Numerical Experiments with Spatial Interaction Models

Martin Clarke
University of Leeds

Contents

- Background: the 1970s
- The Harris Wilson Model
- Theoretical Properties versus Numerical Experiments
- Designing Experiments
- Examples
- Moving from experiments to the real world: GMAP and beyond
- The Future, Big data and SIM?

Background

- I graduated in 1976 and started work as a Research Assistant with Alan
- I was surrounded by physicists, mathematicians and operational researchers. A steep learning curve.
- I even shared an office with Nigel Thrift!

Background

- What was apparent (to me at least) that despite all the impressive theoretical developments in urban modelling there was little applied work
- So was it possible to understand the properties of spatial interaction models by undertaking numerical experiements?
- That is, run models under a variety of scenarios in which the parameters of the models were varied and the results examined

Starting Points

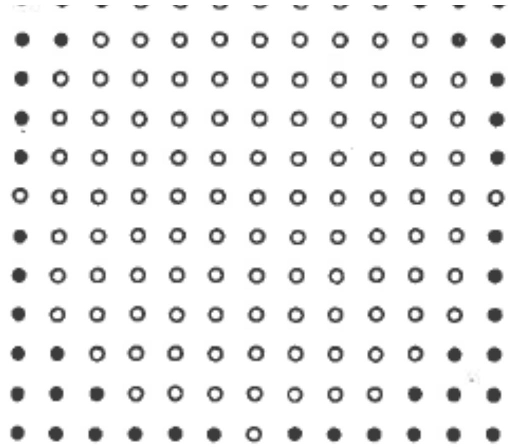
- SPAINT – A spatial interaction model written in Fortran and run on the university's ICL 1906A mainframe (thanks John Stillwell)
- Electricte de France non-linear optimisation package run on the University of Manchester Regional Computer Centre's CDC 7600 (thanks Jose Coehlo)
- Initial results presented in Wilson and Clarke (1979)

Problems!

- Apart from the 1971 census there was very little data on consumer demand, the retail supply side, spatial interactions or flows or travel time or costs
- So we had to ‘invent’ data for our numerical experiments
- Not as straightforward as it might seem!

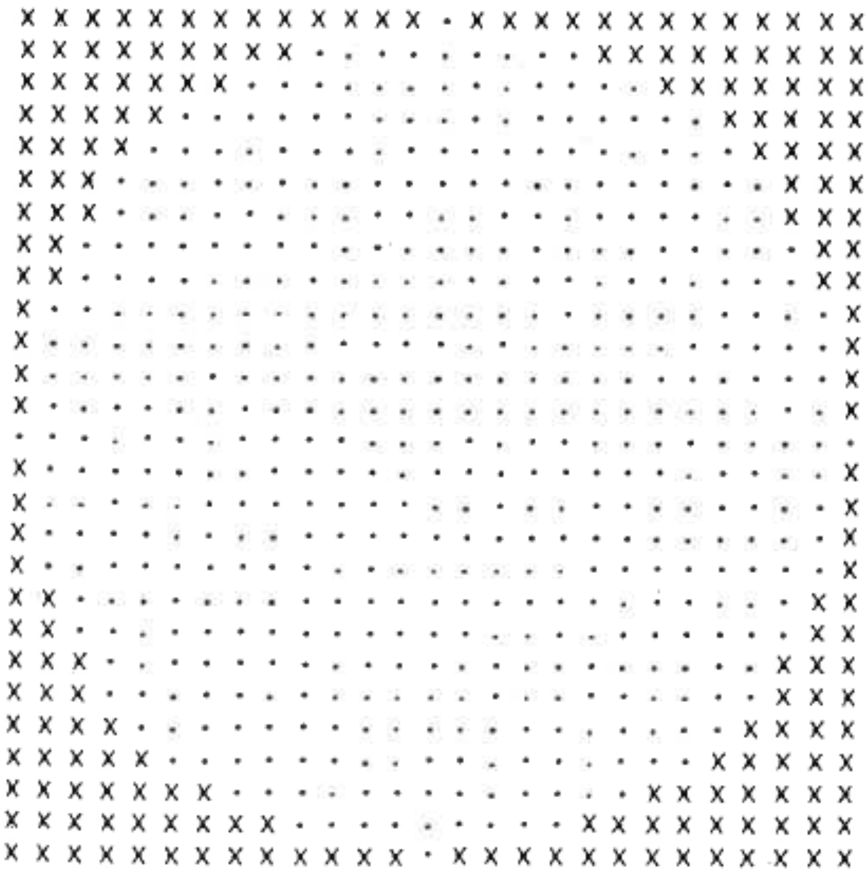
RET729 – the Harris-Wilson model

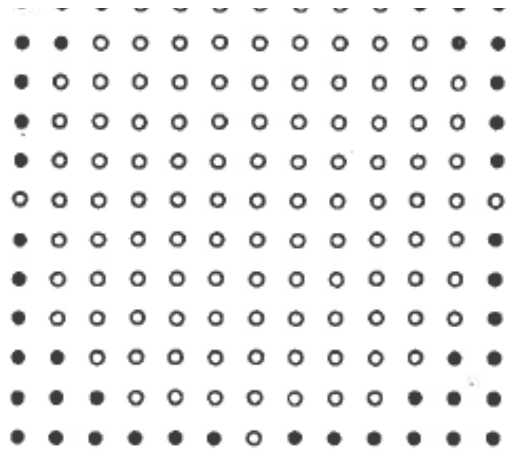
- I wrote a Fortran program to solve the H-W model for a 729 zone imaginary spatial system.
- 729 is a 27x27 spatial system (see next slide) that ensures perfect spatial symmetry
- There is therefore a 729x729 interaction matrix.
- Just about the limits of what the university's Amdahl mainframe could handle at the time



● indicates exogenous zone

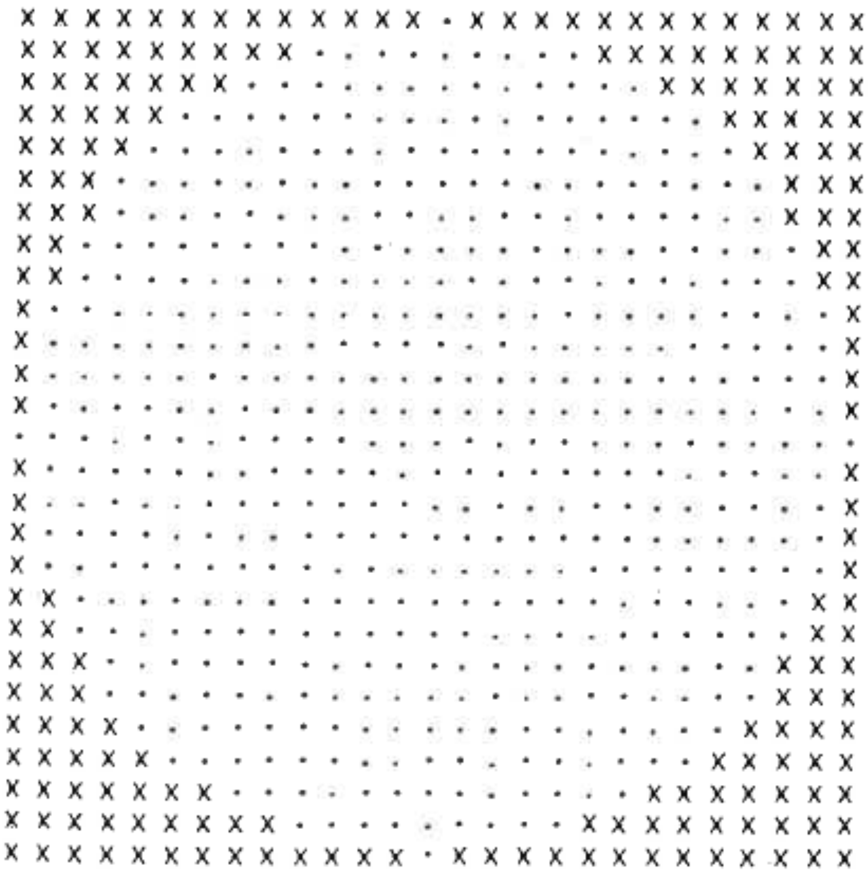
fig 3.19 169 zone hypothetical spatial system





● indicates exogenous zone

fig 3.19   169 zone hypothetical spatial system



RET729

Visualisation of the results was a key requirement

In 1980 this was possible using a combination of an innovative mainframe package called SYMVU and judicious use of a photocopier!

Results presented at the Durham Regional Science meeting in 1981 and published in the Papers of the RSA in 1983 (Clarke and Wilson)

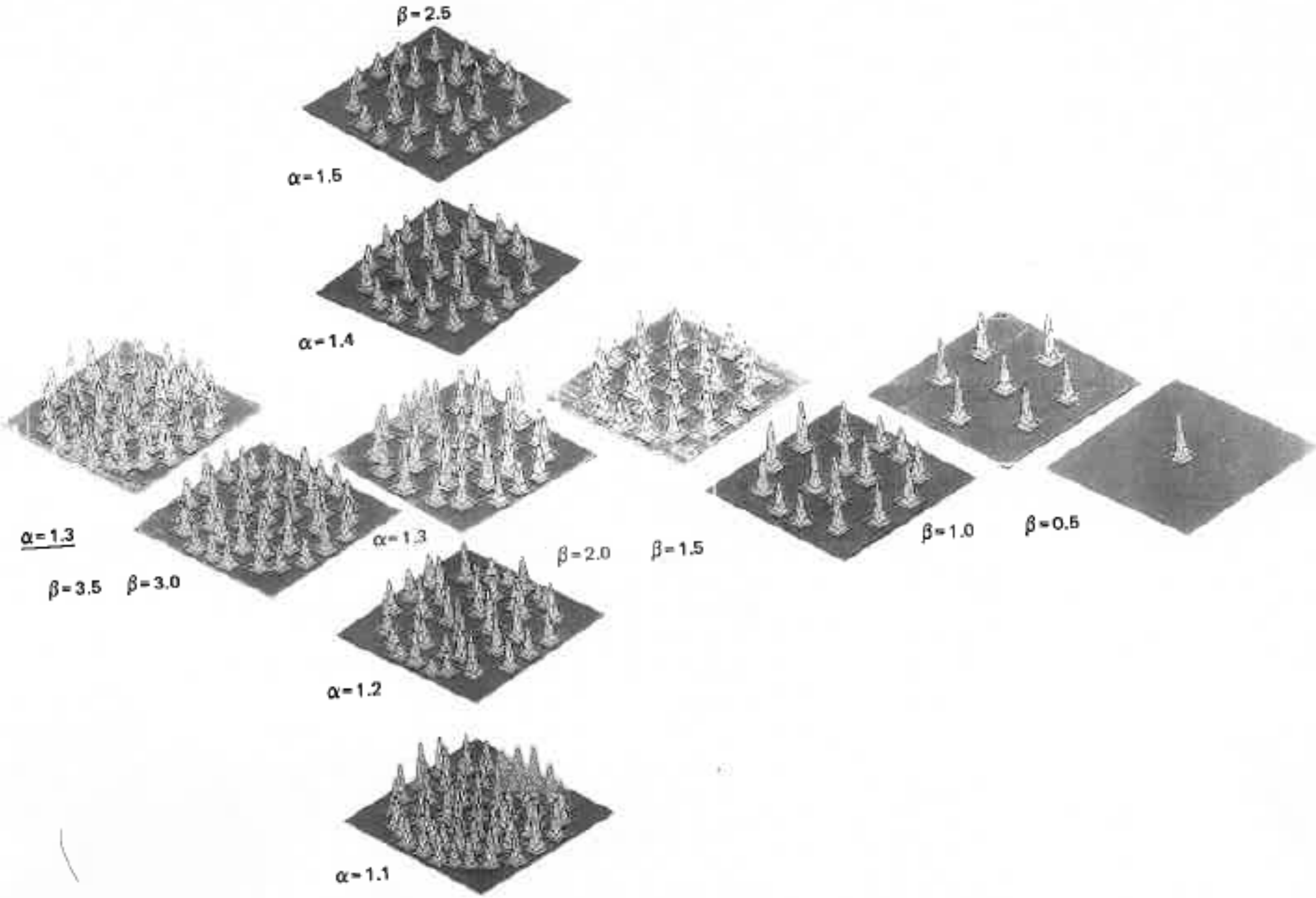


Figure 6. Retail patterns for various values of α and β

From Imaginary to Real World Experiments with SIM

- During the mid-80s more data became available but mainly through commercial sources (e.g. Pinpoint’s LUPIN)
- This quickly escalated as retailers (in particular) realised the value of the data they were capturing (EPOS, loyalty card, etc)
- The time was ripe to try to exploit the value of this data within a SIM framework
- This is when GMAP was established!

GMAP

- A perfect opportunity for applied SIM!
- The Data explosion
- Availabilty of PCs
- GIS sofware
- Increasingly competitive retail market place
- Lack of modelling skills in industry

GMAP

- Clients included some of the world's largest consumer facing organisation – Tescos, Walmart, Ford, ExxonMobil, HSBC, HBOS.
- GMAP grew rapidly, eventually employing 120 staff by 1997. In total we calculate that the business employed over 350 geography/computer science graduates between 1987 and 2015
- However, getting SIMs to work for real was not straightforward!

An Example

Measuring "Retail Attractiveness"

- In the literature represented as: W_j
- In our models something like:

Brand

Store maturity

Size

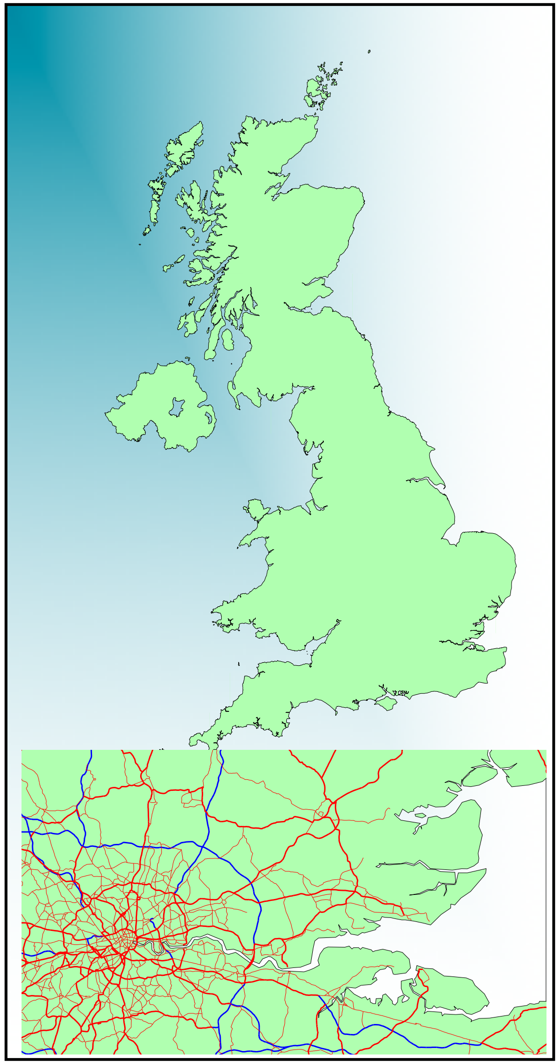
$$W_J^{kln} = \omega_J^{kln} \sum_{j \in J} R_j^{kl} Z_j^{k} \gamma_{\psi(j)}^{\varepsilon(j)kl\phi(j)n} \mu_j^{kl} \chi_j^{kl}$$

Centre performance

Store performance

Store agglomeration

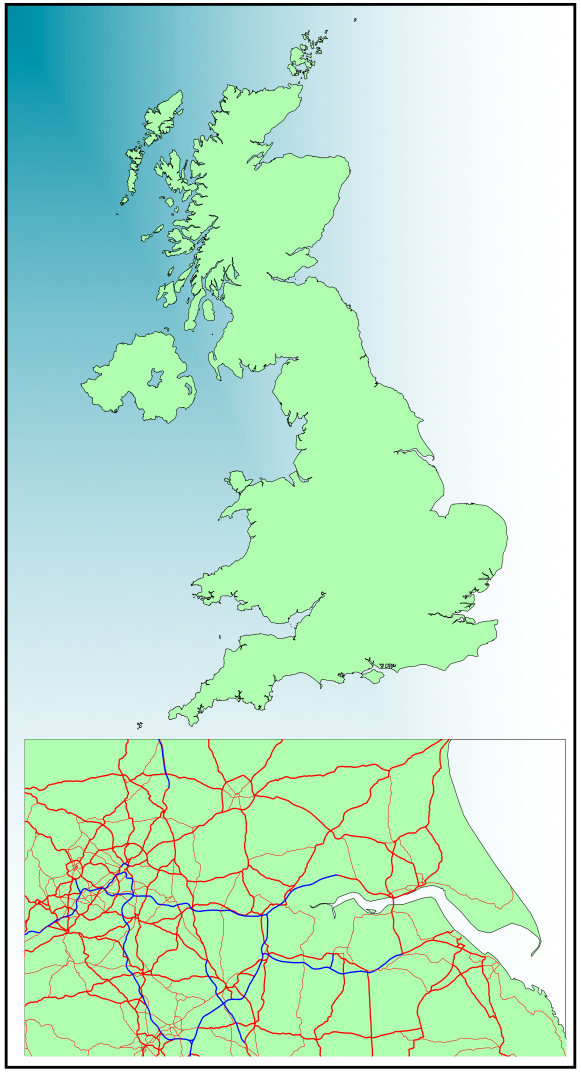
Predicting DIY Shed Revenue



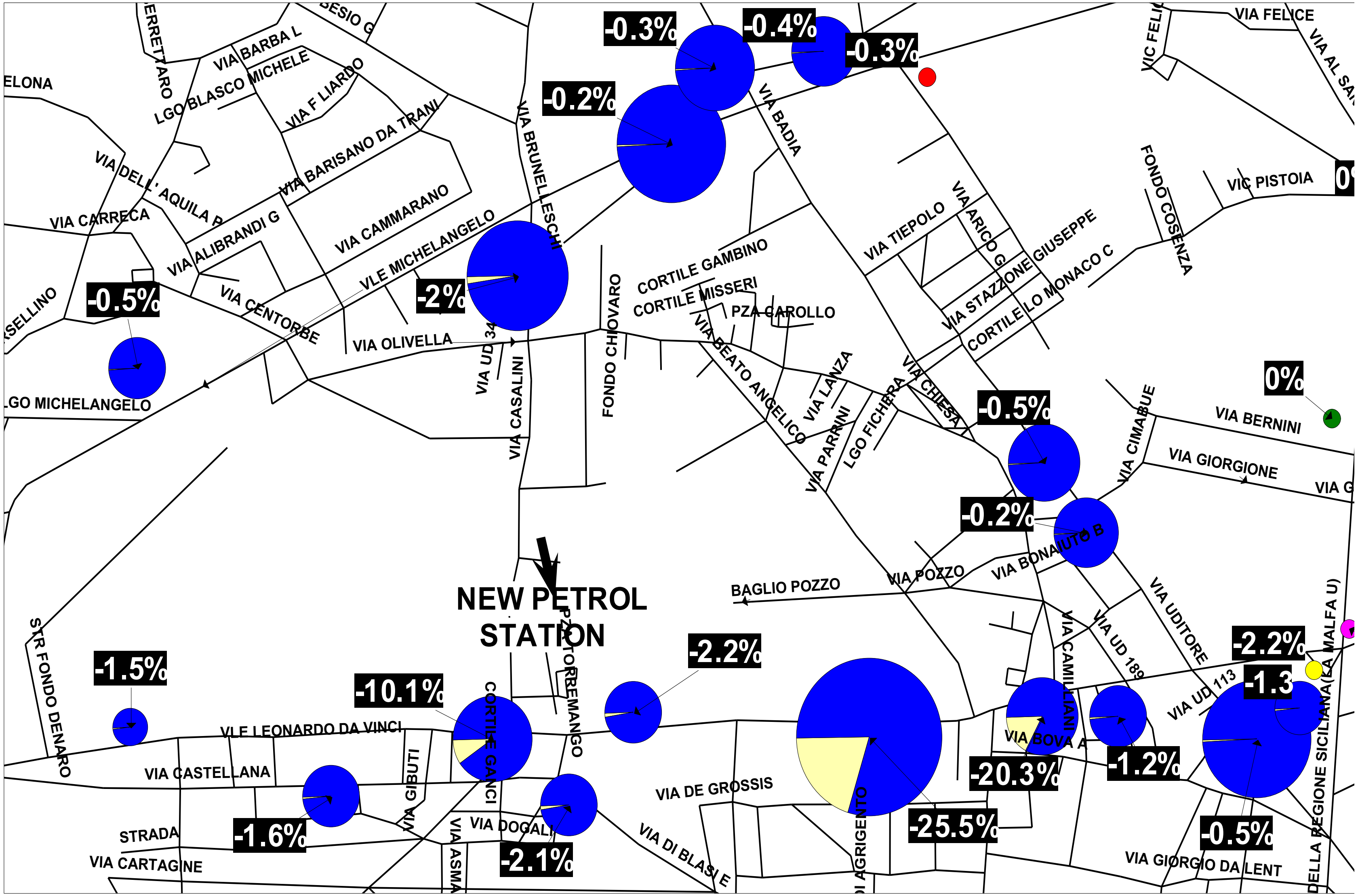
Store	Observed (£m)	Predicted (£m)	Store Performance
Gidea Park	3.97	3.83	1.04
Rickmansworth	4.49	4.32	1.04
Edmonton	7.27	7.03	1.03
South Benfleet	2.29	2.22	1.03
Loughton	4.48	4.40	1.02
Tottenham	6.80	6.76	1.01
Ilford	2.71	2.67	1.01
Stanmore	2.24	2.28	0.98
Braintree	3.06	3.12	0.98
Acton	3.63	3.76	0.97
Welwyn Garden City	3.31	3.42	0.97
Brentwood	1.85	1.92	0.96
Bishop's Stortford	2.98	3.13	0.95
Tilbury	3.70	3.90	0.95

Predicting Supermarket Turnovers

Store	Observed Revenue	Predicted Revenue	Perf Index
Castleford	157.40	148.49	1.06
Doncaster	197.25	188.06	1.05
Dewsbury	243.25	233.76	1.04
Leeds	286.10	275.18	1.04
Ecclesfield	182.40	175.56	1.04
Bradford	257.55	248.66	1.04
Barnsley	198.65	192.62	1.03
Cleethorpes	176.15	171.45	1.03
Halifax	112.70	109.97	1.02
Harrogate	190.15	187.68	1.01
Chapeltown	278.30	275.10	1.01
Hull	277.60	276.68	1.00
Crossgates	210.70	211.46	1.00
Morley	261.65	263.37	0.99
Brighouse	79.35	81.07	0.98
Featherstone	126.45	130.73	0.97
Worksop	182.70	189.34	0.96
Scunthorpe	231.75	240.38	0.96
Sheffield	193.75	201.53	0.96
Keighley	173.05	181.04	0.96
York	42.95	45.18	0.95
Wakefield	84.50	89.32	0.95



Accurately Predicting Impacts



Worldwide application of SIMs

- GMAP worked with organisations in:
- - every European country
- - Noth America
- - Japan
- - Australia
- - South Africa
- - Puerto Rico
- Principles of SIM are universal but need a bit of local tweaking!

Importance of Model Drivers by Retail Market

	Supermarket	Retail	Auto	Finance	Petrol
Spatial Aggregation	Fine Zones	Medium Zones	Coarse Zones	Medium Zones	Medium Zones + Network
Brand Loyalty	Moderate/Strong	Moderate	Moderate	Strong (transactions)	Moderate
Attraction Components					
Space	5	3	4	1	4
Parking	5	1	3	1	5
Accessibility	5	4	2	3	5
Product Range	4	2	4	2	1
Prices	5	5	5	5	5
Adjacencies	1	5	1	5	2
Opening Hours	4	3	1	3	5
Complexity of Distribution	Simple/Moderate	Simple/Moderate	Simple/Moderate	Complex	Simple
Travel Distance	Short	Moderate	Long	Moderate	Long
Trip Type	Single Purpose	Multi-Purpose	Single Purpose	Multi-Purpose	Distress
Segmentation	Important	Fundamental	Important	Moderate	Marginal

1 = Relatively Unimportant
5 = Very Important

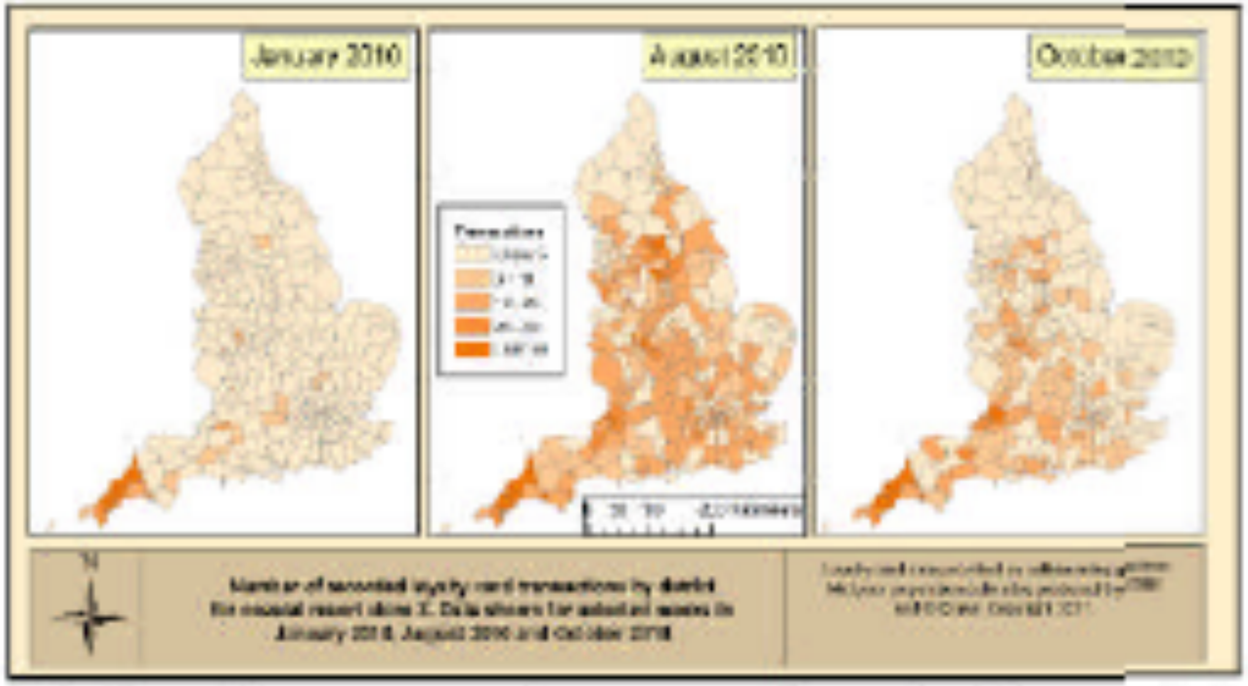
GMAP Summary

- Can be found in 3 books - Birkin, Clarke, G, Clarke, M and Wilson (1996), Birkin, Clarke, G and Clarke, M (2002) and (2017) and for more technical detail in the Geographical Analysis paper Birkin, Clarke, G and Clarke, M (2010)

The Future?

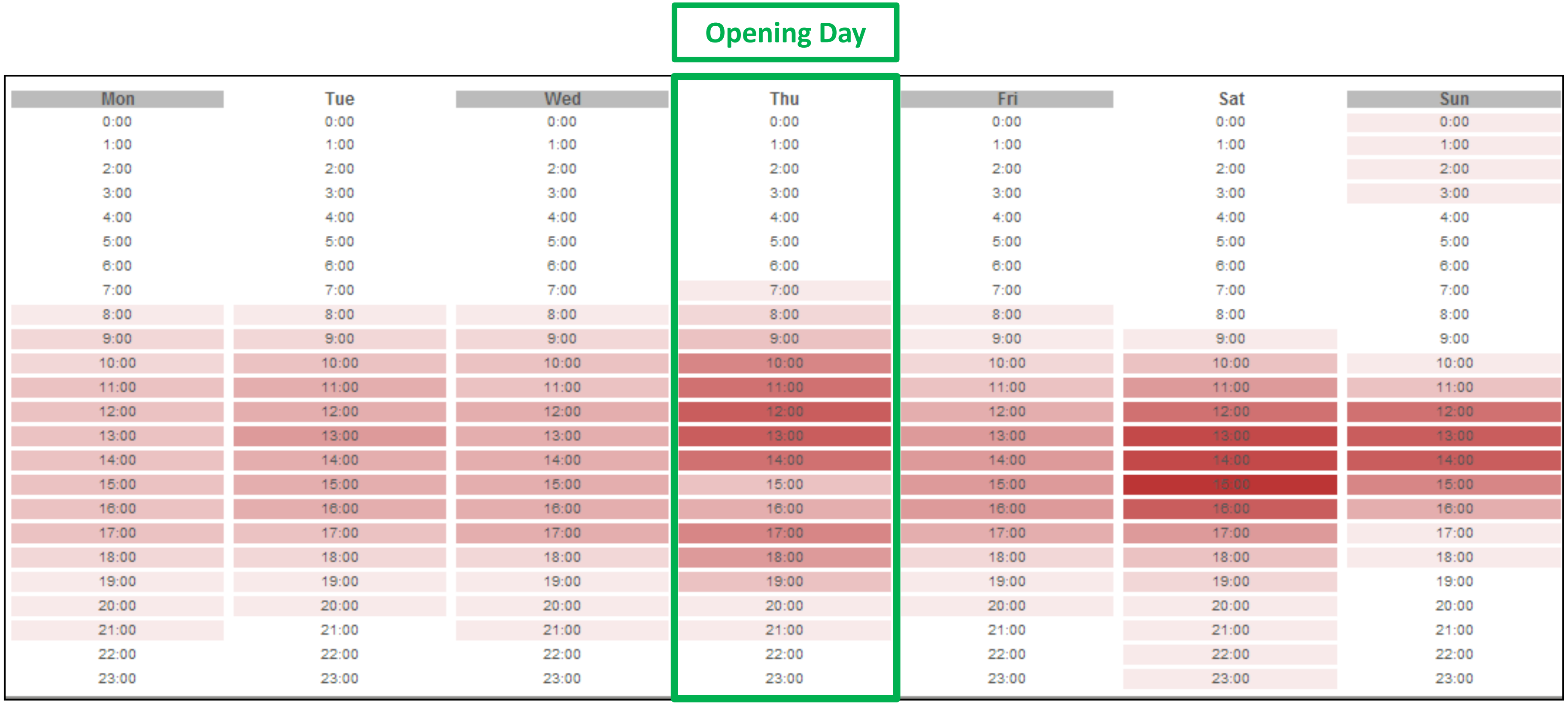
- ‘Gravity modelling (SIM) has no relevance to modern retail planning’ Matthew Hopkinson, LDC , May 2017
- Consumer behaviour has certainly changed over the last 30 years
- However growth in new data sets offers insights into this changing behaviour, not only in retailing but transportation, migration and other areas where SIMs are still relevant

Big Data and Retail Geography



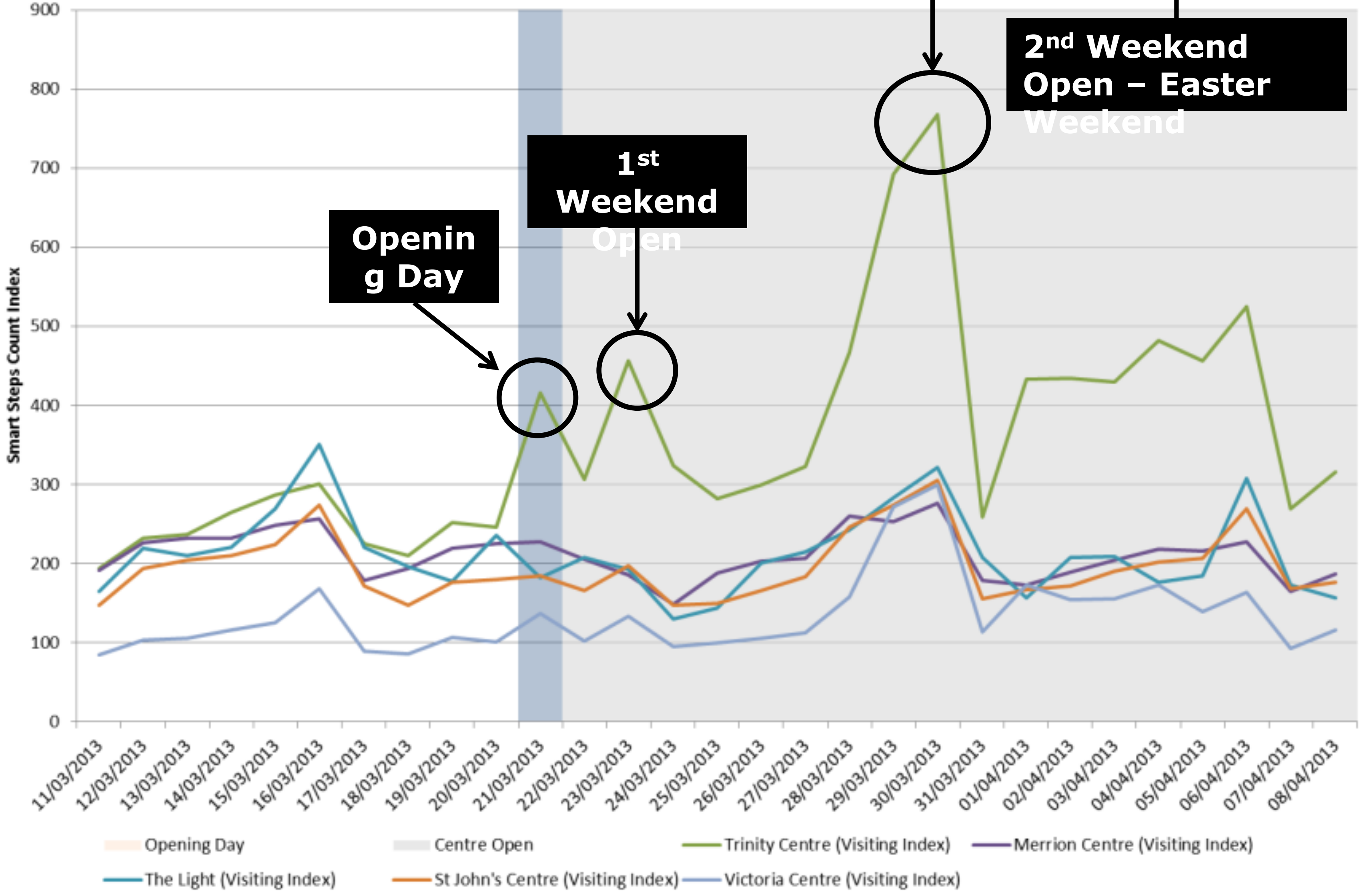
Variations in supermarket expenditure in Cornwall by time of year from Nectarcard data. A collaborative PhD studentship undertaken in the Centre for Spatial Analysis and Policy with commercial partners [27].

Trinity Leeds opening week busy grid

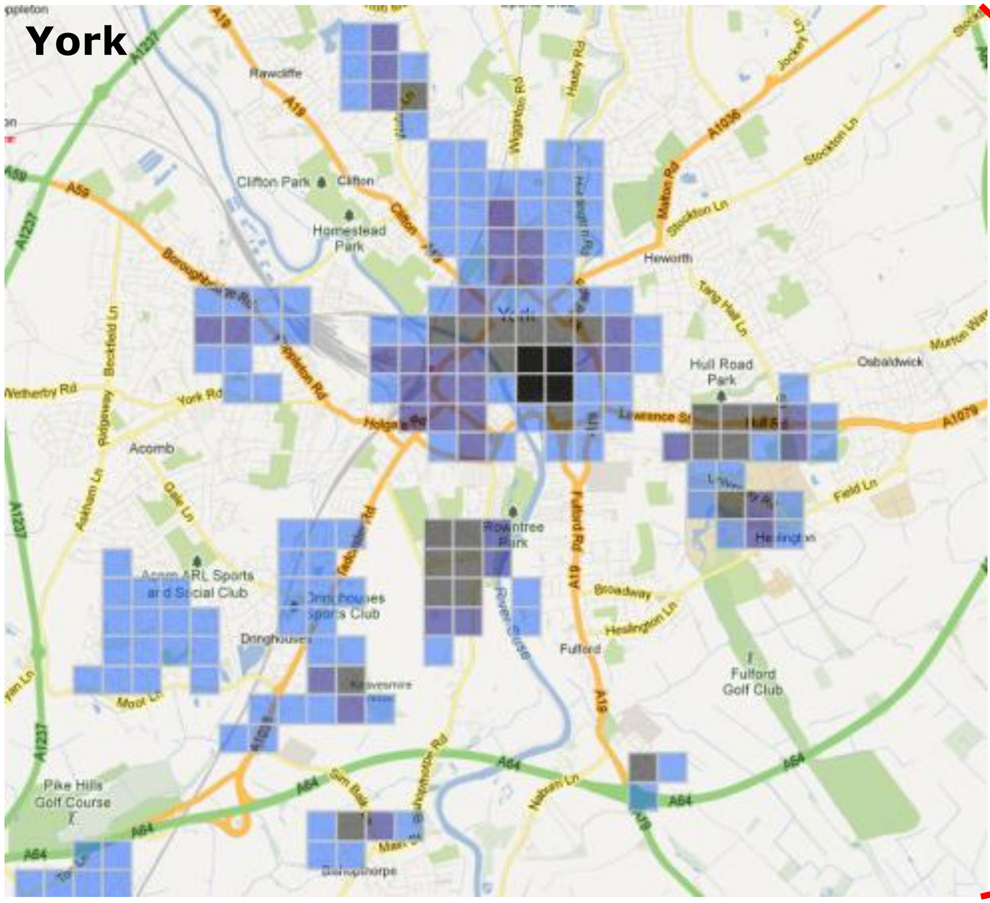


- 60% increase in footfall prior to opening (within Grid) compared to the previous day
- A Sharp peak notable at 10am when the Trinity Centre opened it doors
- Highest footfall activity count occurred at 12pm on opening day
- The Busy Grid shown represents count data in a thematic format

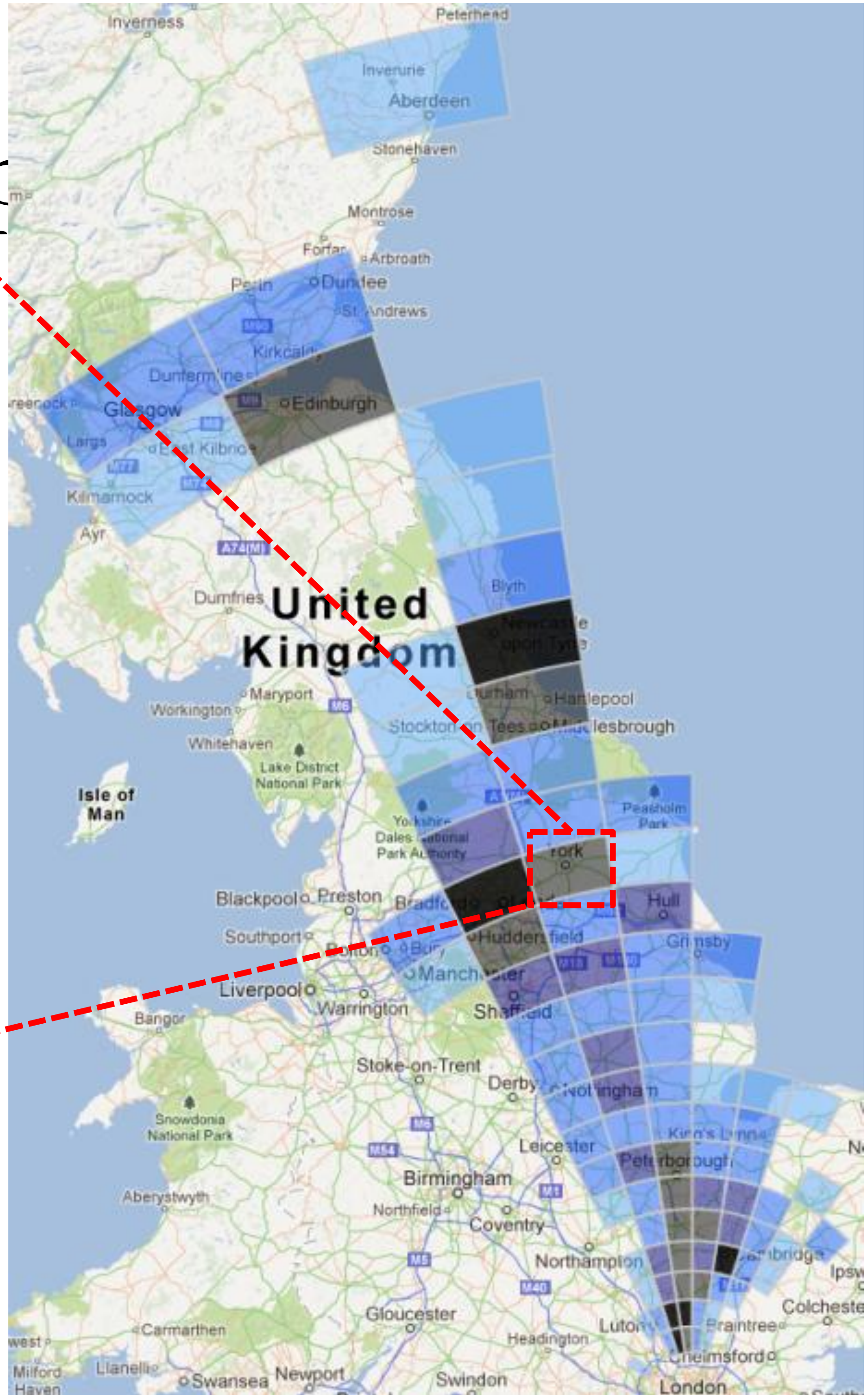
Time Series: Retail Area Comparison



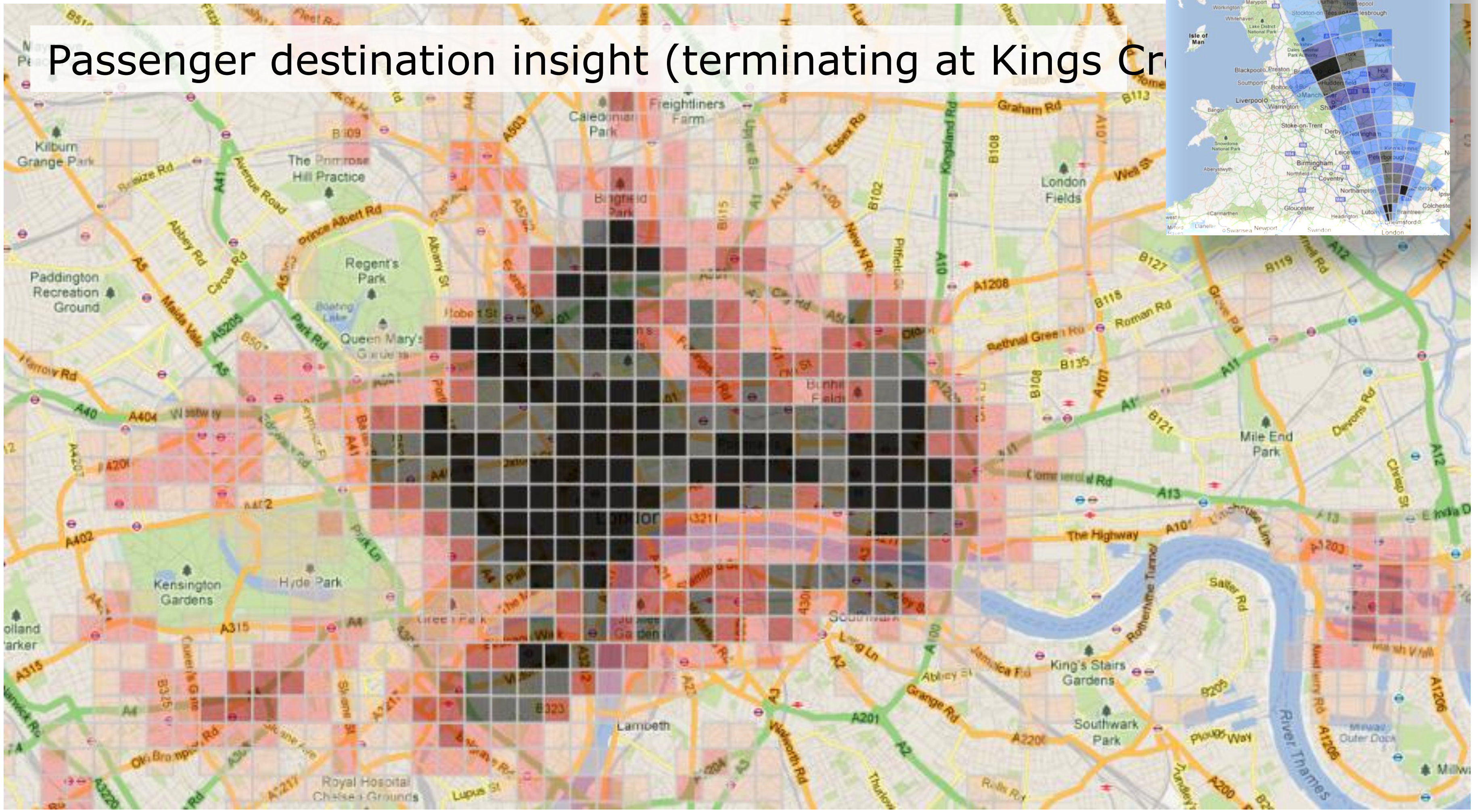
Powerful transp

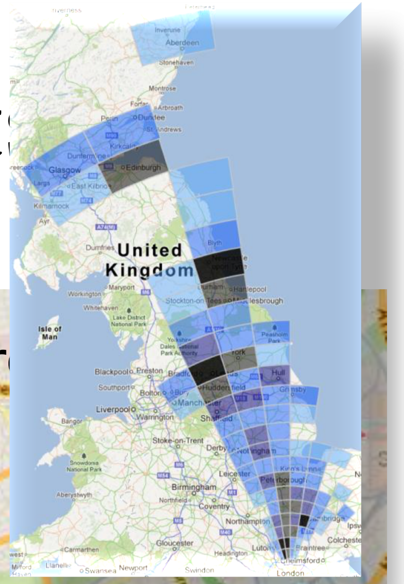


Passenger origin insight (East Coast Main Line terminating at Kings Cross)



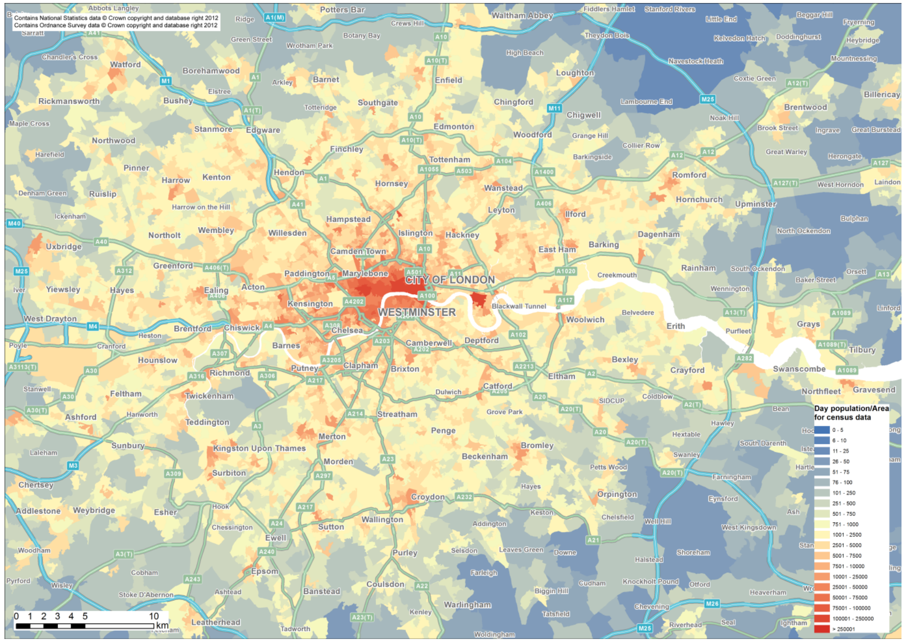
Powerful transport insight



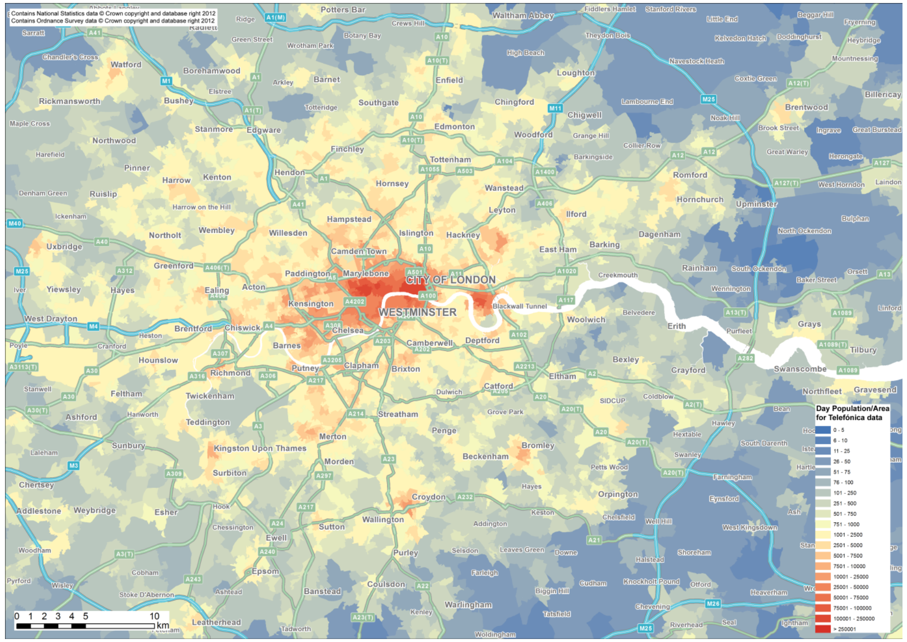


Daytime population density (workers)

Census (LSOA)



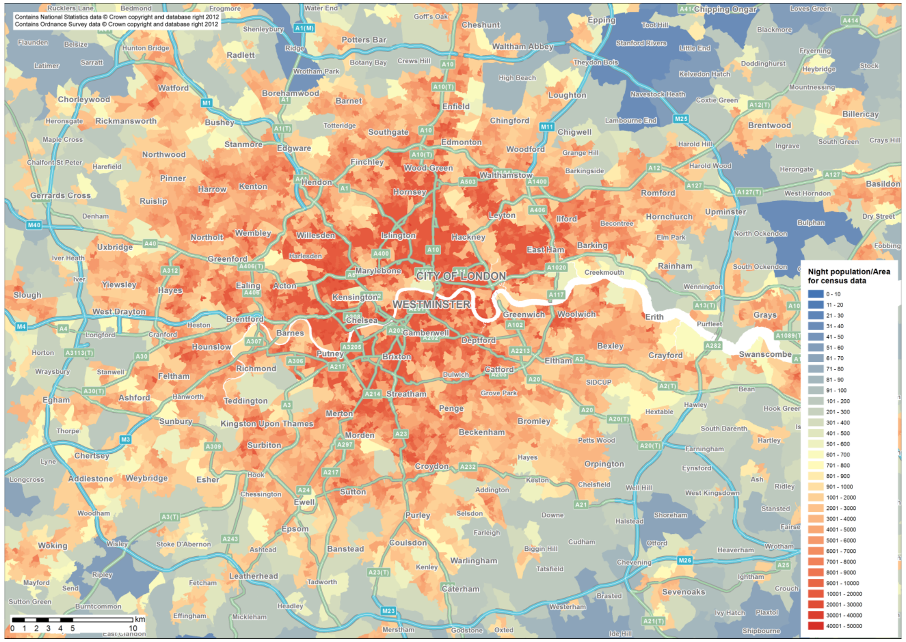
Mobile Phone (LSOA)

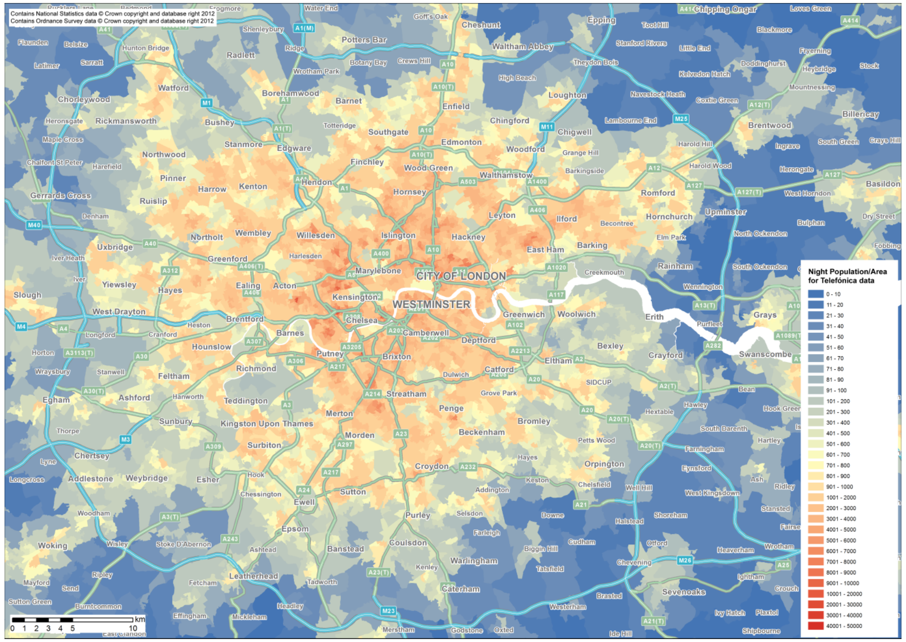


Night time population density (residents)

Census (LSOA)

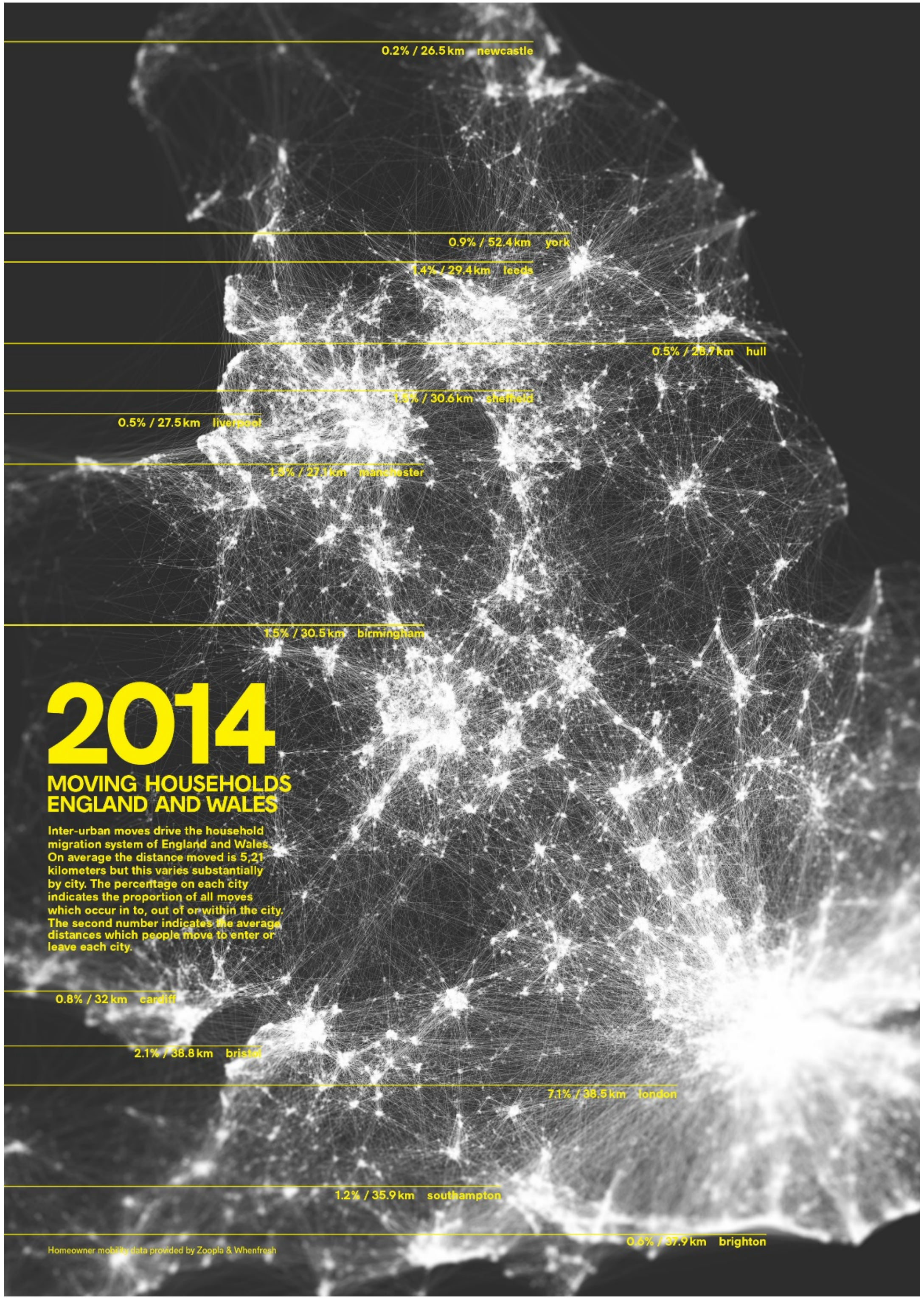
Mobile phone (LSOA)





Sales

- The higher the value of a sale, the further the household moves. This holds up to the >£501k category (where London moves dominate)
- Affluent achievers and rising prosperity groups move further than other groups
- Overall, average distances moved are relatively short



Conclusions

- In the real world you need to deploy an eclectic and pragmatic approach to spatial modelling.
- Extended SIMs work well in many areas but not everywhere (e.g. petrol forecourts) – often a multivariate approach is more appropriate. Also links to other models can be productive – population projections, choice modelling, etc.
- However, I think we have demonstrated over the last 40 years that SIMs have an important role in the quantitative geographer’s tool kit
- But: where is the next generation of Spatial Interaction Modellers coming from?


A.G.Wilson's
Spatial
Interaction Band
BEATLES