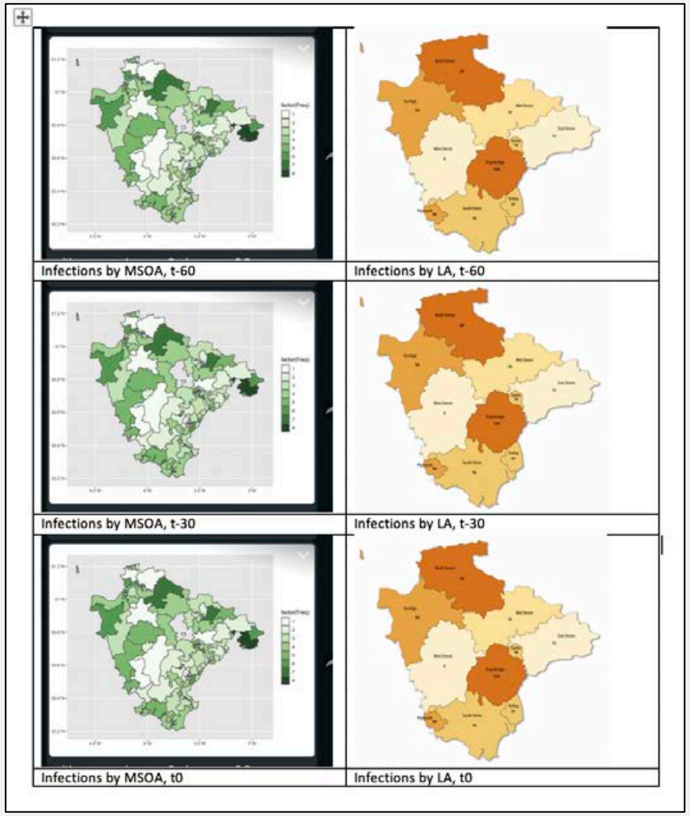




Modelling a New Normal

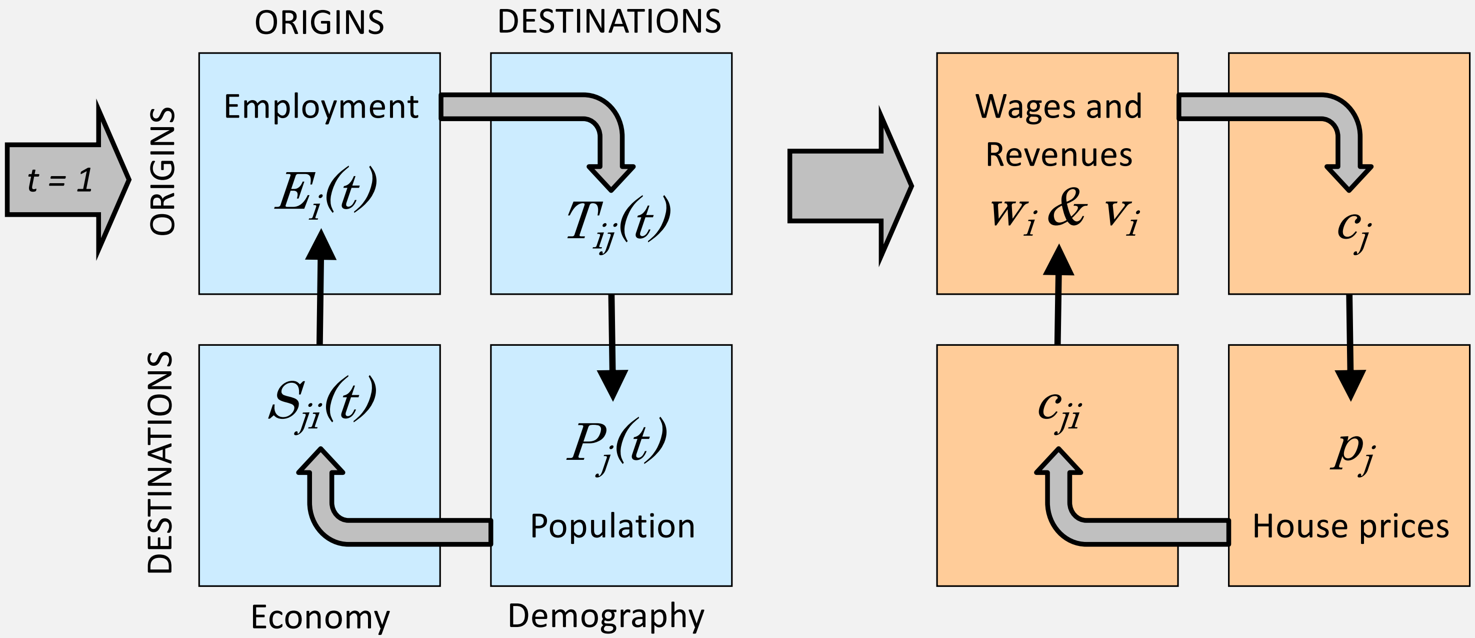
The 60 Day Simulation



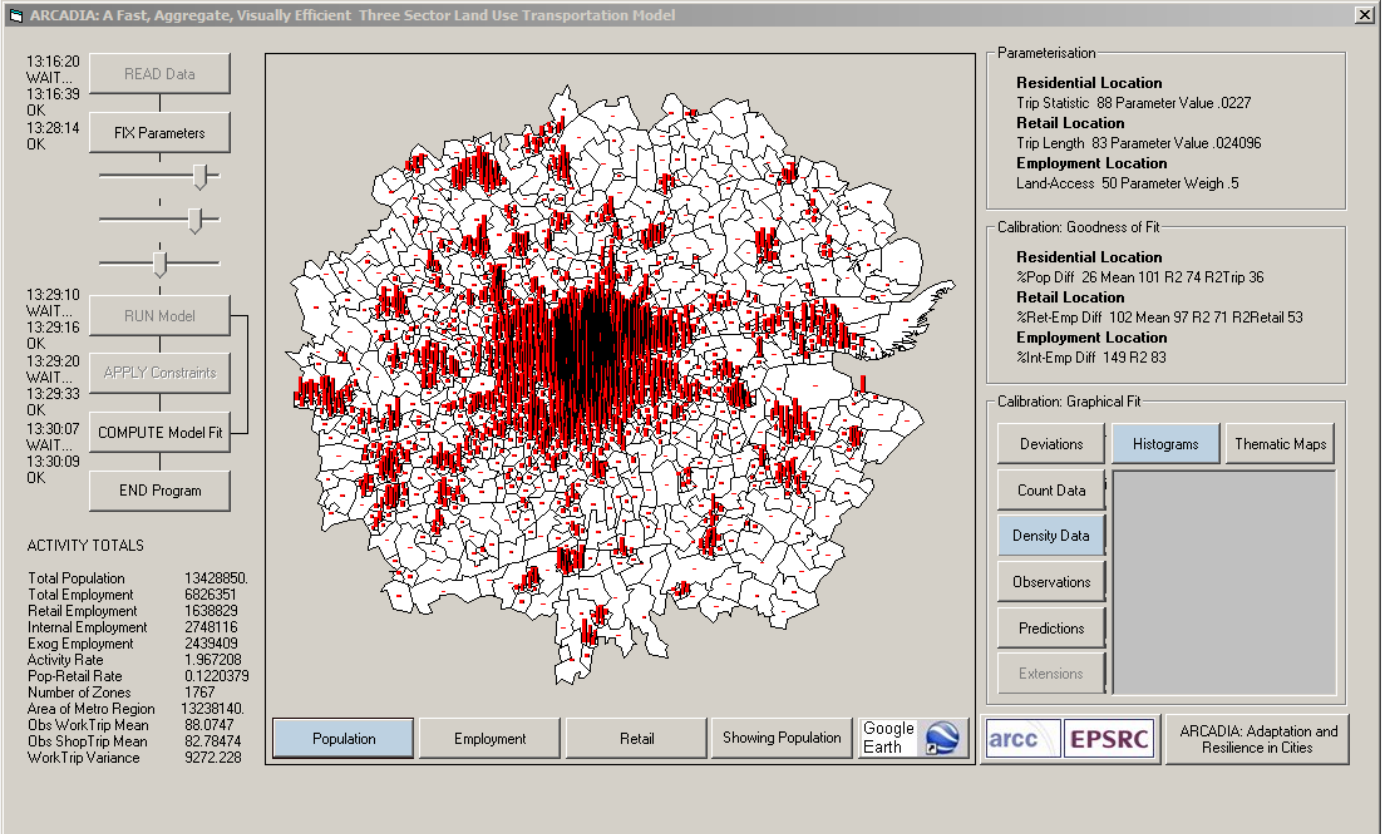


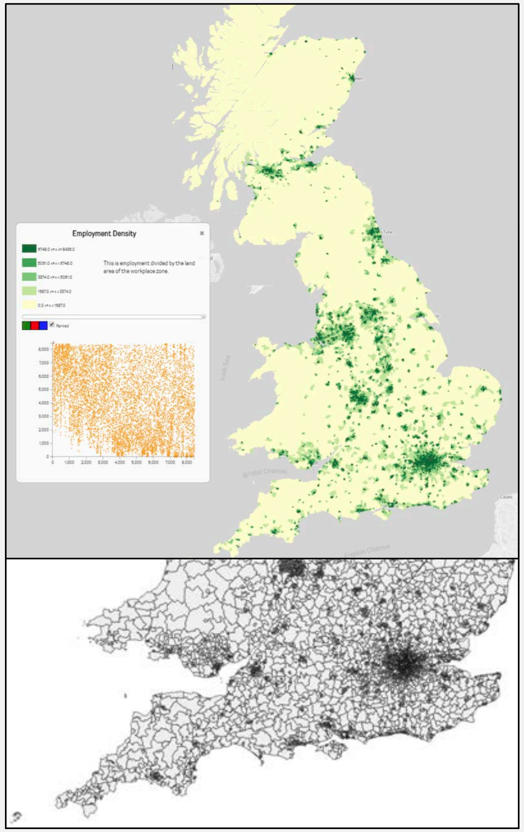
Long Term Urban Change: The QUANT Model

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.

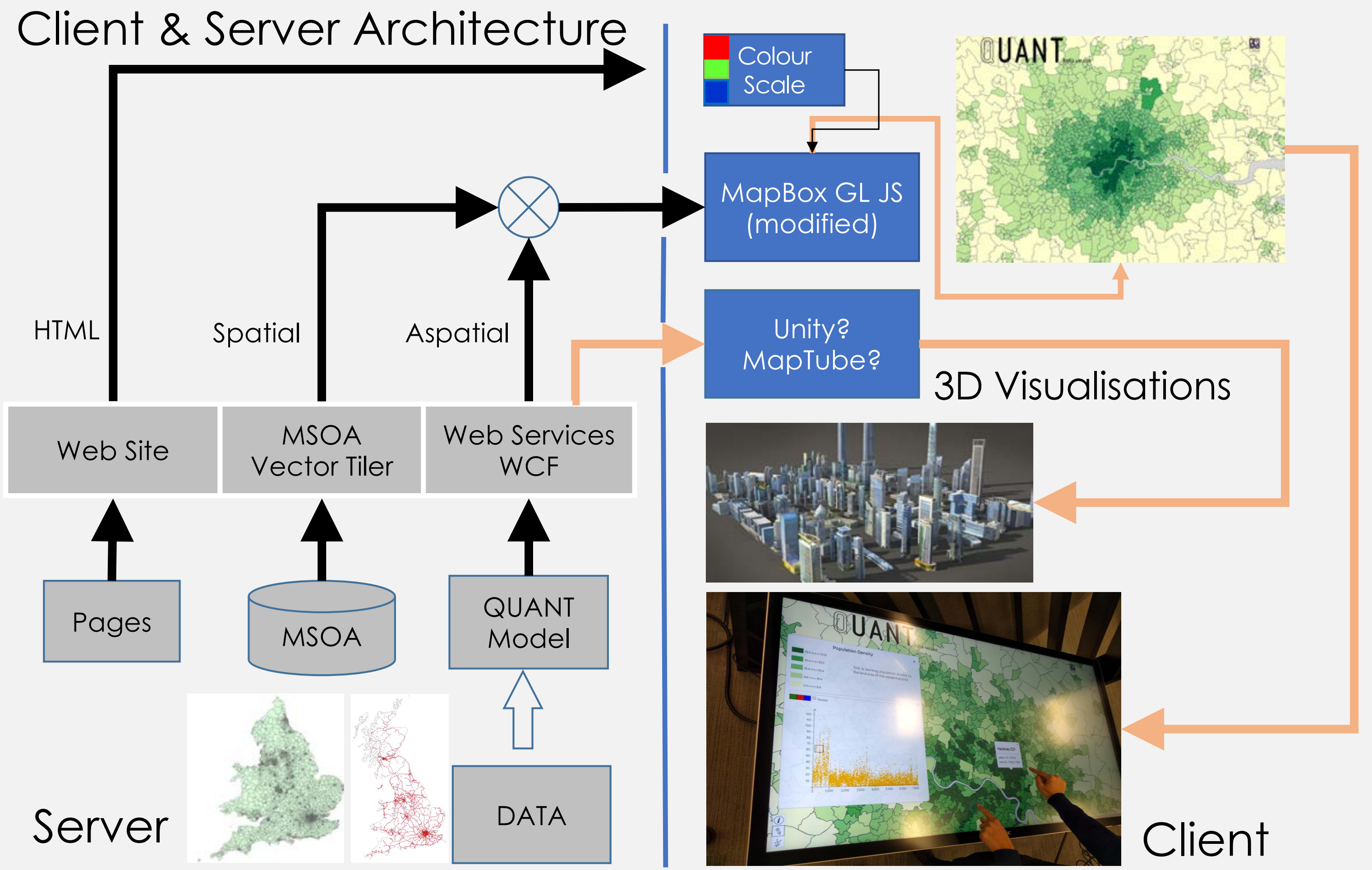


Modelling a New Normal

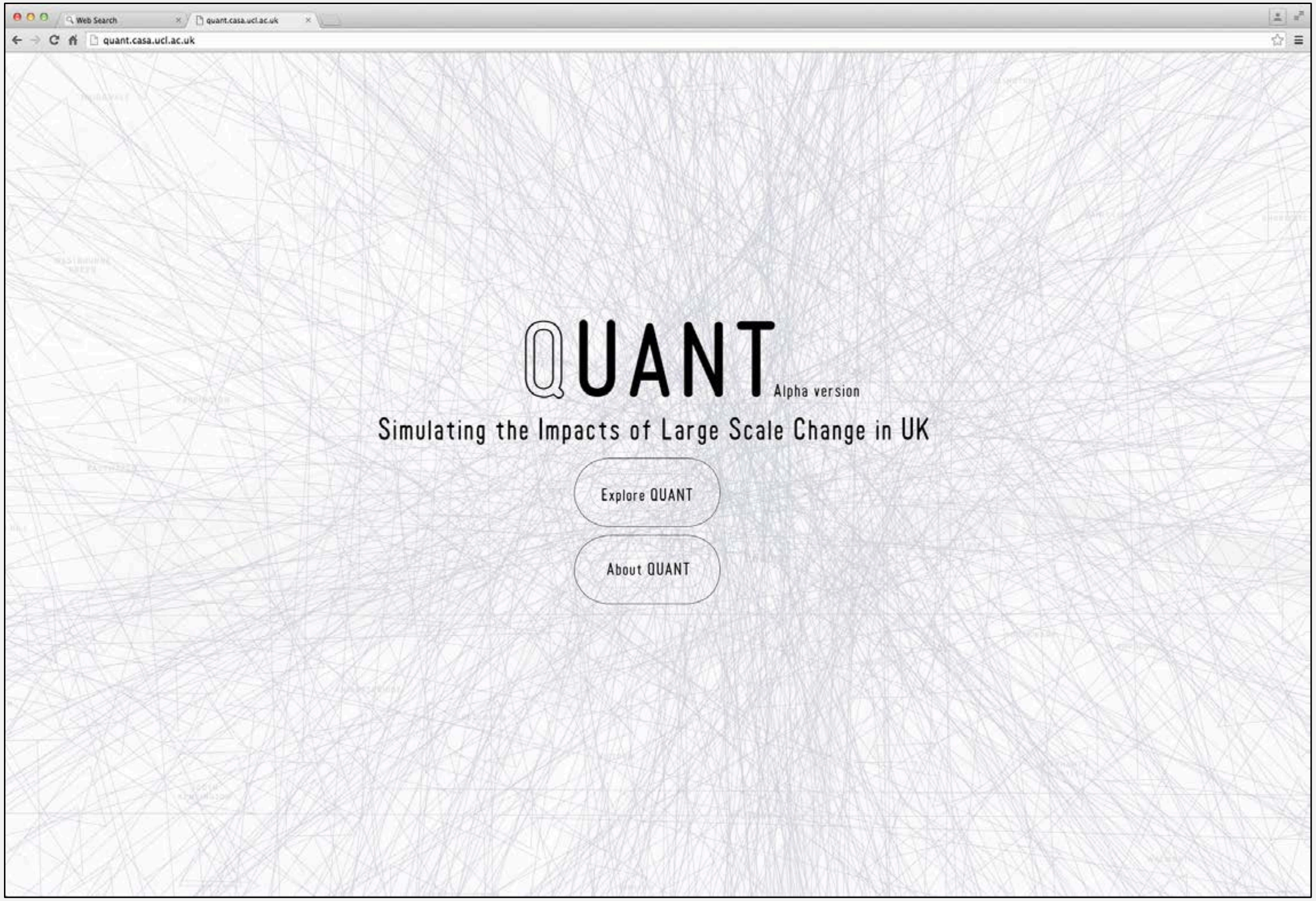




Modelling a New Normal



Modelling a New Normal



Modelling a New Normal

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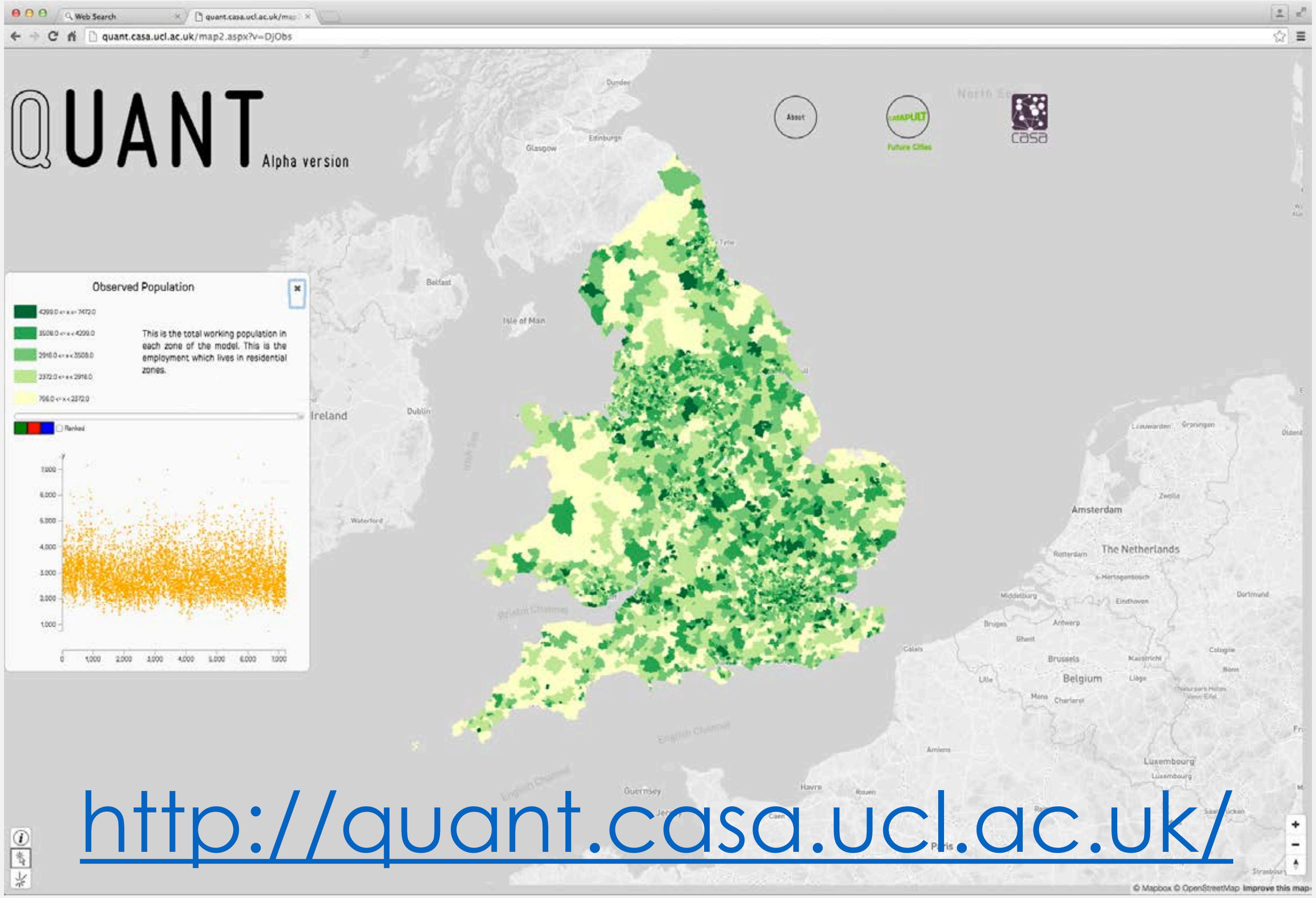
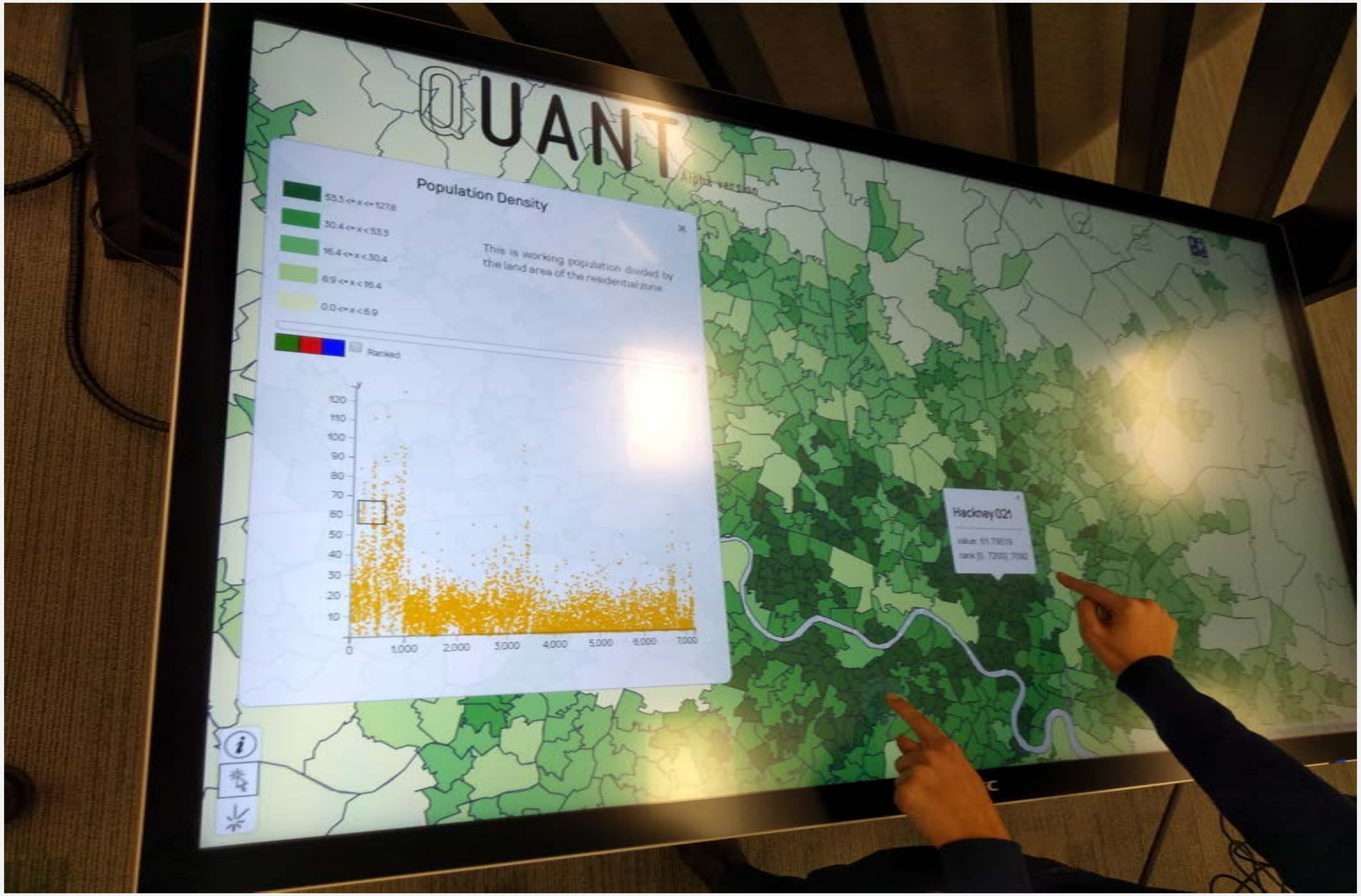
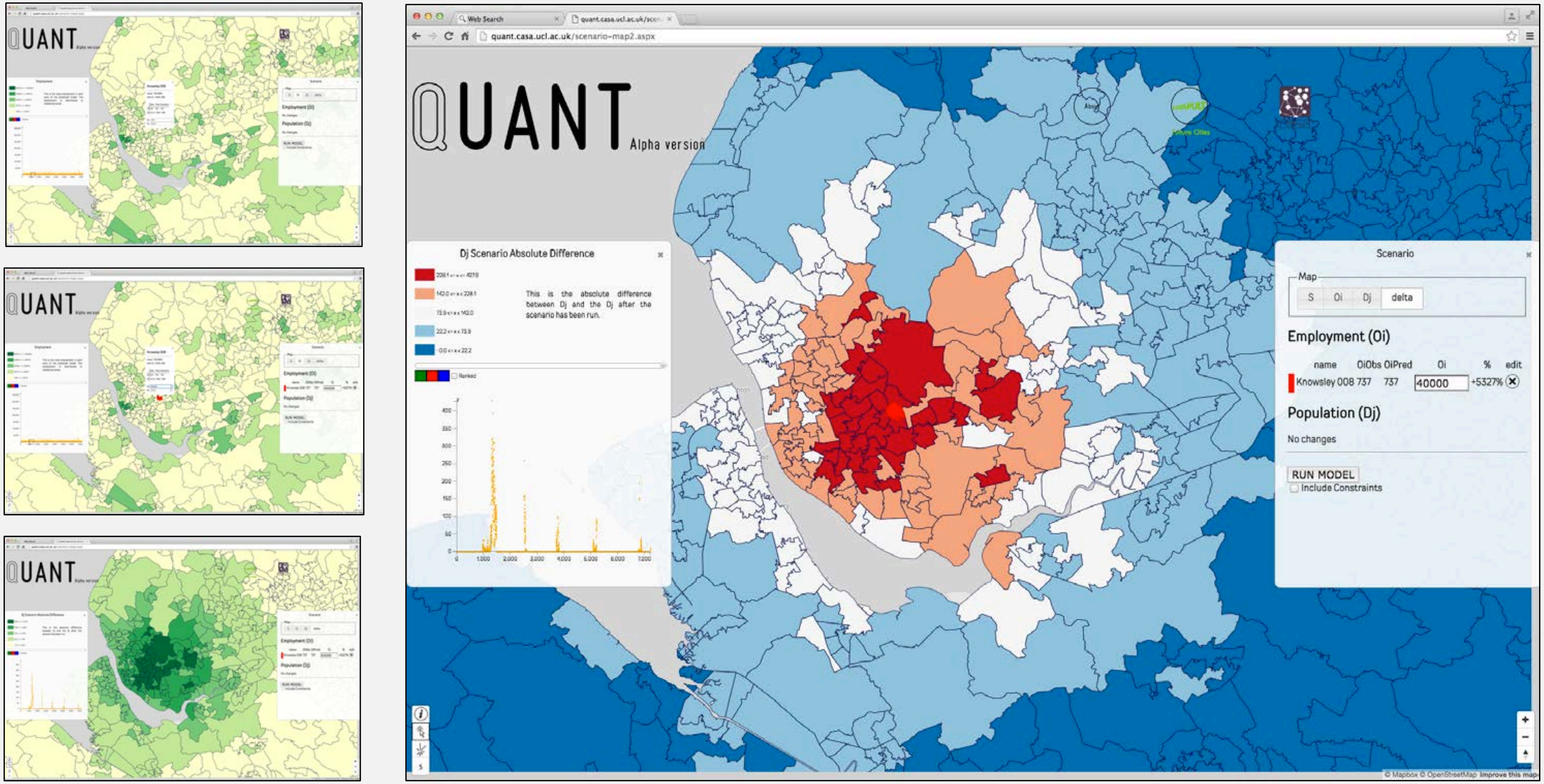


http://quant.casa.ucl.ac.uk/

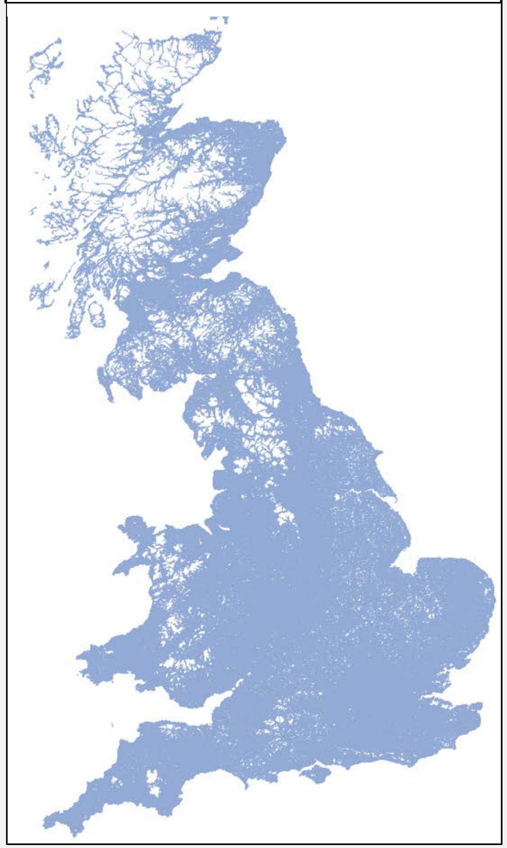


Modelling a New Normal

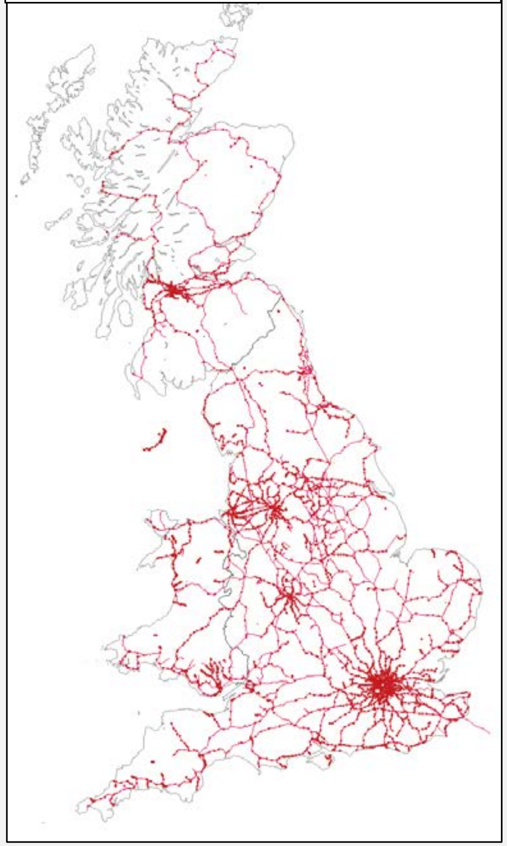


Modelling a New Normal

Road, v=3.5M, e=8.4M

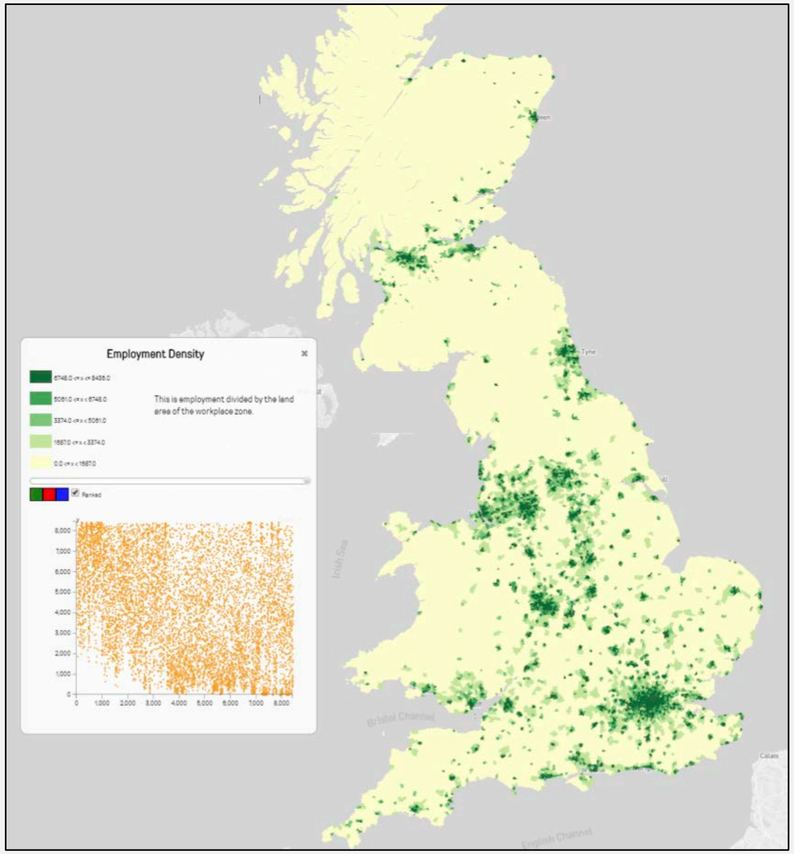


Rail, v=3165, e=10,269

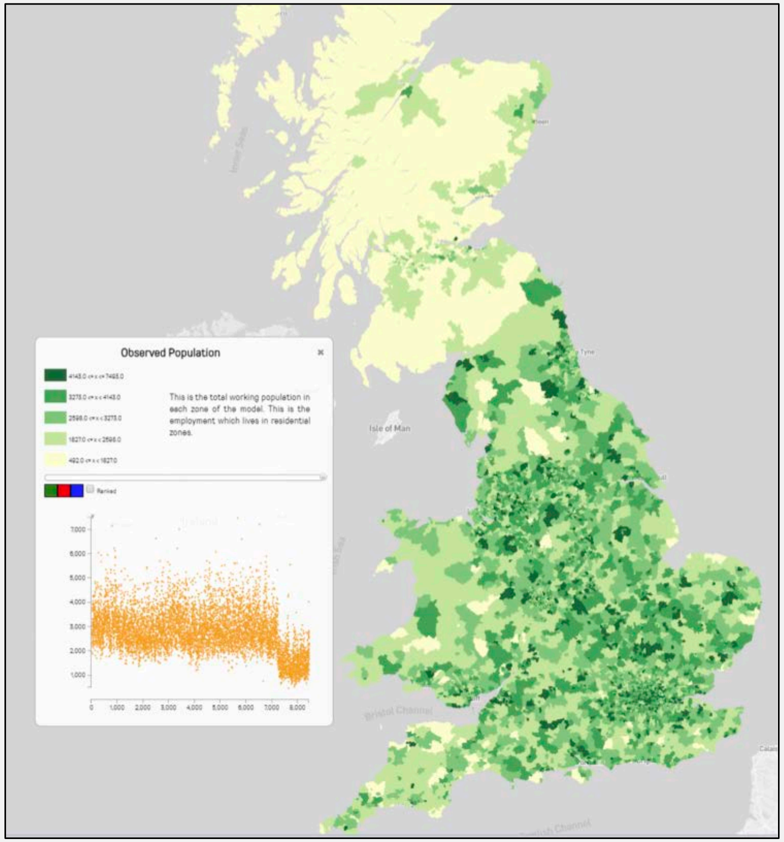


Modelling a New Normal

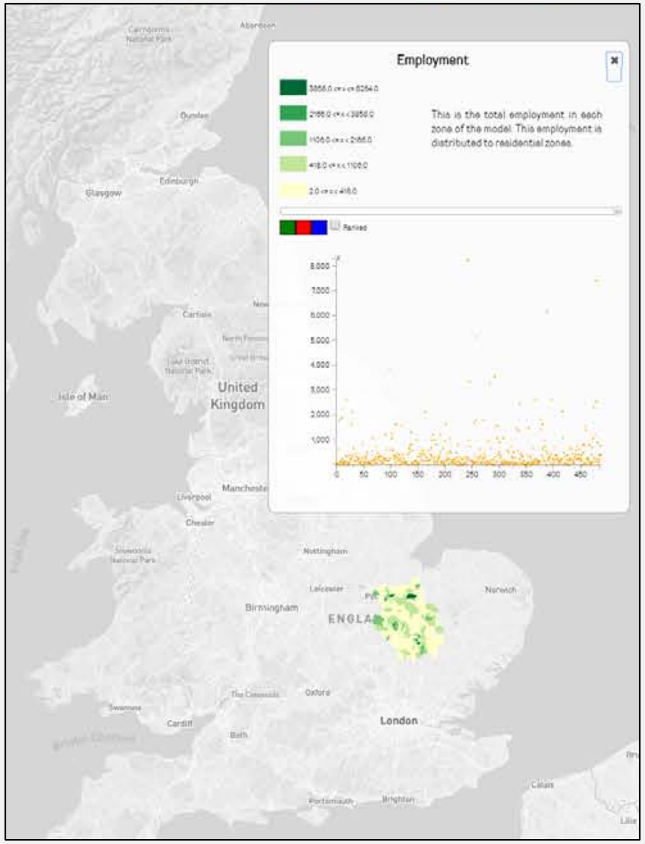
Employment Density

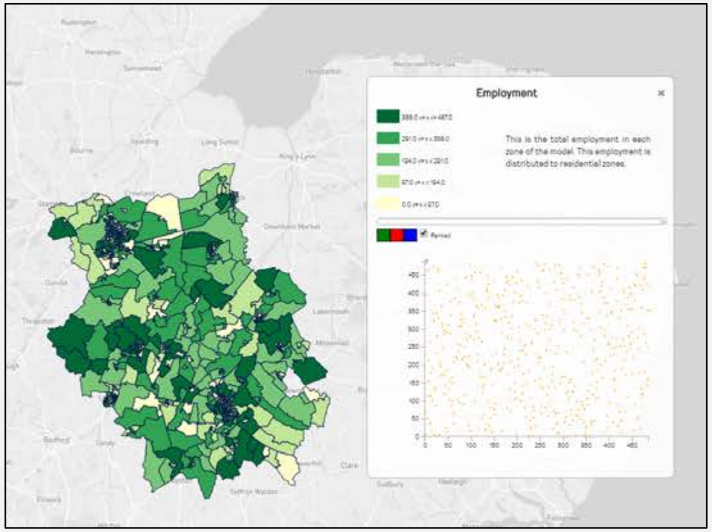


Population Counts



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 –

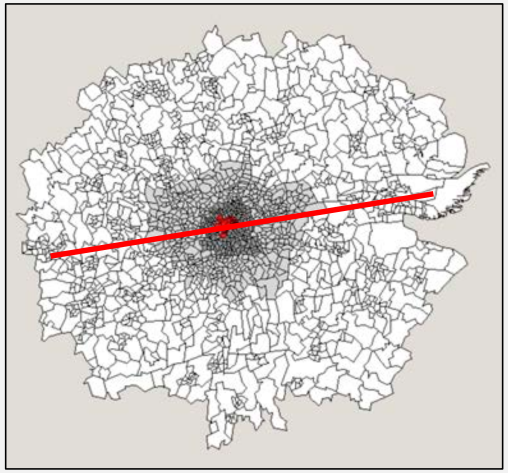
- one that is almost complete is ***Crossrail*** – the high speed tube line under London linking east and west. We will look at this.

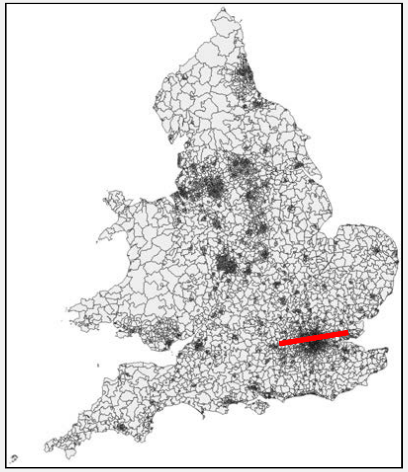
- Then we will briefly look at how high speed rail takes passengers from the road network and how this leads to ***reduction in carbon emissions***

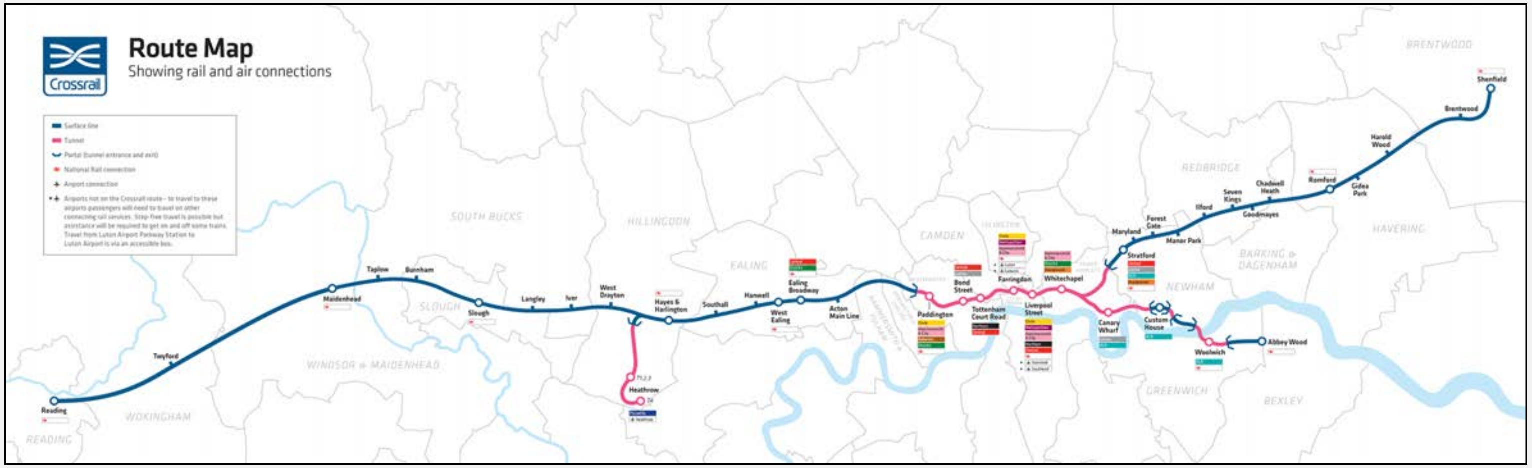
- But also we will look at the ***Impact of social distancing on Network Rail*** – which leads to the suppression of accessibility and volume on national and suburban rail

Crossrail

Reading, Heathrow, Shenfield, Abbey Wood

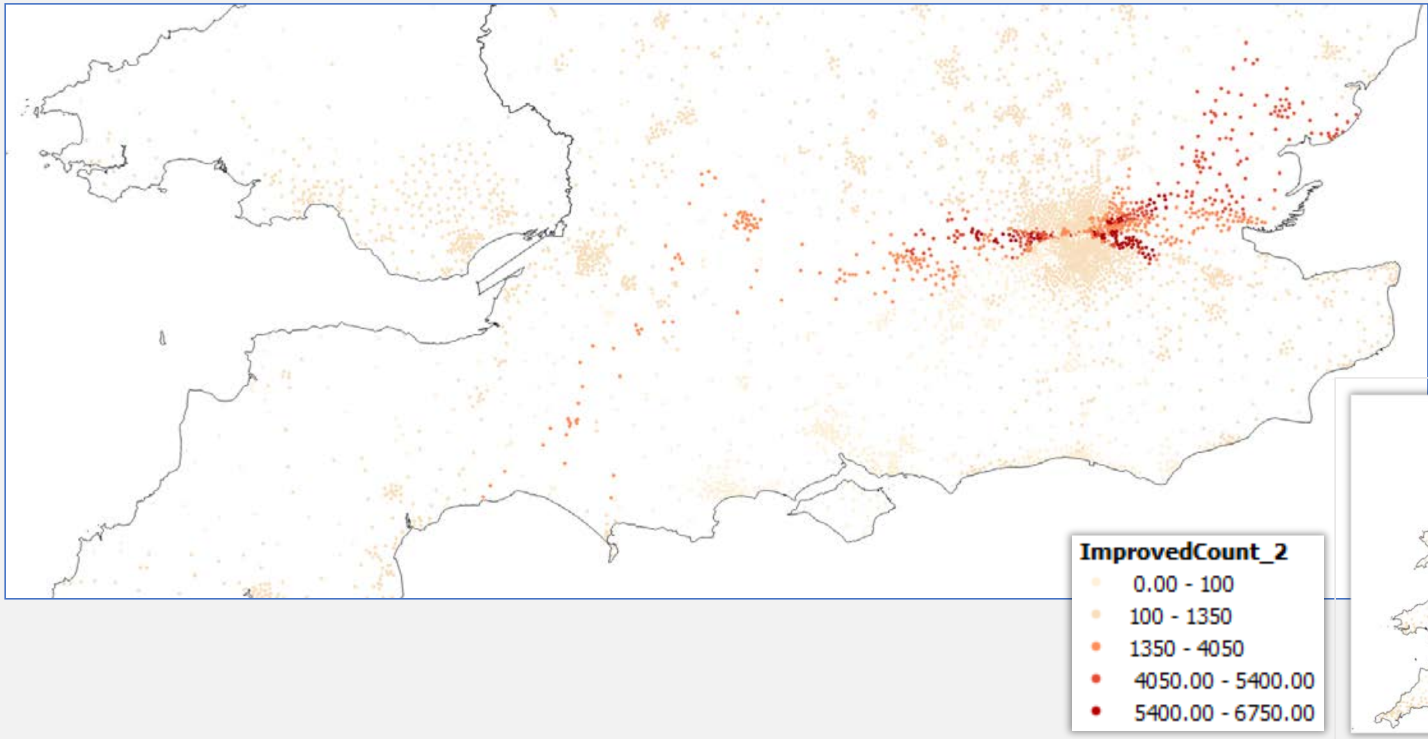


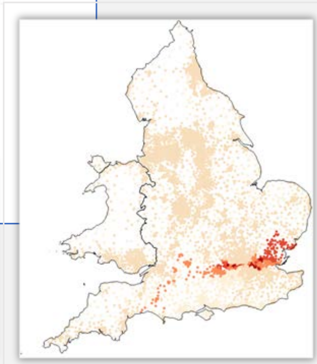




Crossrail

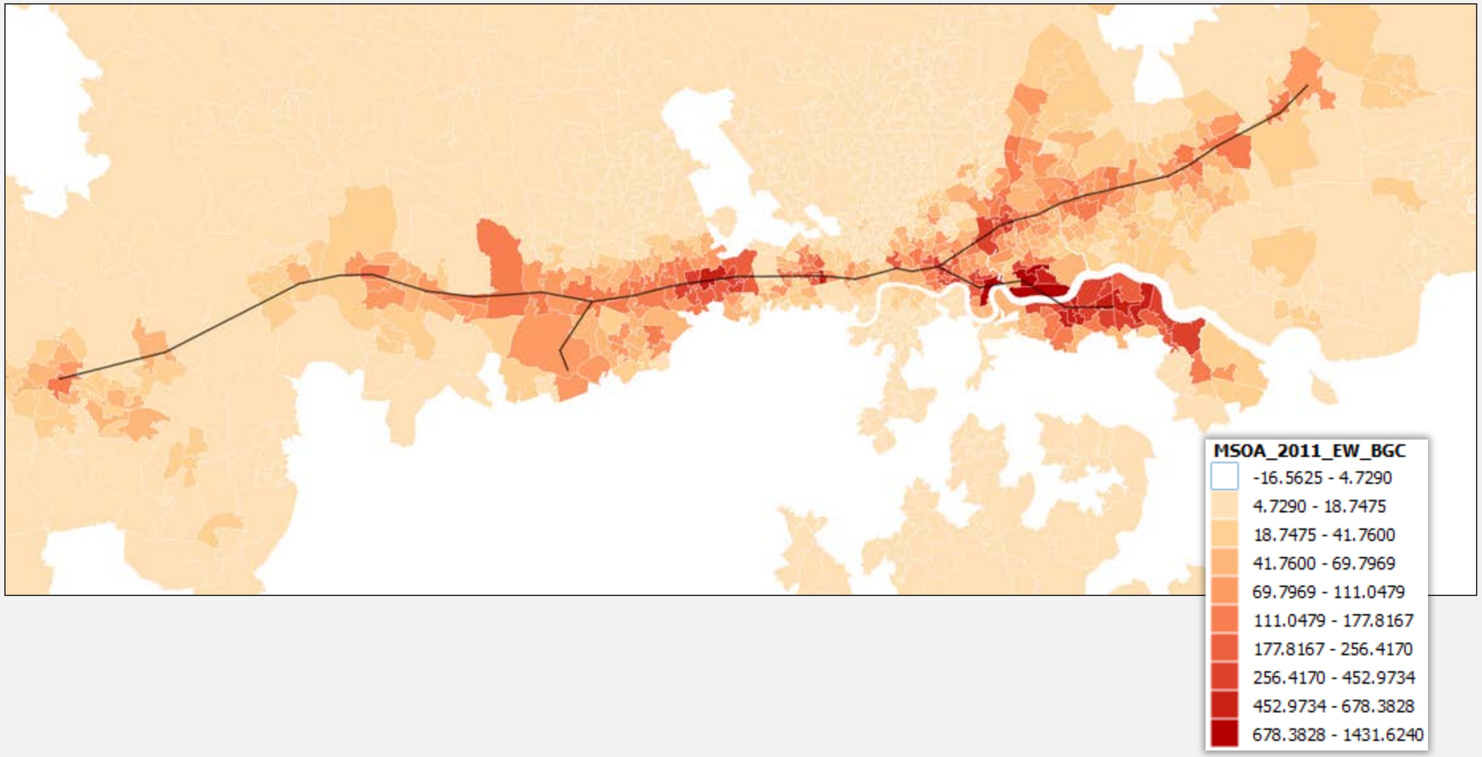
Number of Improved Journeys (n_i)





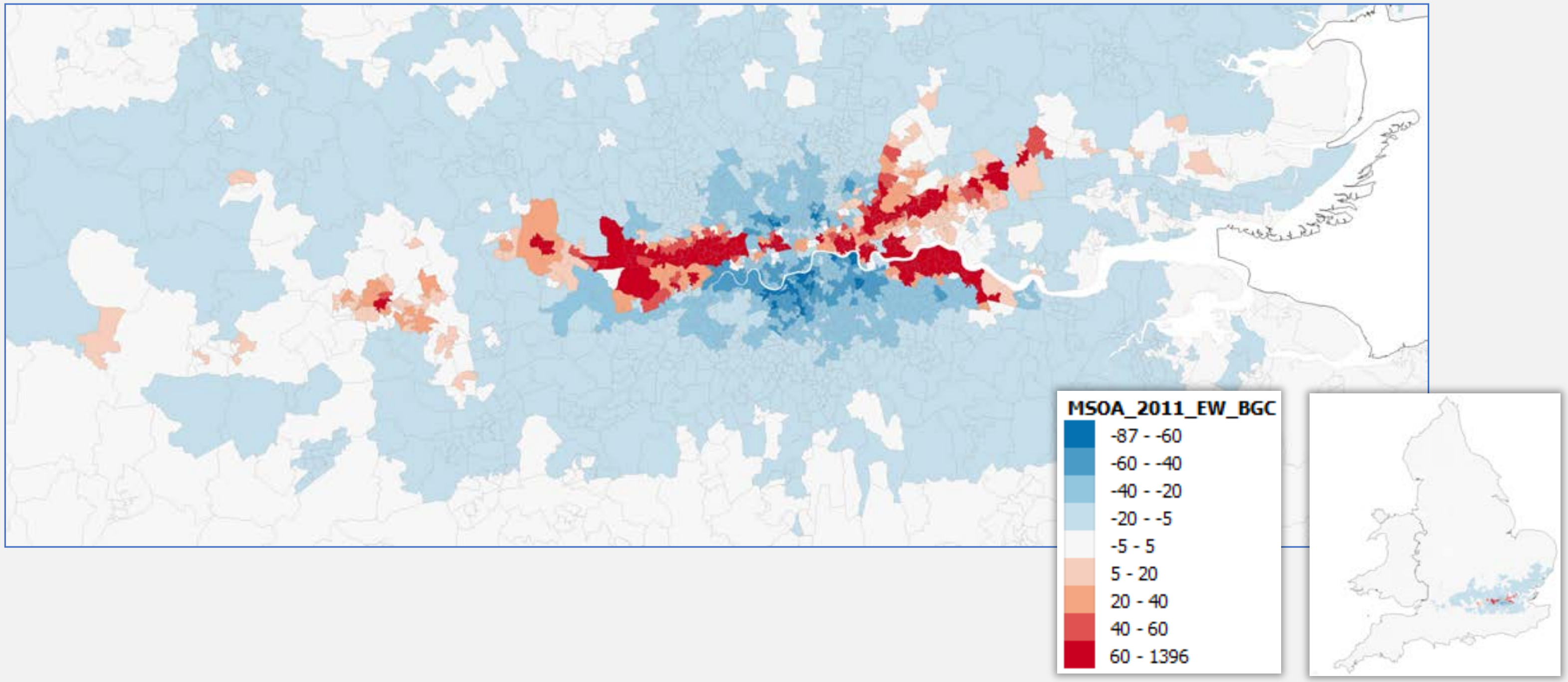
Crossrail

Population change (rail mode only)

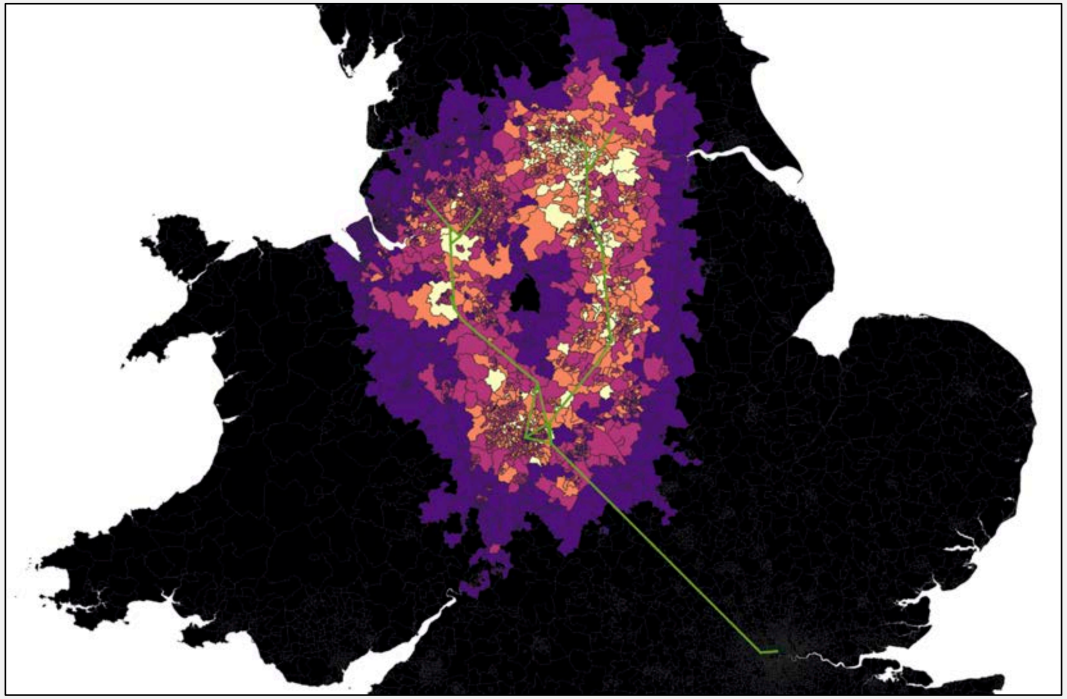


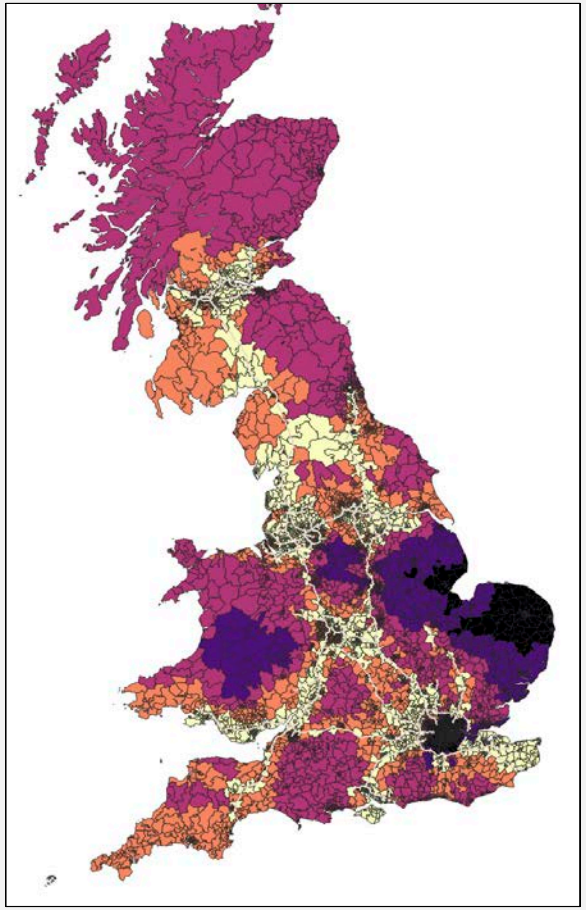
Crossrail

Population Change (all modes)



Impact of High Speed Rail and Reduction of Carbon Emissions





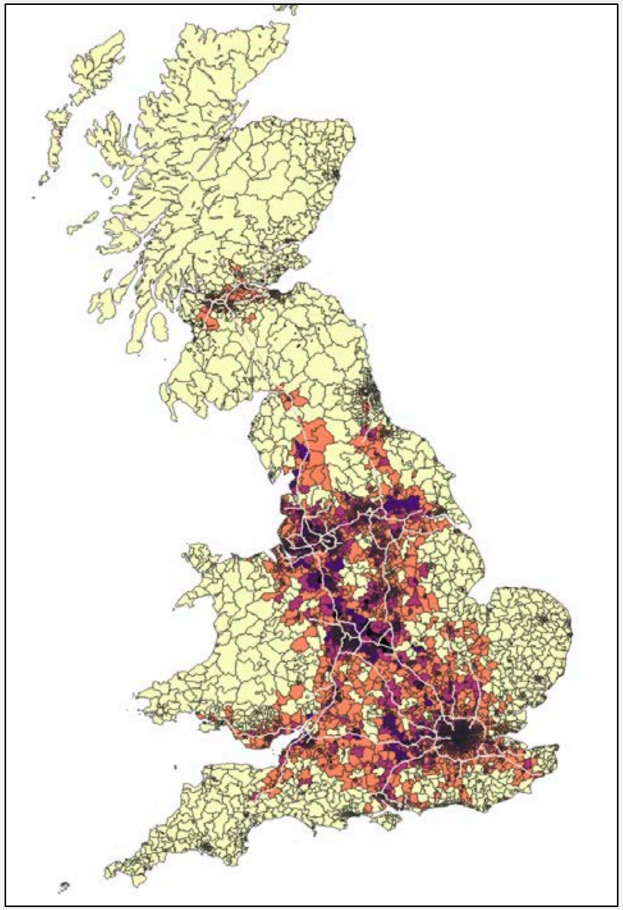
Keeping Rail to a Capacity of 15% for Social Distancing

$$T_{ij}^k = O_i \frac{D_j^{obs} \exp(-\beta^k d_{ij}^k)}{\sum_k \sum_j D_j^{obs} \exp(-\beta^k d_{ij}^k)} \quad k=1,\ k=2,\ k=3 \quad road, rail, bus$$

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

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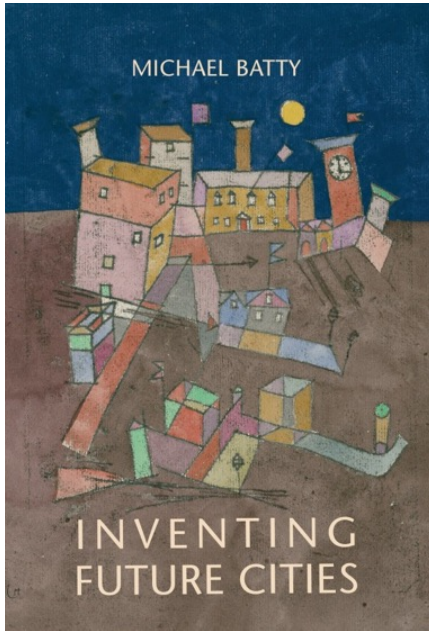
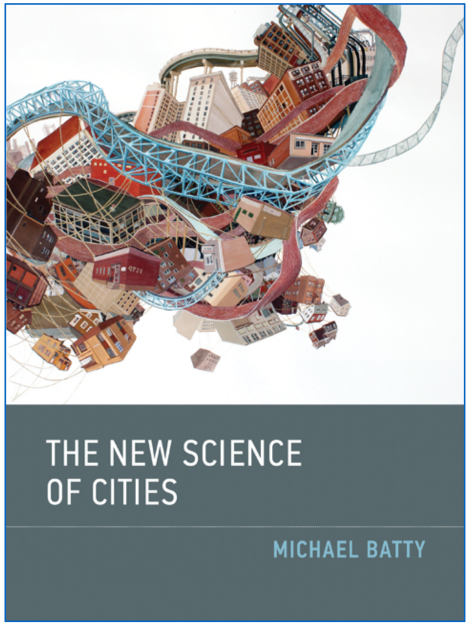
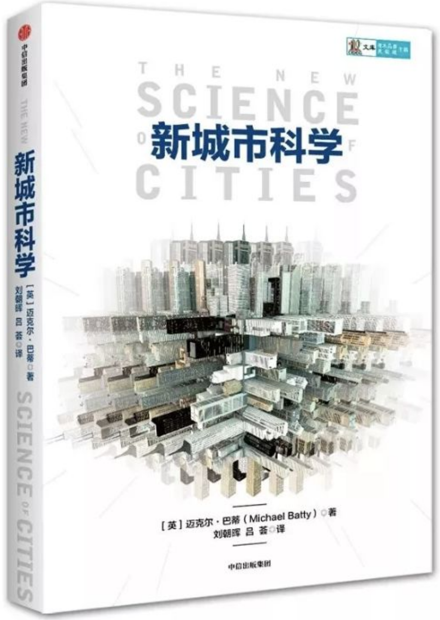
A Selection of my Publications in English and Chinese That Cover Some of the Background Ideas

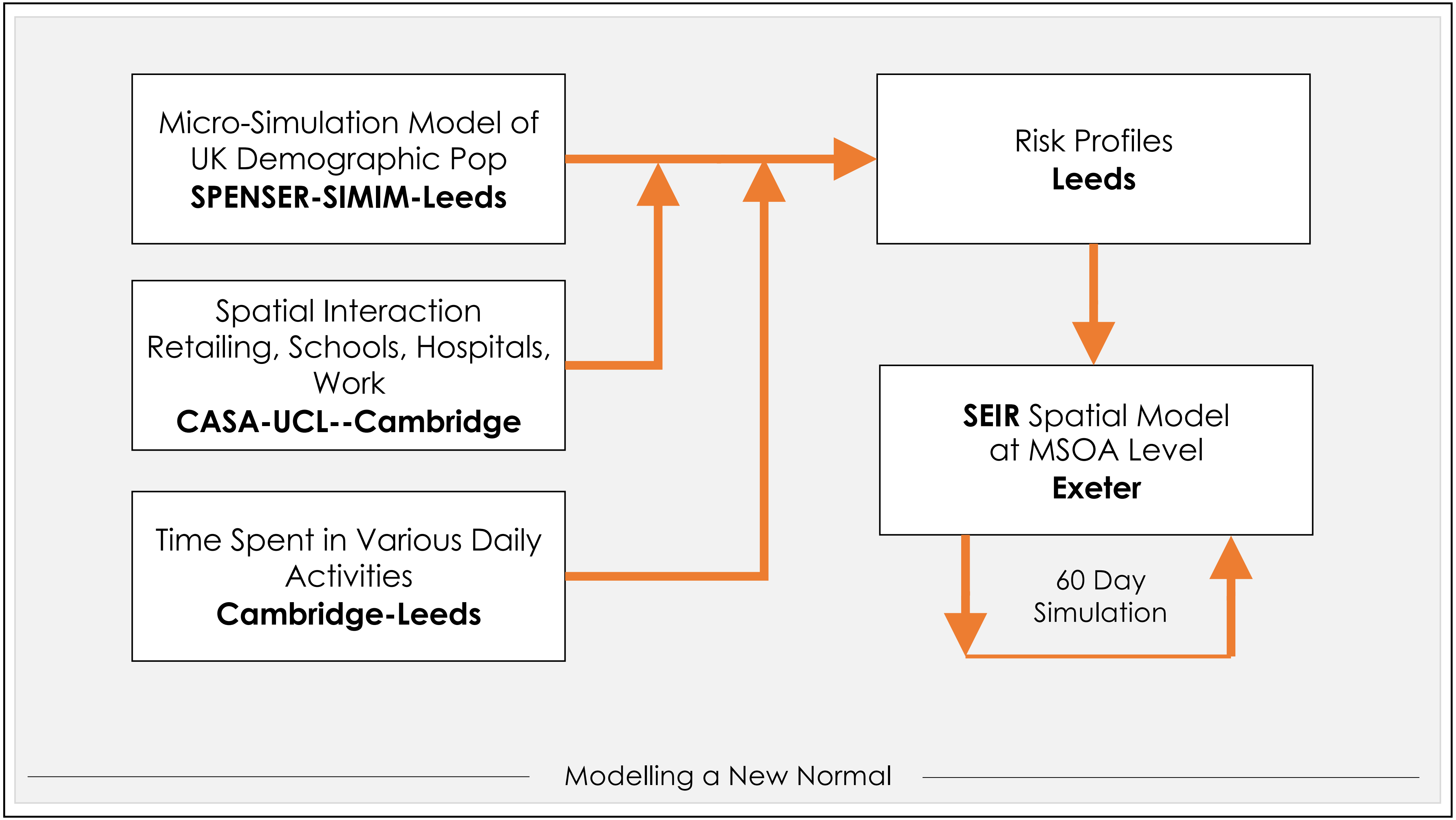


创造未来城市





MIT Press, 2018 | Translated 2020 | MIT Press, 2013 | Translated 2019



Micro-Simulation Model of
UK Demographic Pop
SPENSER-SIMIM-Leeds
Spatial Interaction
Retailing, Schools, Hospitals,
Work
CASA-UCL--Cambridge
Time Spent in Various Daily
Activities
Cambridge-Leeds
Risk Profiles
Leeds
SEIR Spatial Model
at MSOA Level
Exeter
60 Day
Simulation
Modelling a New Normal