RAMP Urban Analytics – Behavioural Models

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Behavioural Models - Context

- In carrying out their daily activities, people visit different locations where interactions with other humans will occur and infectious disease transmission may take place.
- These sites could include:
  - Homes
  - Workplaces
  - Schools
  - Supermarkets and other retail outlets
  - Hospitals and other medical facilities
  - Pubs and Restaurants
  - Public Transport
  - Gyms and leisure centres

Behavioural Models - Context

- Which sites people interact with will vary according to demographic and socio-economic characteristics such as age and occupation
- Local spatial configurations these sites vary considerably
- Temporal interaction with these sites varies from brief 10 minute trips to the corner shop, to entire days spent at school
- All other things being equal, the spatial and temporal evolution of infectious disease transmission will vary according to the differing interactions of residential populations at sites of potential disease transmission

Behavioural Models – The Challenge

- If we know where people live, can we model the different places they visit during their daily / weekly activities and the exposure to disease risk they may experience as a result (and under different lock-down scenarios)?
- Gravity / Spatial Interaction models are a well established methodology for estimating these flows between residential origins and sites of activity destinations. Interactions will vary according to:
  - the size and composition of residential populations in residential zones
  - the relative attractiveness of different shops/schools/hospitals/pubs accessible to these residential zones
  - the cost of travelling between them

The basic behavioural (spatial interaction) model

$$T_{ij} = B_i O_i A_j^{\alpha} \exp(-\beta c_{ij})$$

- T_{ij} is the transition/trip or flow, T, between origin i and destination j
- O is a vector of origin attributes - in this case is the known residential population likely to interact with a destination. O_i is a constraint such that $O_i = \sum_j T_{ij}$
- B_i is a balancing factor to ensure constraints are met: $B_i = \frac{1}{\sum_j A_j^{\alpha} \exp(-\beta c_{ij})}$
- A is a vector of destination attributes relating to the attractiveness of all destinations in the dataset, j – these could be school roll numbers or retail floor space
- c is a matrix of costs (frequently distances, but often also travel time or financial cost) relating to the flows between i and j.
- α and β are all model parameters to be estimated. β is assumed to be negative, as with an increase in cost/distance we would expect interaction to decrease

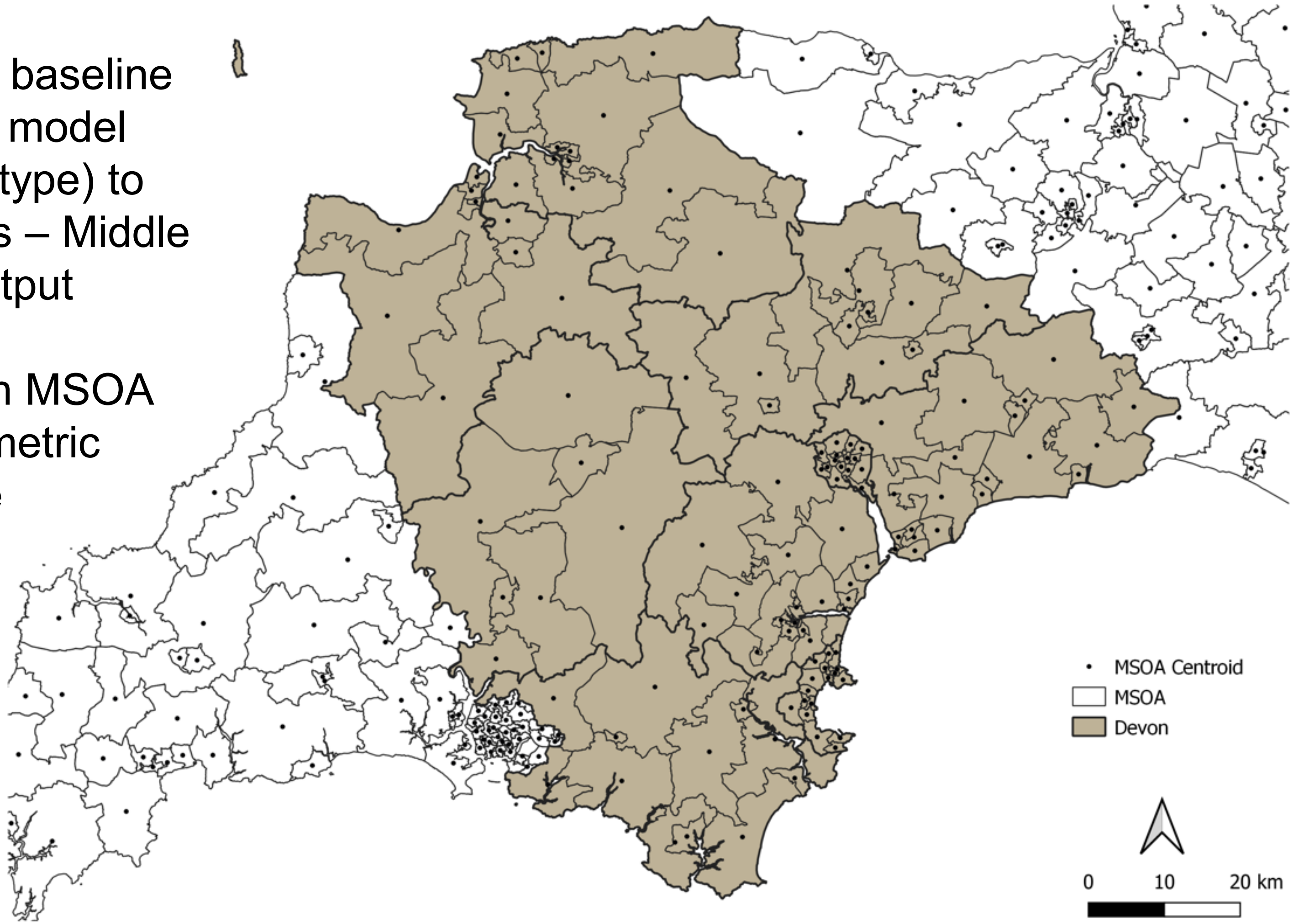
- Flow probabilities, S, to each destination (from each origin) can be derived from these estimates: $S_{ij} = \frac{T_{ij}}{\sum_j T_{ij}}$

The basic behavioural model - health warnings

- The model will estimate the probability of an individual in residential zone i, visiting site j, compared to all other sites – will not capture variations in daily/weekly trips or durations at each destination site and we are yet to work in different lock-down scenarios, but will be able to in the future
- Model currently not disaggregated to capture, for example, daily trips to the local corner shop AND weekly big shops at the out-of-town superstore
- A disaggregated model will be required to capture the differing preferences of resident types – e.g. families with children and a car vs lone pensioners vs student house-shares etc.
- In the absence of datasets of observed flows, calibration of parameters and validation of flow probability outputs is challenging – to be worked on in future

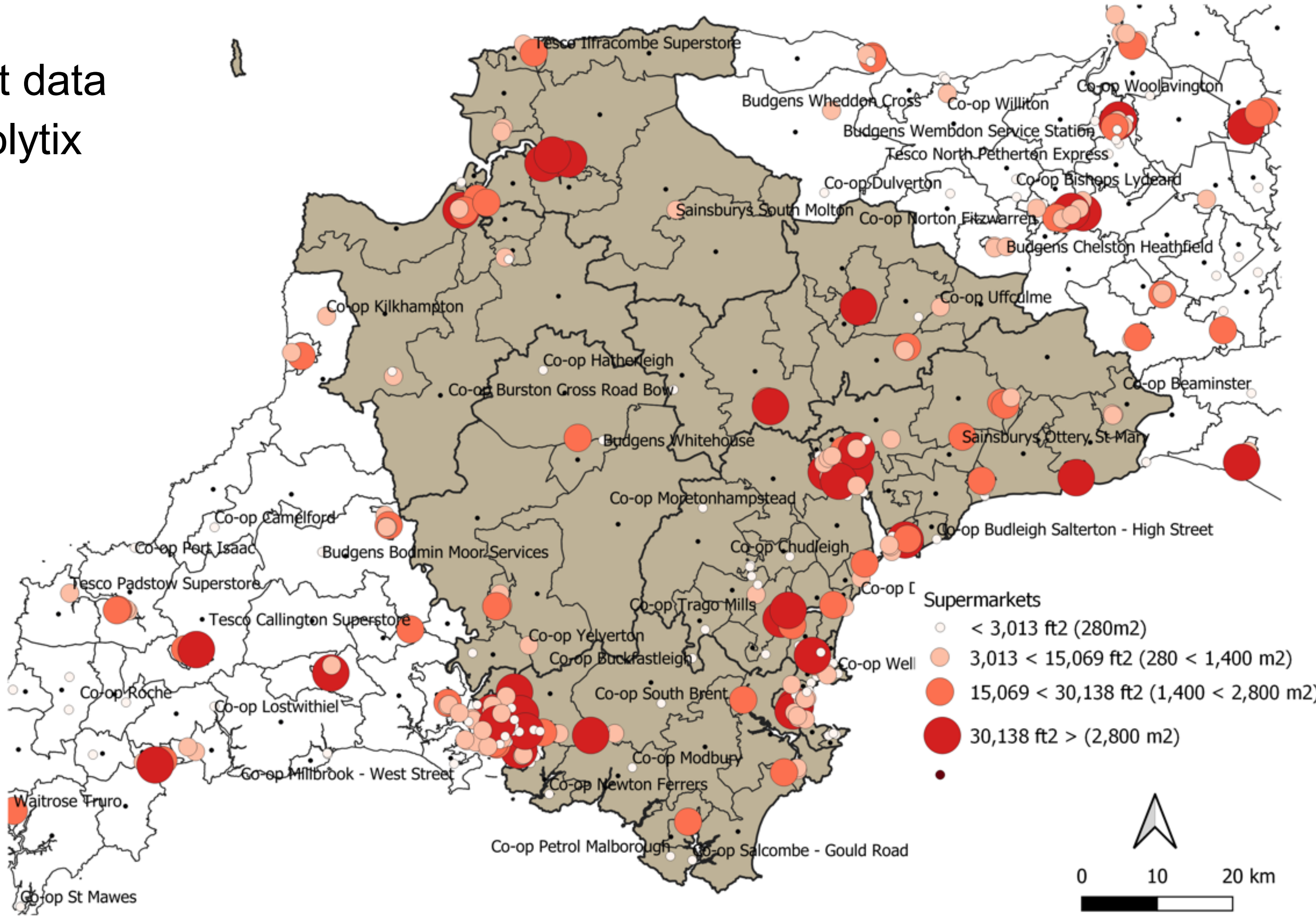
Behavioural System

- Individuals from baseline Microsimulation model aggregated (by type) to residential areas – Middle Layer Super Output Areas
- Location of each MSOA defined be geometric centroid of zone
- An O_i for each zone



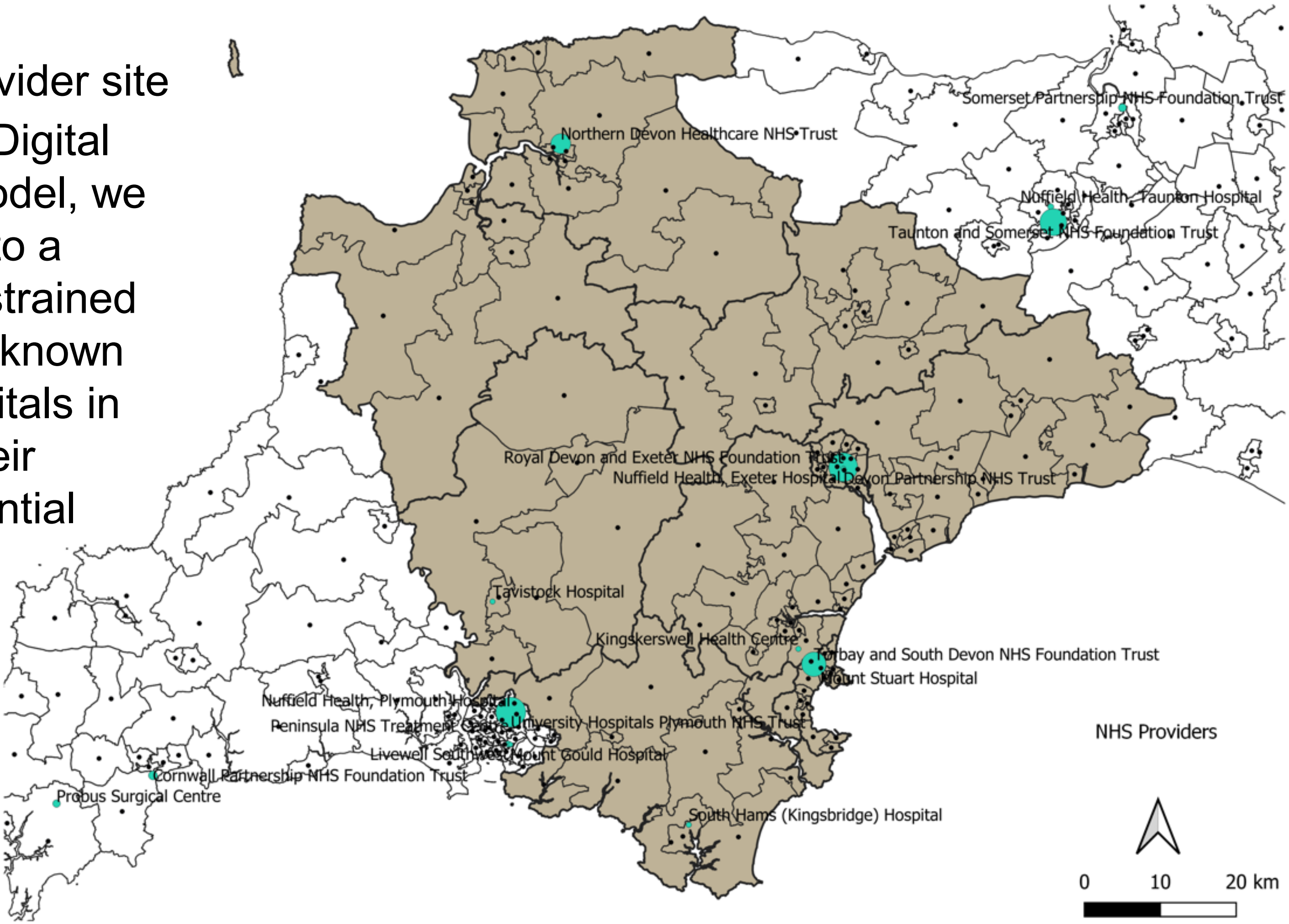
Behavioural System

- A_j Supermarket data supplied by Geolytix



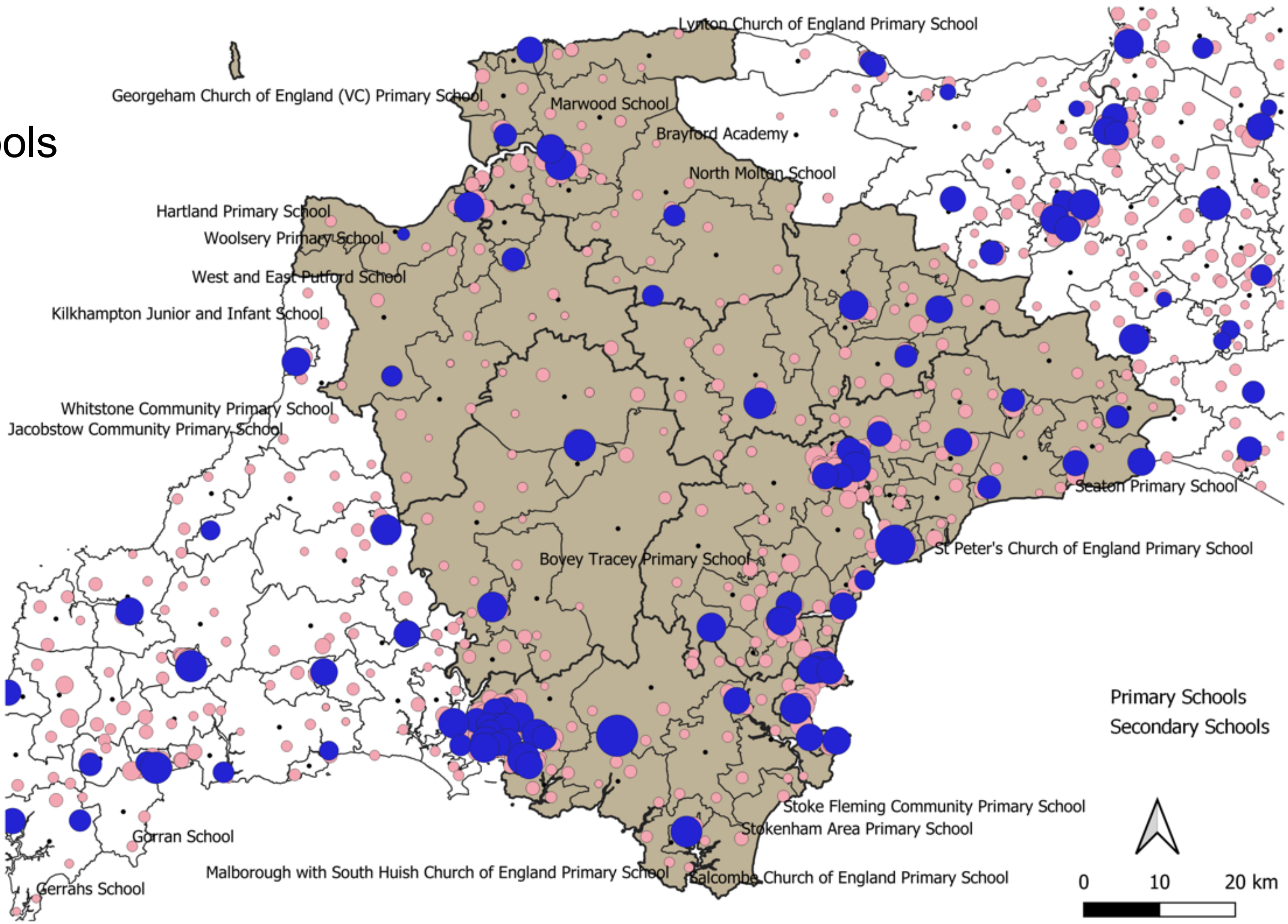
Behavioural System

- A_j Hospital Provider site data from NHS Digital
- **Note in our model, we actually flipped to a destination constrained model and sent known patients at hospitals in 2019 back to their expected residential locations**



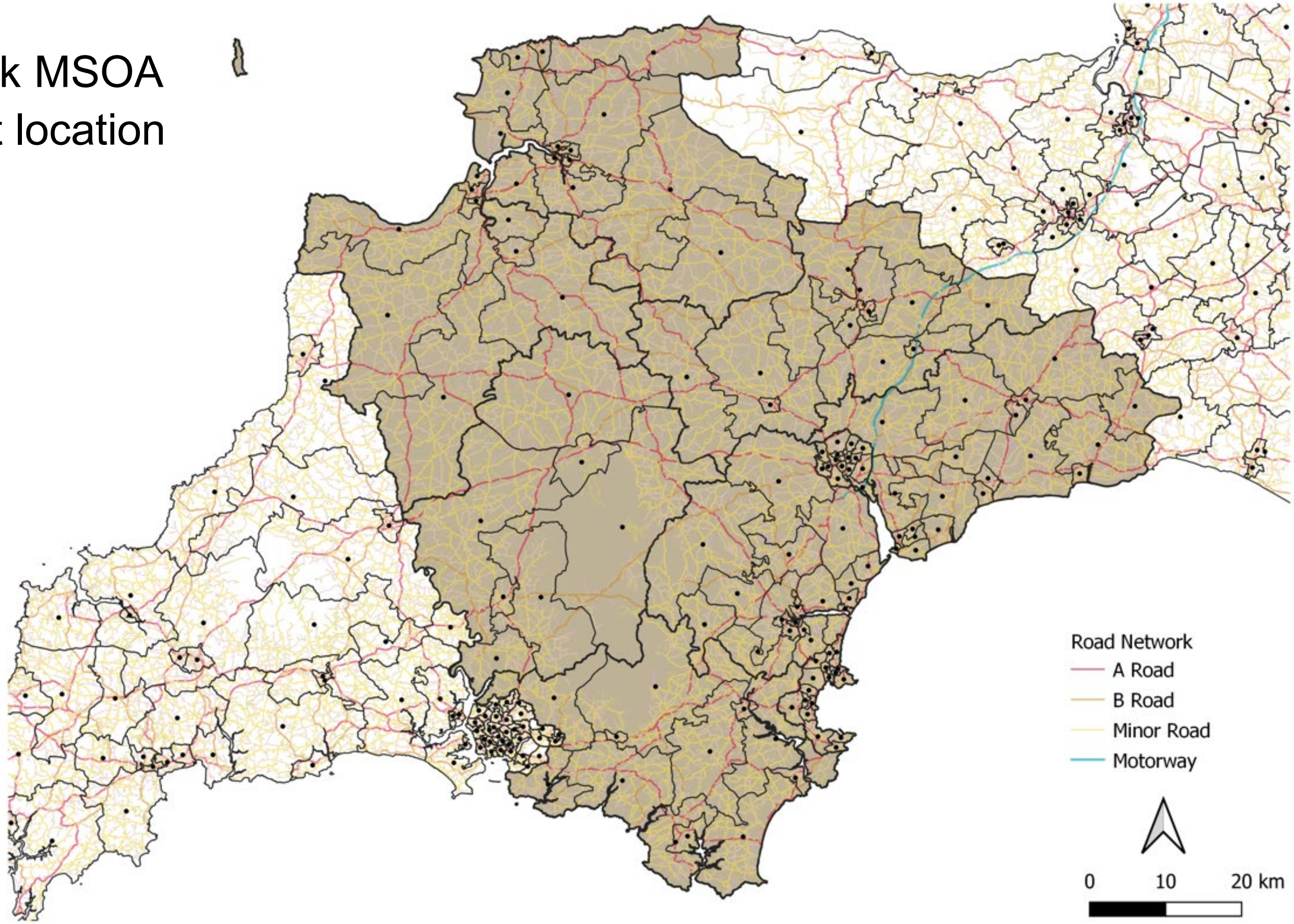
Behavioural System

- A_j Primary and Secondary schools

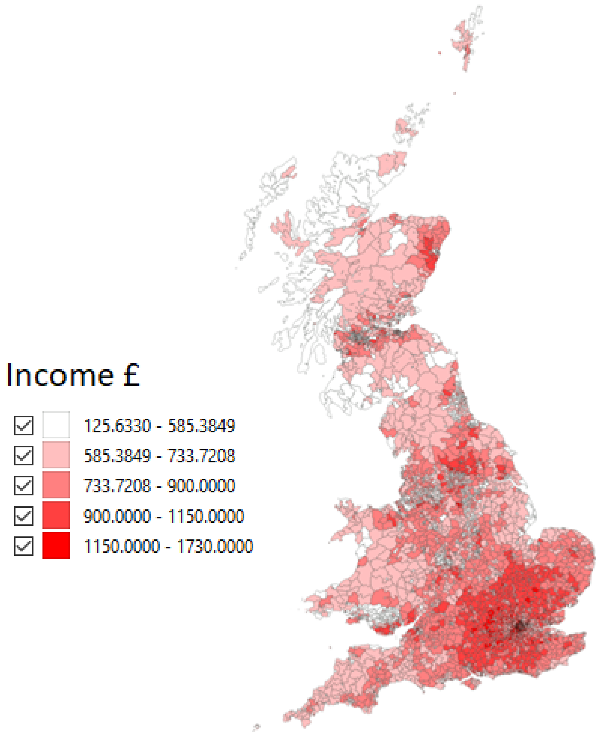


Behavioural System

- c_{ij} Road network MSOA centroid to point location travel time



The Model



$$S_{ij}^a = E_i^a \frac{A_j \exp\left(-\beta^a c_{ij}\right)}{\sum_j A_j \exp\left(-\beta^a c_{ij}\right)} \quad , \quad \sum_j S_{ij}^a = E_i^a$$

[1]Lakshmanan and Hansen (1965)

$A_j = floorspace\ or\ annual\ turnover$ (attractor)

$E_i^a = disposable\ income$ (population)

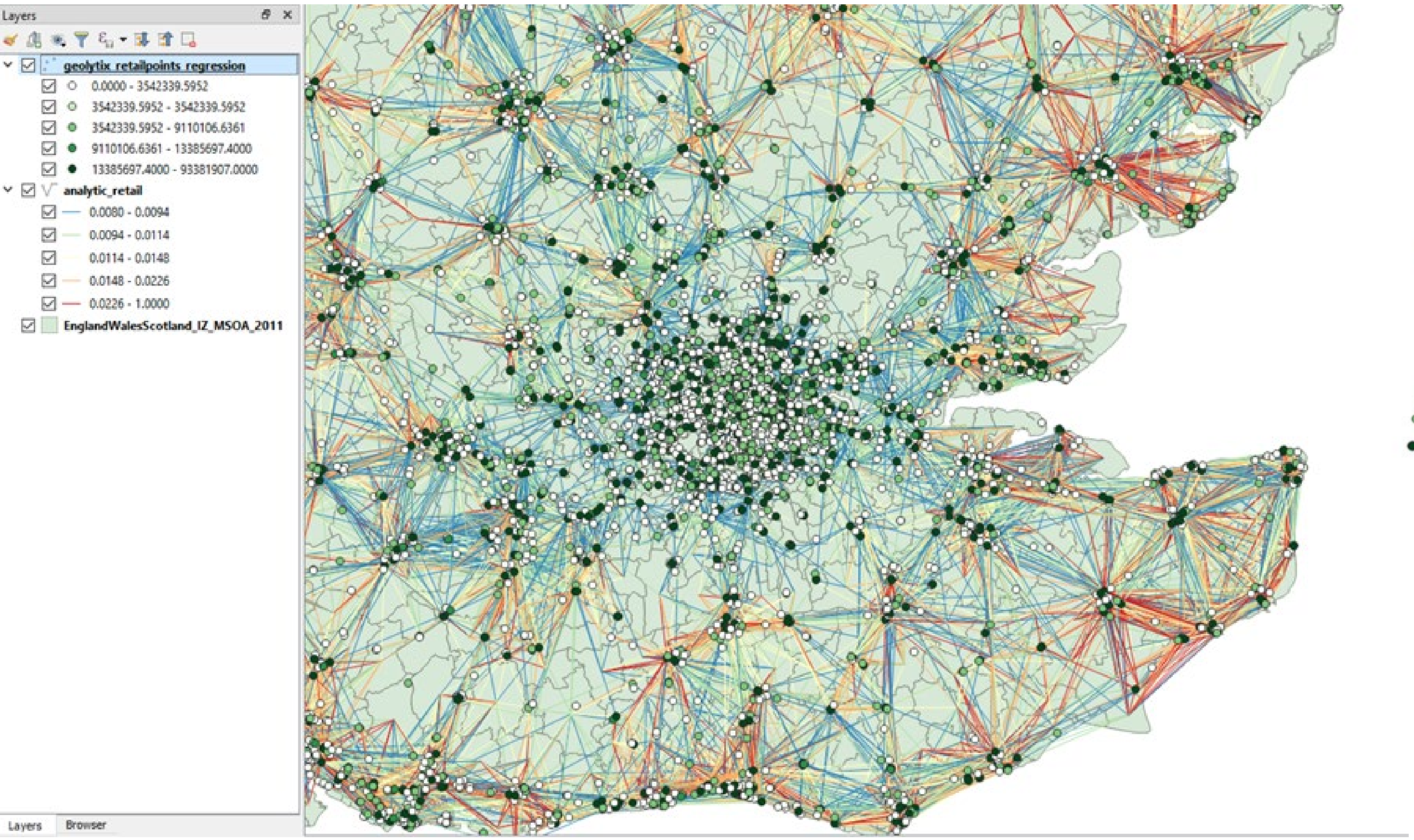
$\beta = distance\ decay$ (=0.13)

$c_{ij} = cost\ of\ travel\ between\ i\ and\ j$

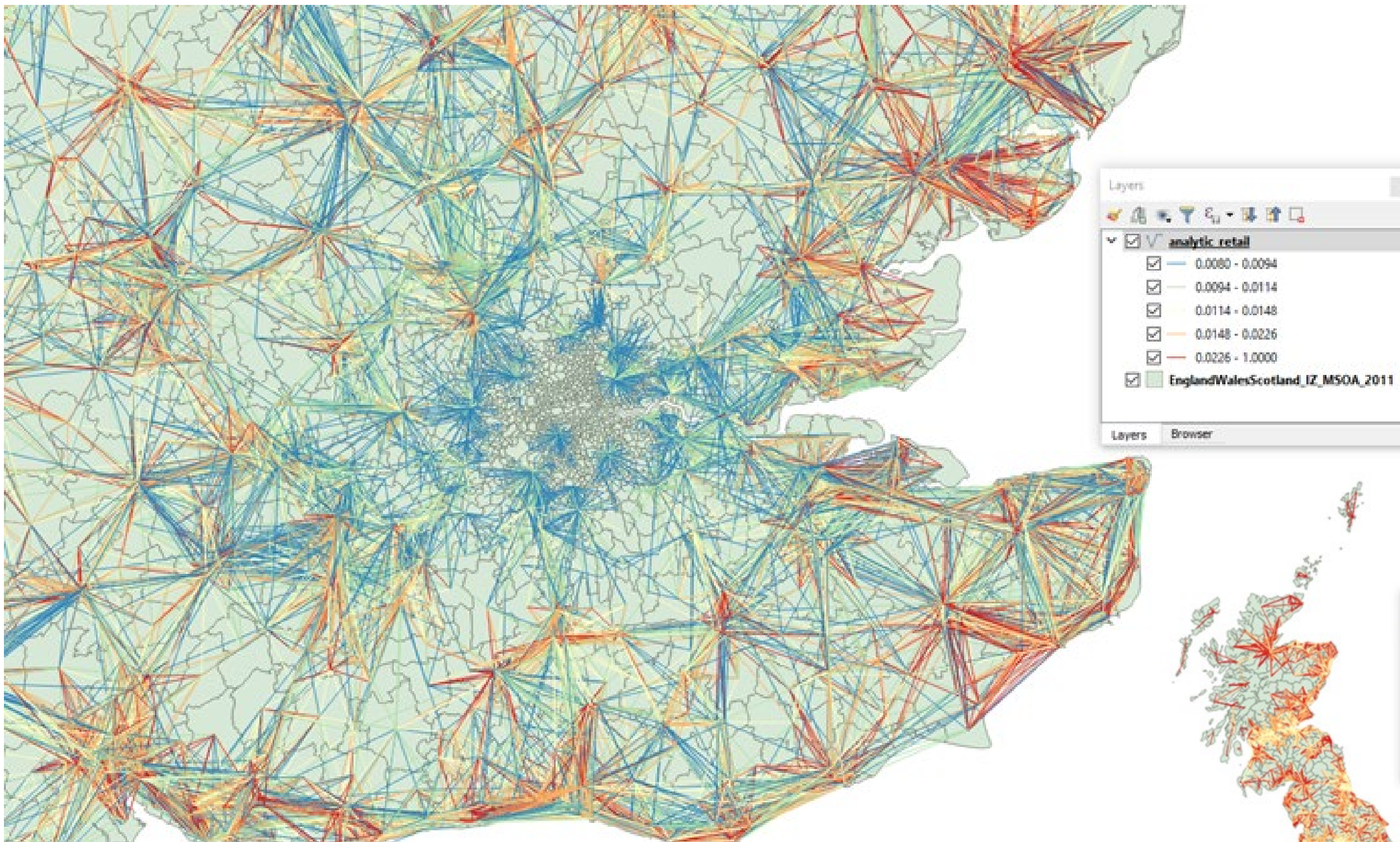
8436 MSOA+IZ zones

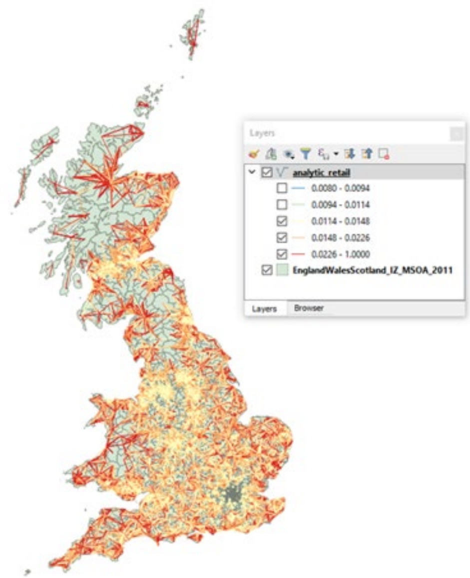
[1]Lakshmanan, J. R. and Hansen, W. G. (1965) A Retail Market Potential Model. *Journal of the American Institute of Planners*, *31*, 134-143.

Geolytix Regression Points

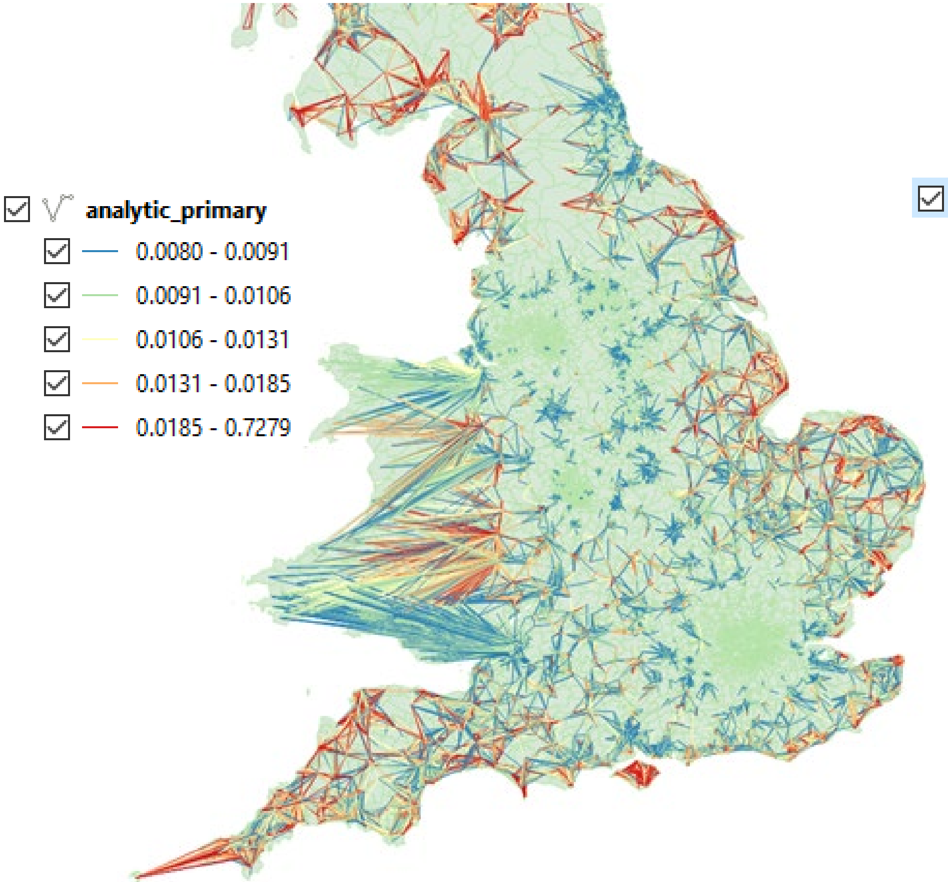


Retail (Geolytix)

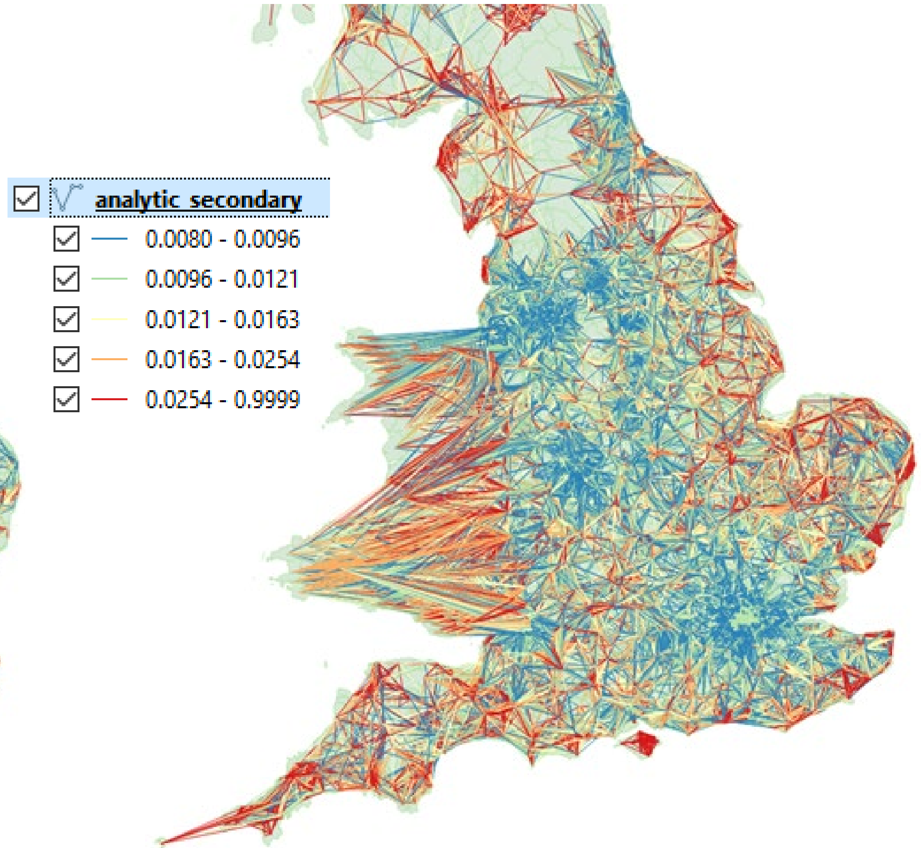




Schools

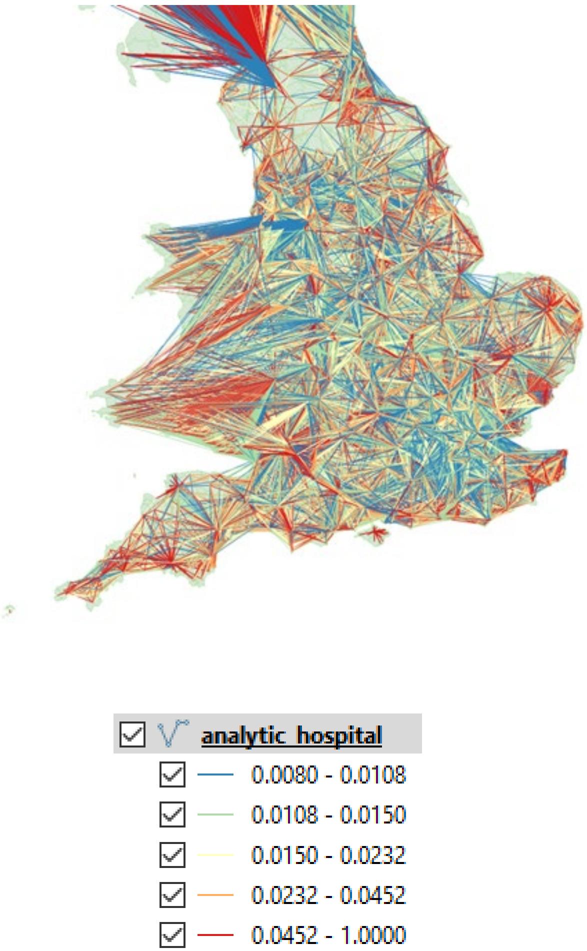


Primary (18,742 schools, 500,257 pupils)



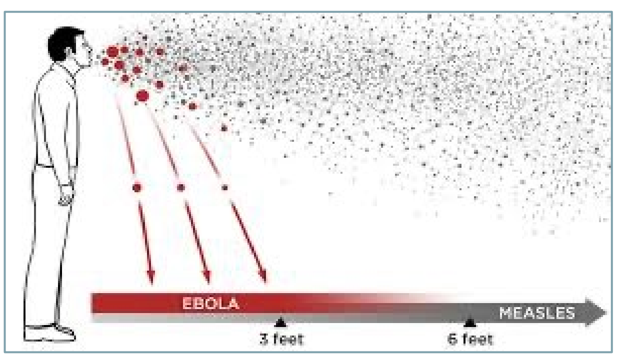
Secondary (3,601 schools, 3,676987 pupils)

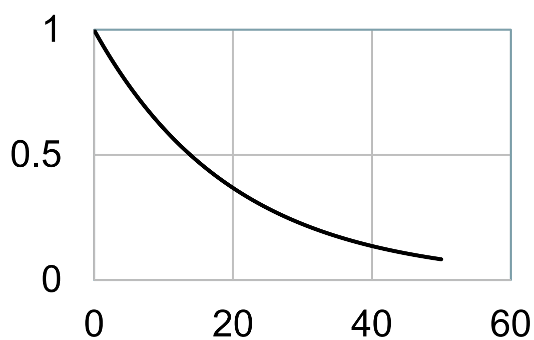
Hospitals

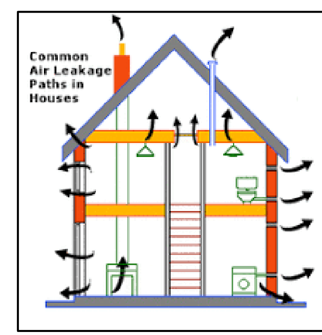

analytic_hospital
0.0080 - 0.0108
0.0108 - 0.0150
0.0150 - 0.0232
0.0232 - 0.0452
0.0452 - 1.0000

Links to Further Fine Scale Spatial Models

- When individuals move to the places where they engage in activities – as shoppers, school children, patients or workers – then they interact with one another, thus being exposed to or transmitting any infection.
- If there are S_j shoppers say visiting retail outlets at j, potentially interact as S_j^2 but much less than this due to density of crowding and a small proportion infect others, let us say $(\beta S_j)^\alpha$, $\beta \ll 1, 1 < \alpha \ll 2$
- We need to build detailed models of these infections which relate to how people transmit the virus, by coughing, people moving around and mixing the air, ventilation, people getting too close etc







RAMP is the Rapid Assessment of Pandemic Modelling of which is the urban analytics model being proposed here is a key task Three of these tasks are related and are Task 3 Urban Analytics, Task 6 Human Dynamics in Small Spaces, and Task 7 Environmental and Aerosol Transmission