University College London

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Session 2: Smart Cities Are About Information, Hardware And Software: Data And Technology

1. The Wired City: Computable City: Information Infrastructure

Michael Batty

July 7th 2018

http://www.spatialcomplexity.info/

If we look at other elements of computing, data and organisation, which we might refer to as dataware and orgware, then these are becoming more important in the value chain – how much more so is tricky to figure but organisation is absolutely key to good operation and integrated data too is key – orgware and dataware will be the keys to the smart city, rather than hardware and software

The next era in this nexus will be clouds of data and programs and access using various kinds of hand-held device –or even voice. Do you have an Alexa? Yet? Well let me show you …..

But before we deal with the kind of data that is now being generated in terms of smart cities, let us take one last look at history and see how all this has emerged. Graphics is key as we will see.

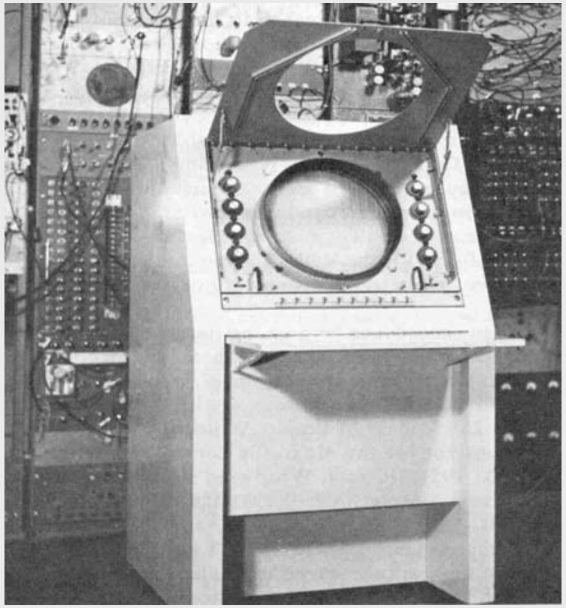
https://www.theguardian.com/lifeandstyle/video/2017/jan/26/alexa-amazon-echo-virtual-assistant-friend-gadget-video

Two More Keys to the Smart City: How We Access Computers: ***The Graphical User Interface GUI***

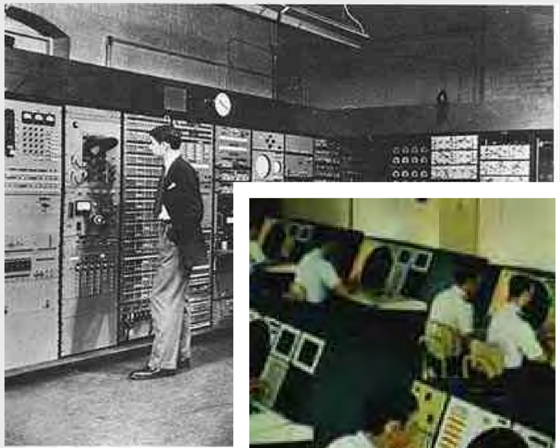
Graphics began almost as soon as computers were invented between 1940 and 1950; essentially to connect up components, oscilloscopes were used to interrogate the worked of the machine as these were based on probing using an electron beam, they presented an early form of graphics

Somewhat ironically for our field, the person who wrote the book ***Urban Dynamics*** in 1969, Jay Forrester, led the Whirlwind computer project at MIT after the war – a defence related project to do with missiles – and in 1950 he went on the Ed Morrow show, ***See it Now*** and demonstrated the first computer graphic – a bouncing ball on an oscilloscope. There are other stories for example in Wilkes lab in Cambridge UK.

I am now able to show you the clip from the Ed Morrow show. When I last gave this talk it was not online but it is from the MIT video collection so here it is. Here is the oscilloscope on which it was played too.



I also want to show you *Whirlwind at MIT* and also a clip from Ed Morrow’s iconic show from the early 1950s about networks



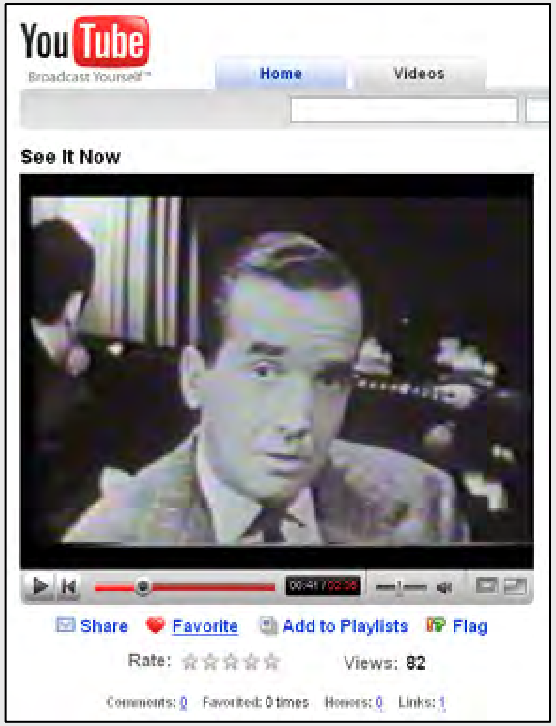
1951

- MIT´s Whirlwind debuted on Edward R. Murrow´s "See It Now" television series. Project director Jay Forrester described the computer as a "reliable operating system," running 35 hours a week at 90-percent utility using an electrostatic tube memory.

Start of 1945 project:

Completed: 1951

YouTube Broadcast Yourself™



But lest we think that it was America that produced graphics then is worth showing a Russian clip of how they programmed an animated cat ***Kittie*** in 1967 – using a symbol mapping kind of animation. The movie was produced by Nikolay Kostantinova

This kind of animation was also used in our own field to animate the ***Growth of East Lansing Michigan*** by Alan Schmidt at Harvard computer graphics lab in the same year – long before we began to directly associated screen memory with graphics

I will show you the two clips before we go and stalk about how graphics really was driven by miniaturisation on the one hand and the fact that many many more people had access to machines due to the PC revolution from 1980 on.

The earliest computer movie I found in YouTube

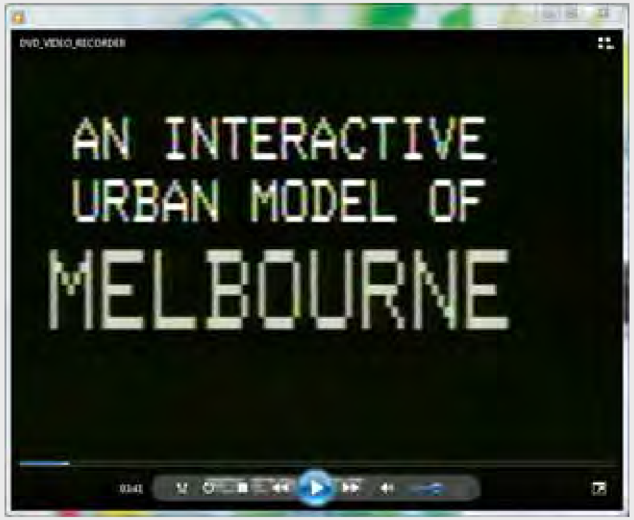
I can’t show you the movies here but you can get them on YouTube

And now I will try and show Alan Schmidt's movie of the growth of East Lansing from the mid-1850s to the late 1860's

Ok, graphics which did not get going until miniaturisation reached the point were we could produce cheap personal computers – the PC – depended intimately on Moore's Law

Before then graphics was done either by producing frames from a computer as hard copy **SYMAP** or but tracing out an image on a display tube by electron beam and then capturing the image with some sort of copier – often by taking a photograph. The great insight which came a little earlier in the 1970s was to associate the computer screen with memory and it was at Xerox Parc that the really path breaking work on interaction with computers was done. The story is well known that at Xerox Parc they intend most things that have become commonplace – the mouse, windows, ethernet, hypertext. The story was that Steve Jobs pinched all the stuff for the Apple Mac …but PCs were stuck in the command line mode

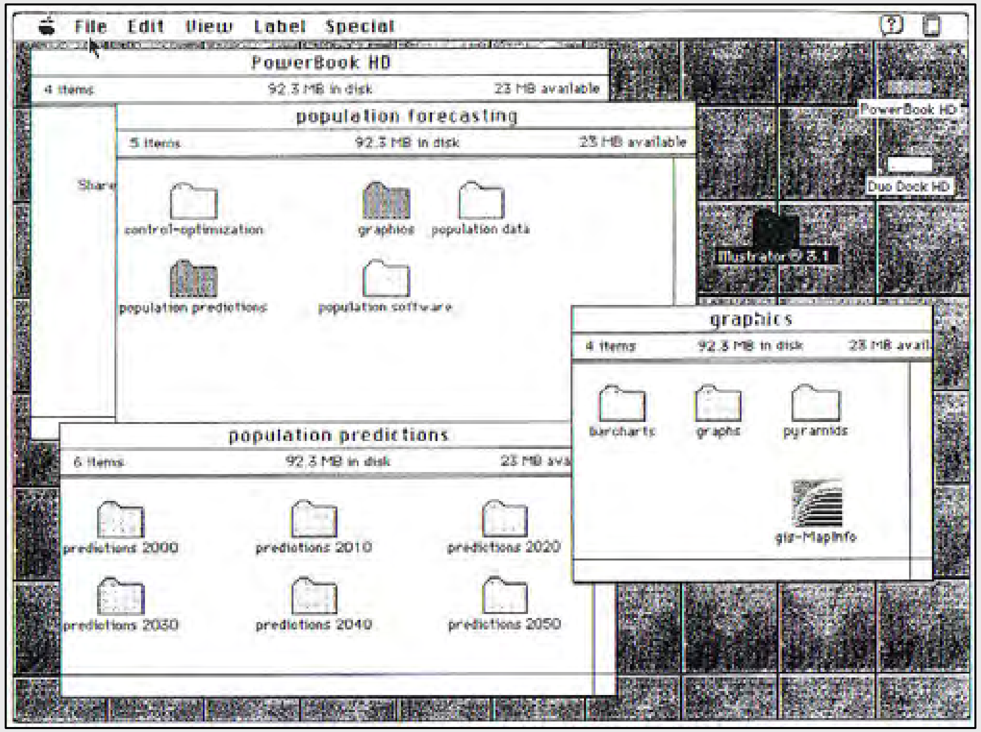
But most PCs were truly stuck in the command line mode really until the mid 1990s with the development of Windows 3.1. This is the way we interacted which was painful – here is an example of an early command line driven system – an urban model for Melbourne which was accessed through a graphics terminal where command line and graphics were quite separate in terms of the memory – you can actually see this – 1982 -



If you go to www.complexcity.info, you can find this movie and others that show early computer graphics and land use models

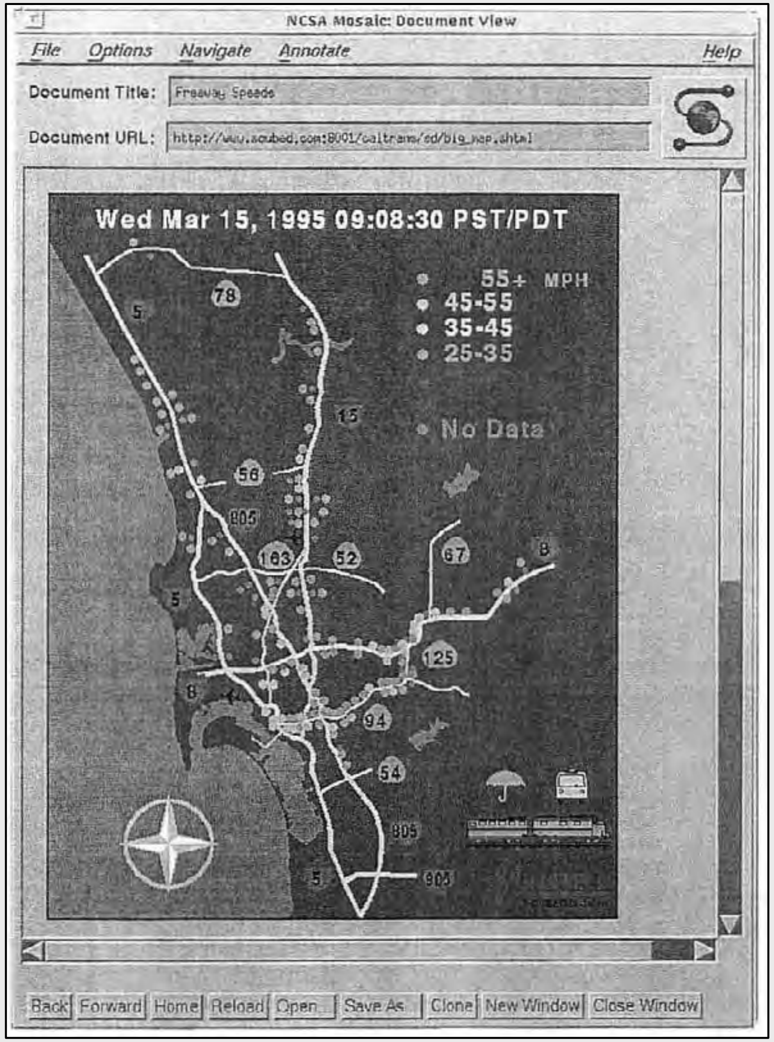
In the 1980s, the development of the user interface was very fast and the Macintosh, a whole generation of workstations such as those from Sun and SG were introduced with graphical user interfaces but it wasn't really until Windows 95 that things really began to take off. It took a long time too to see the interface in the way I am showing it today on this powerpoint – and there are rapid developments all the time, of course now on phones and tablets and so on

However what was clear was that the web – the world wide web which was essentially a graphics interface to the internet – is the first browsers were essentially graphic. Of course there were access software before **Mosaic** which was the first effective interface like **Gopher** but the decision to make it graphic was key – I don't quite know why – not sure it was to do with Tim Berners Lee. More likely Larry Smarr at NCSA.



A Desktop PSS for Population Forecasting
on a Mac circa 1993 ↑

A Web-based Feed of Real Time Traffic Data
In San Diego circa 1995 →



If we look briefly now at the web and its graphics, then the essential distinction between web 1 and web 2 – web 1 is really passive – read, while web 2 is more interactive – read and write – to use TBL nomenclature

Web 3 is more like using a degree of intelligence in interacting with the web – it has not got a very clear definition but some say that it is the web with AI or rather the semantic web

Anyway the key issue is that the web is completely graphic – that is the predominant way of access and in essence the mouse and keyboard are also being displaced in hardware terms by touch screen

3D graphics, and animation are now taken for granted – massive developments but progress with good HCI is slow and problematic

There is now a key move from the desktop to the web – a kind of enfranchisement where it is essential to have graphics – another component of modern computing and this of course is central to the idea that new styles of computing will be participatory – as we see in information systems in the city – and this of course will be the essence of the smart city.

What is now happening is quite hard to comprehend. I think we are a bit close to it all - too close to it – a lot of these developments seem to be slowing down in terms of interfaces and this focus is now on very simple Apps on phones and these is likely to be some critical merger with TV. The thesis about productivity gains is an issue here and we will return to is later – the real gains are where we make new things possible but graphics is only making most things a bit better

Our Second Key to the Smart City: ***The Convergence of Technologies: IT → ICT***

My second major point is by now quite obvious to us all but is was barely anticipated –obvious in hindsight of course – but it required miniaturisation and new materials based on the notion that computers would converge with other technologies, with people and with their activities.

The first convergence is linkage of computers and communications and there are two modes: *the first mode*: software and data are linked across the desktop with the user providing the momentum for this; *the second mode* is software and data linked across the net and this is part and parcel of the client-server architecture that now dominates.

This is a shift from moving people to information or to people with information versus moving information to people – face to face contacts - moving is more than just information, it involve people and activities – the electronic cottage is essentially a myth; it never took account of networking and it didn't anticipate the power of wireless, thought to be dead technology in general until its resurrection for connectivity

- second convergence is TV, video, phones, and of course computers where networking is assumed
- third convergence – computers in mechanical devices which is happening extensively at a low level
- fourth convergence – computers into places – the smart city
- fifth convergence – computers inside people. – implications for space and interaction are profound.

We will come back to all this at the end of the talk today when we talk about how ICT is affecting distance and time as this is key to the smart city.

But we should also flag the fact that ICT and natural systems, particularly biological systems are converging. This is a very controversial area – it is no accident that just as Shannon was doing his famous work on coding and people like von Neumann were building the first computers, the other essential insight into coding was developed: DNA and the genetic code which was discovered by Watson and Crick in 1953. I think there will be some profound developments in this domain in the near future – there already are and this may be where the momentum will drift.

Where the Wires Are, Telecoms, Broadband, G3, G4

Ok we have done a lot on the essential background but we need to say something very quickly about where all this hardware is embedded and to do this I will give you a quick summary.

The location of the hardware, the wires and the wireless are also key to delivering information but it is hard to figure all this out because everything is so bottom up

Essentially most of our connectivity still is sitting in front of a computer and interacting directly but as I type this slide, I keep going back to the web – because I am connected – wirelessly in the office in the hotel at University, and I search for information on the web. So basically although probably 70% of my interaction now is me and the computer, some 30% is me, the computer & the net.

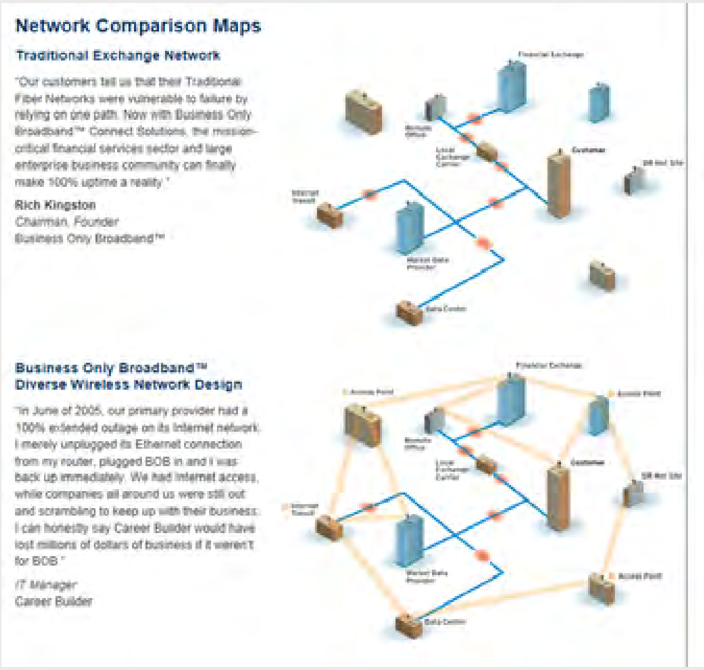
This is important as it is growing fast and the ratio of desktop to net will fall. When I first wrote this slide it was 80/20, now I reckon 70/30, and probably next year 60/40.

Ok let me show you three things – where the wires are – some of them – where the wireless is – some of it and then something about how data is transmitted and where the data centres are.

First let me look at the big wires between continents like the north Atlantic cable. There is a very nice interactive map of this and let us see if we can pull it http://www.cablemap.info/

This was first done for the electric telegraph – read Tom Standage's book – but these cables are being put in everywhere. I need to tell you my experience outside my flat in central London where the street is dug up at least 15 times a year

Wireless requires repeaters – wireless towers to capture the data and then transmit it on – remarkable really radio waves compared to fibre optics – generally wired is much faster still and can also take massive amounts of data in the cables – under sea cables back to the idea of the telegraph and telephone http://atlantic-cable.com/Maps/index.htm



The way data is communicated is that it is broken up into packets and packets are switched and make use of redundancy of the network – assembled at the other end – I think this is how it works – it always seems to work – indeed one of the major issues about electricity is that is it so robust but I expect this must be the case if it is everywhere

The last point about the wires involve data centres – You have probably heard about the big Google data centre in Oregon where they are taking over a whole town (in terms of jobs that is I guess) – there are many of these big server factories and farms and big switches for the internet –

Let me show a couple of pictures and then also point you to a very interesting Google web site that tells you the story and we will load it and see

Telehouse west in London……………………in Amsterdam

http://www.google.com/about/datacenters/gallery/#/

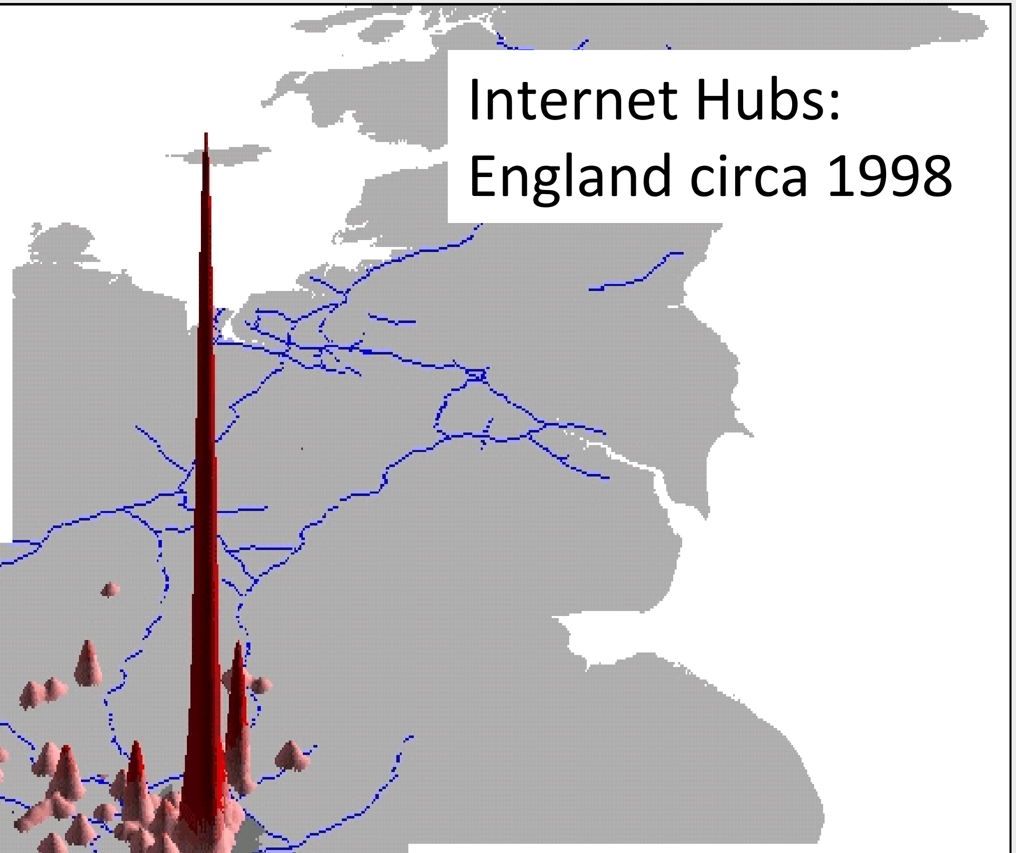
https://www.youtube.com/watch?v=avP5d16wEp0

Early Smart Cities: Networking: Wiring Industry, Technopoles, Science Hubs and Parks

Let me say something very briefly about how people thought of smart cities as soon as it became possible to develop wide area networks in the mid to late 1980s. Combined with a lot of hype about fibre optics – but remember the internet was not yet invented – as such – then the idea was to network places and putting in the fibre was the key issue. It still is and in fact the biggest concentrations of wired stuff and probably wireless is in big cities

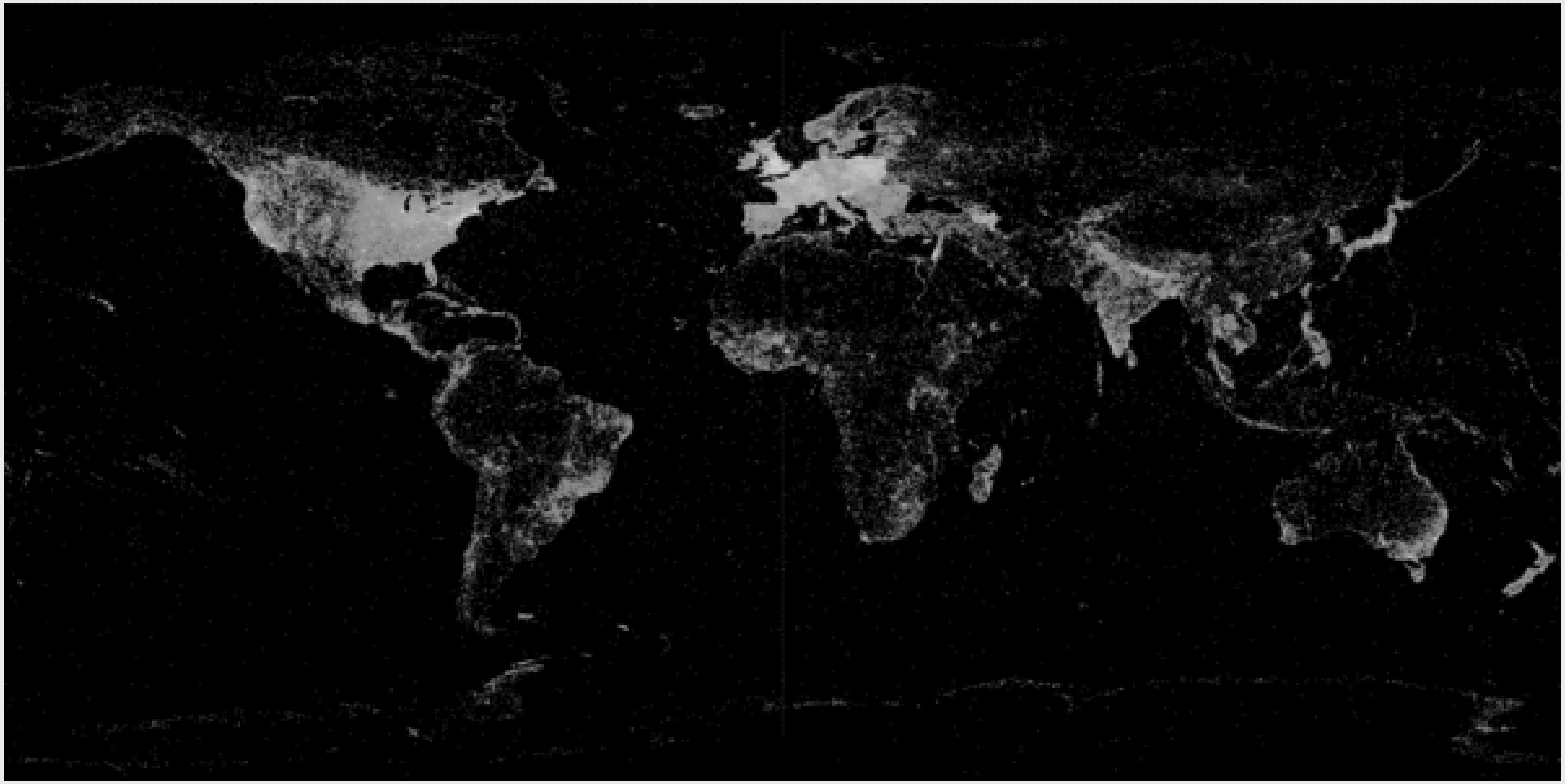
Not particularly in high tech concentrations where hardware and software is being developed but in places where it is being used – financial centres. Here is a map of the UK in terms of internet hubs in the late 1990s

Internet Hubs: England circa 1998

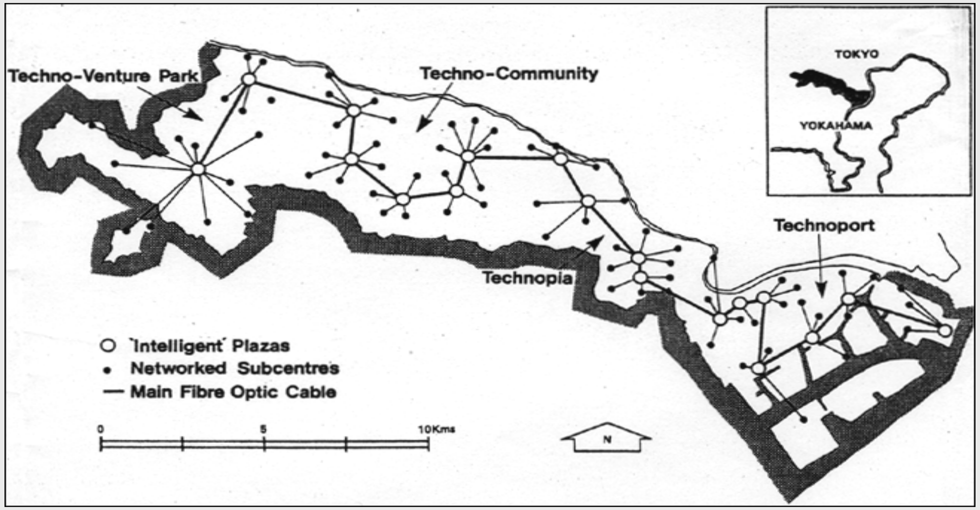


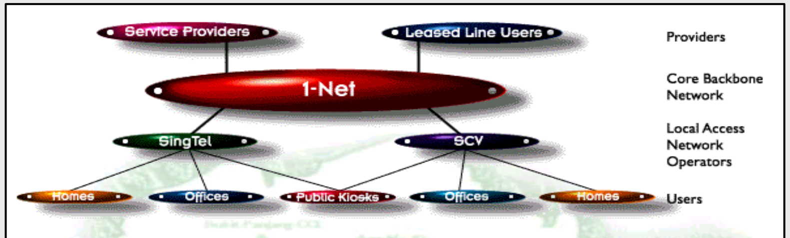
The NY stock exchange above and the London stock exchange below. Note how traders are now gone as a physical force – it is all electronic trading

I can't find a good map of computer IT/ICT concentration per se but these are Wiki points – there are many maps like this that tend to show use rather than hardware



Singapore: The Intelligent Island; Malaysia: The Multimedia Super Corridor, Kawasaki Japan 1989

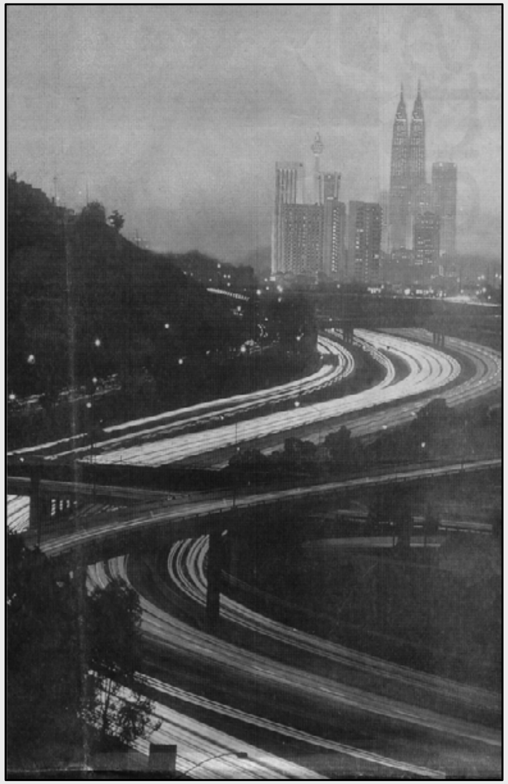




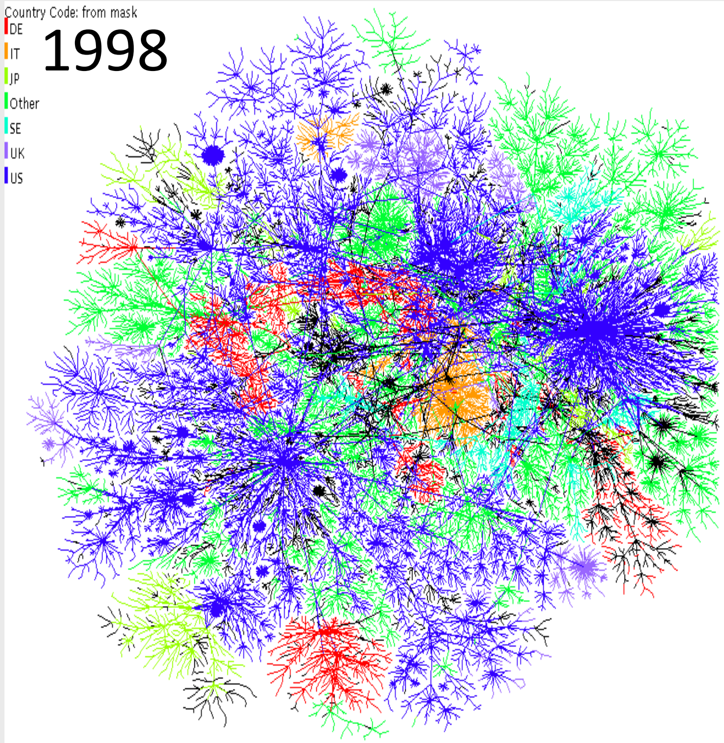
2. Local Access Networks:

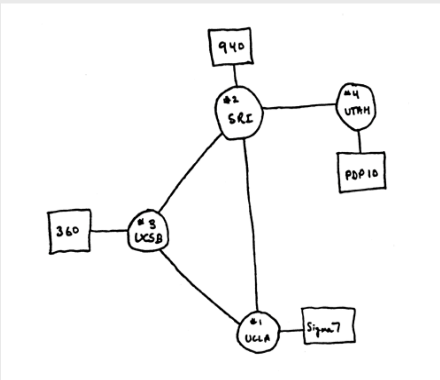
Connected to the core network are the local access networks that covers throughout the nation. The two operators Singapore Telecom and Singapore Cable Vision will utilise the existing telephony and cable TV infrastructure respectively to deliver broadband multimedia services to the end-users.

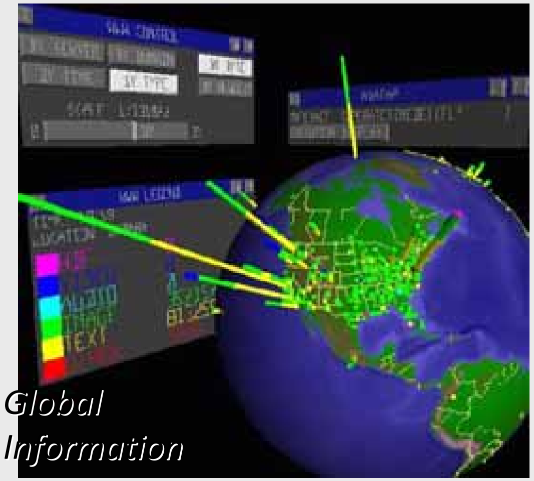
They will employ advanced technologies of Asymmetric Digital Subscriber Line (ADSL) and Hybrid Fibre Coaxial (HFC) cable modems in their existing infrastructure to deliver multimedia services at high speeds to the end-users at home, schools, offices or public areas.



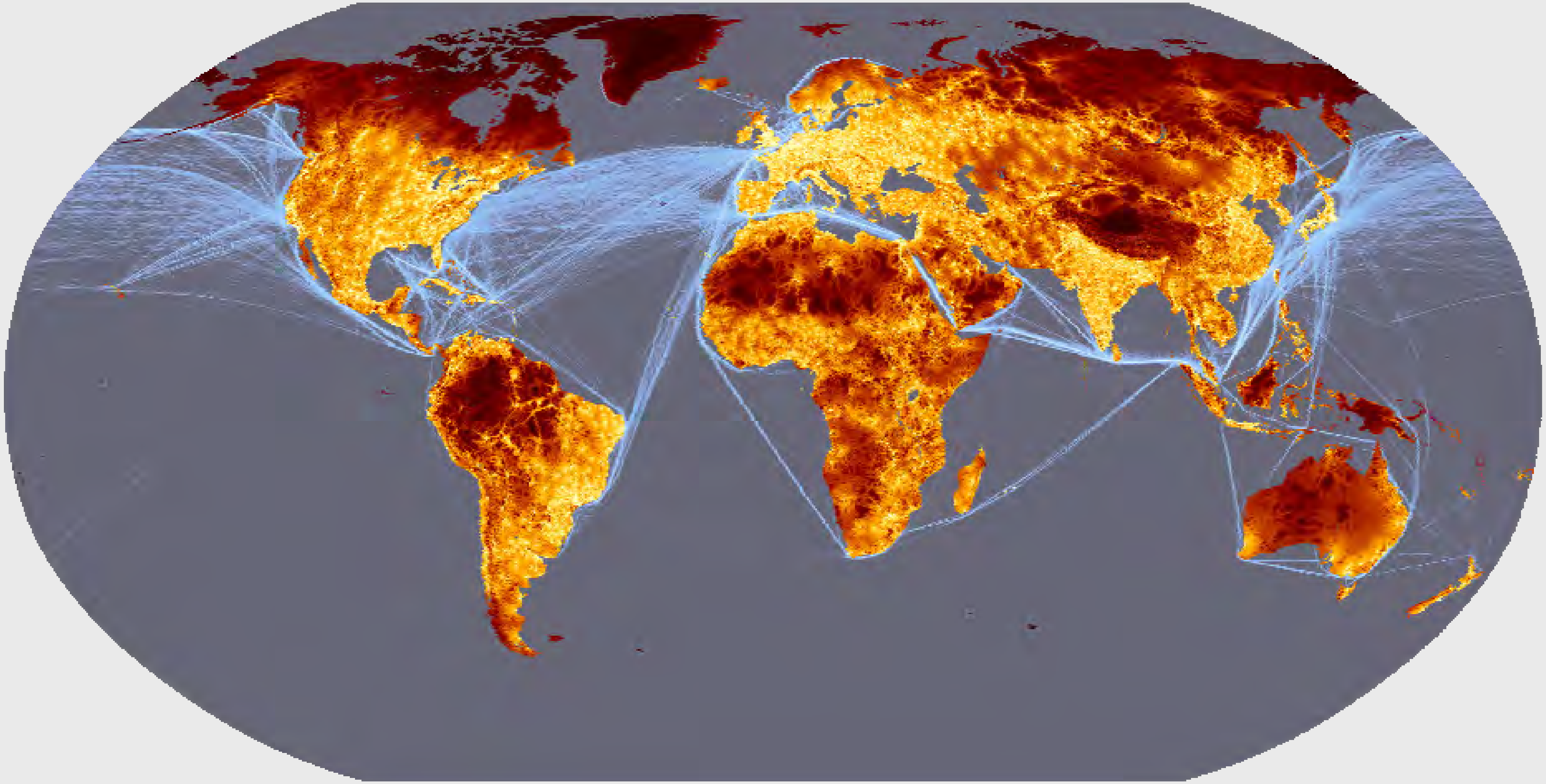
The Internet: Arpanet to The Web







Global Information

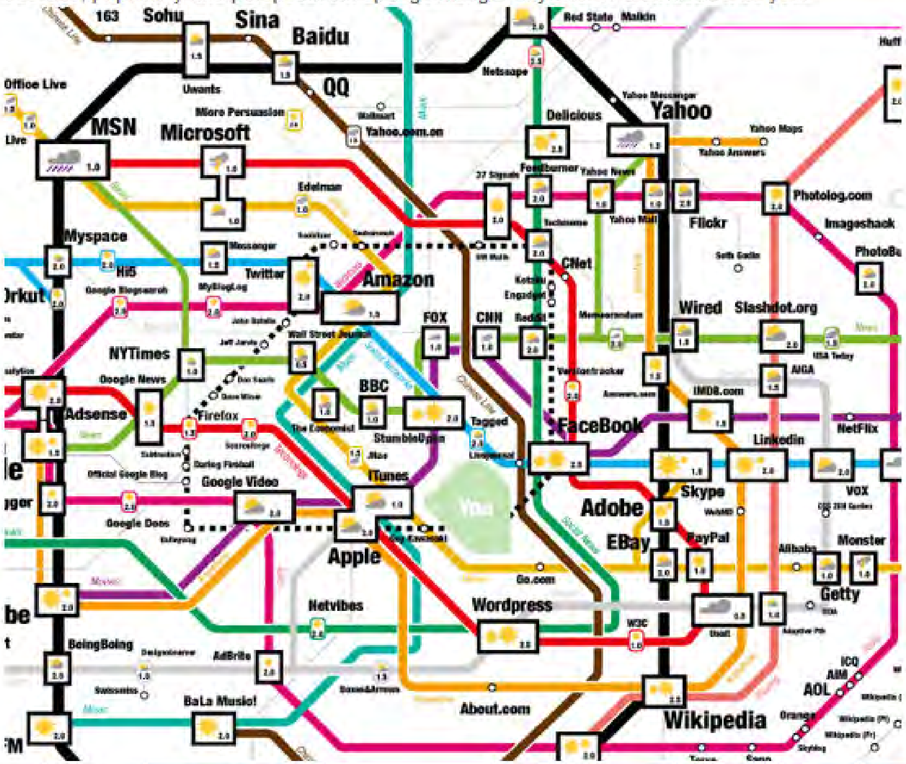


A TUBE MAP OF THE WORLD WIDE WEB

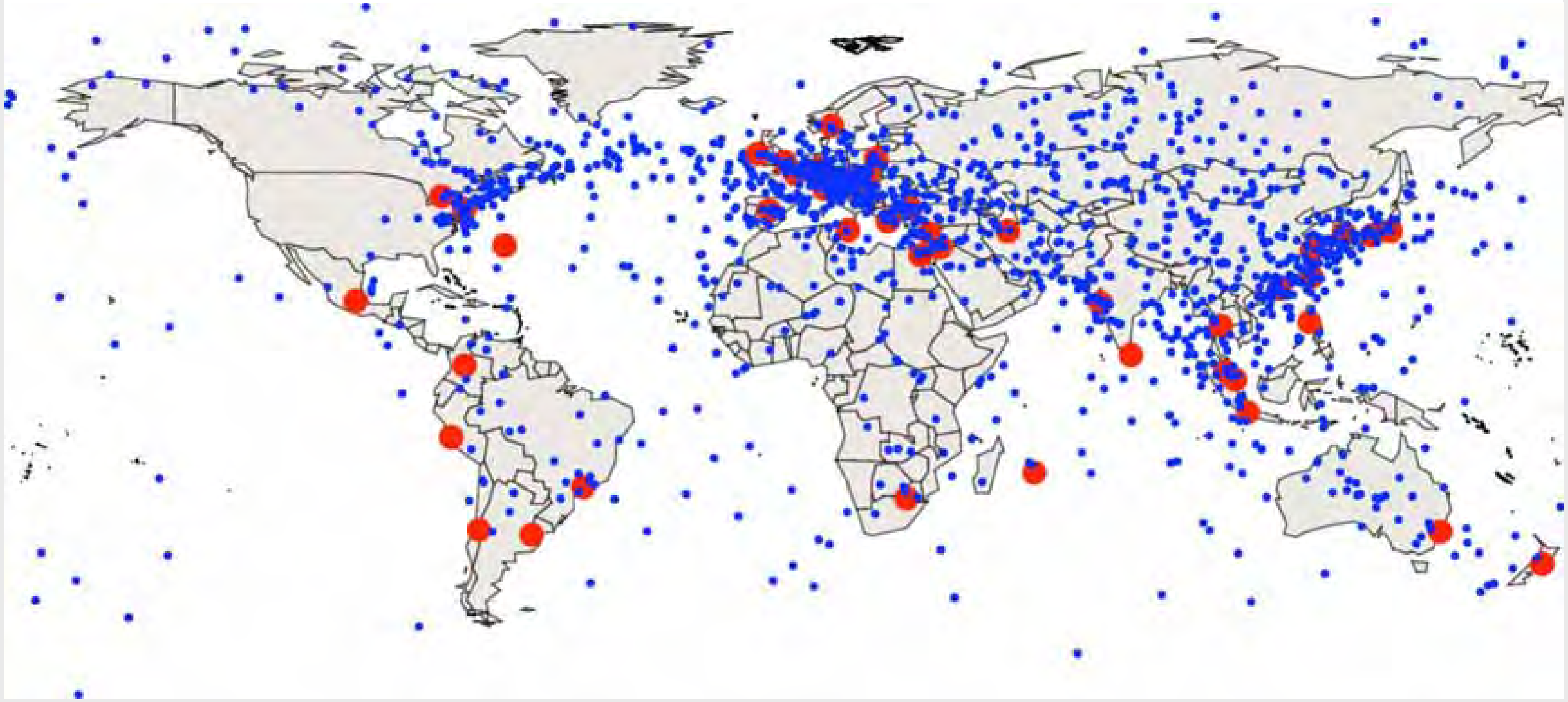
Updated Jul 26 2007 - 11:58pm · Posted Jul 25 2007 - 3:00pm by GeekSugar · 24 comments

Internet Subway · Map

Our Dear Mr. Internet letters have finally been answered! Thanks to the creative peeps over at Information Architects, there is now a web trend map that offers a visual of the ginormous world that is the internet (or internets as I like to call it). The masterpiece uses a subway map template to pinpoint the 200 most successful websites on the web, ordered by category, proximity, success, popularity and perspective... spot geeksugar anywhere? Download it as your

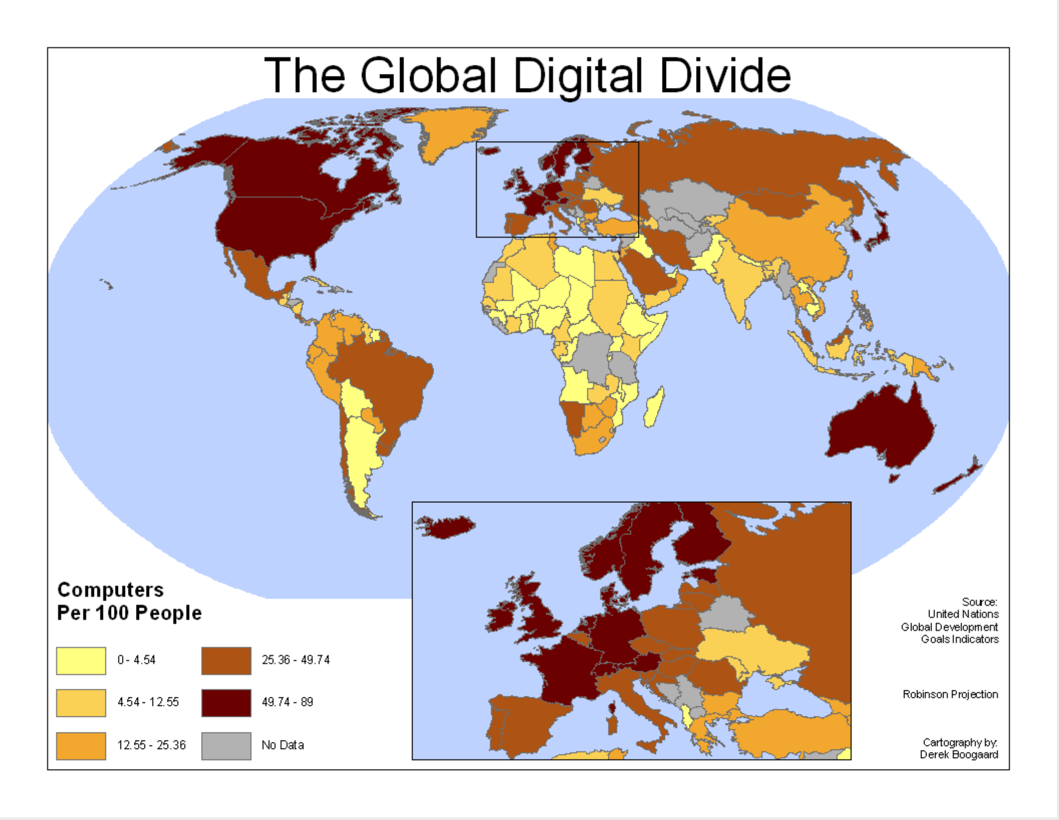


Financial Concentrations : High Frequency Trading



The Information Divide

I need to flag the fact that all these things are part of the smart city and the fact that smart cities are global in this sense. In some respects we should have maps of the use not the actual ownership and this is a key point. We will not say any more other than flag the divide as a recurring issue



The Impact of Technology on Distance and Time: Another Key to the Wired World and the Smart City

Ok – a long talk – but let me focus on my last theme because as geographic scientists and urban researchers we are clearly interested in space.

Clearly each wave of technology through the industrial revolutions has meant change in the way we interact – in particular the distances over which we can interact and also the speed of that interaction

First came the internal combustion engine and steam and this led to railways and then to automobile – so average distance that some one could travel increased dramatically from say 5 or 6 miles to 10s of miles, and the time taken decreased

Then came electricity and the telegraph and the phone with very long distances being possible in terms of communication, not physical travel so this was an information medium

The computer and ICT has accelerated all this and in fact it has led to almost continual communication

Air travel has led to global movement but in general we are still restricted by how long it takes to drive – however there are strange and insidious things going on with travel. It is hardly the death of distance but there are strange transformation going on with respect to locational decision-making and it is this that we need to get a handle in in terms of the smart city.

Productivity gains have slowed in fact due to the fact that most of what is now happening is improvement not massive disruptive change – we will continue to speculate here….

There are many references but look at

http://www.spatialcomplexity.info/technicity and read, peruse

Andrew Blum (2012) **Tubes: A Journey to the Center of the Internet**, Ecco, New York.

George Dyson (2012) **Turing's Cathedral: The Origins of the Digital Universe**, Vintage, New York.

Dava Sobel (1997) **Longitude: The True Story of a Lone Genius Who Solved the Greatest Scientific Problem of His Time**, Walker and Company, reprint, New York

Tom Standage (2007) **The Victorian Internet: The Remarkable Story of the Telegraph and the Nineteenth Century's On-line Pioneers**, Walker and Company, reprint, New York.

A Theory of the Smart City

Let me take one step back but at the same time propel us forward.

Having developed a lot of background, we are now ready to think about smart cities and what the real focus is now. Essentially computers and their communications can be applied to any and every aspect of the city but the *idea of the smart city is narrower than the application of all digital computation to cities.* In fact here we will take a broad view beginning by making a key separation between using ICT in cities for

a) *Routine purposes* – how to operate the city, manage it, and design the city in the very short term, and

b) *Strategic purposes* - how we understand and plan for the city in the much longer term

So ***temporal*** rather than ***spatial*** is a key organising distinction.

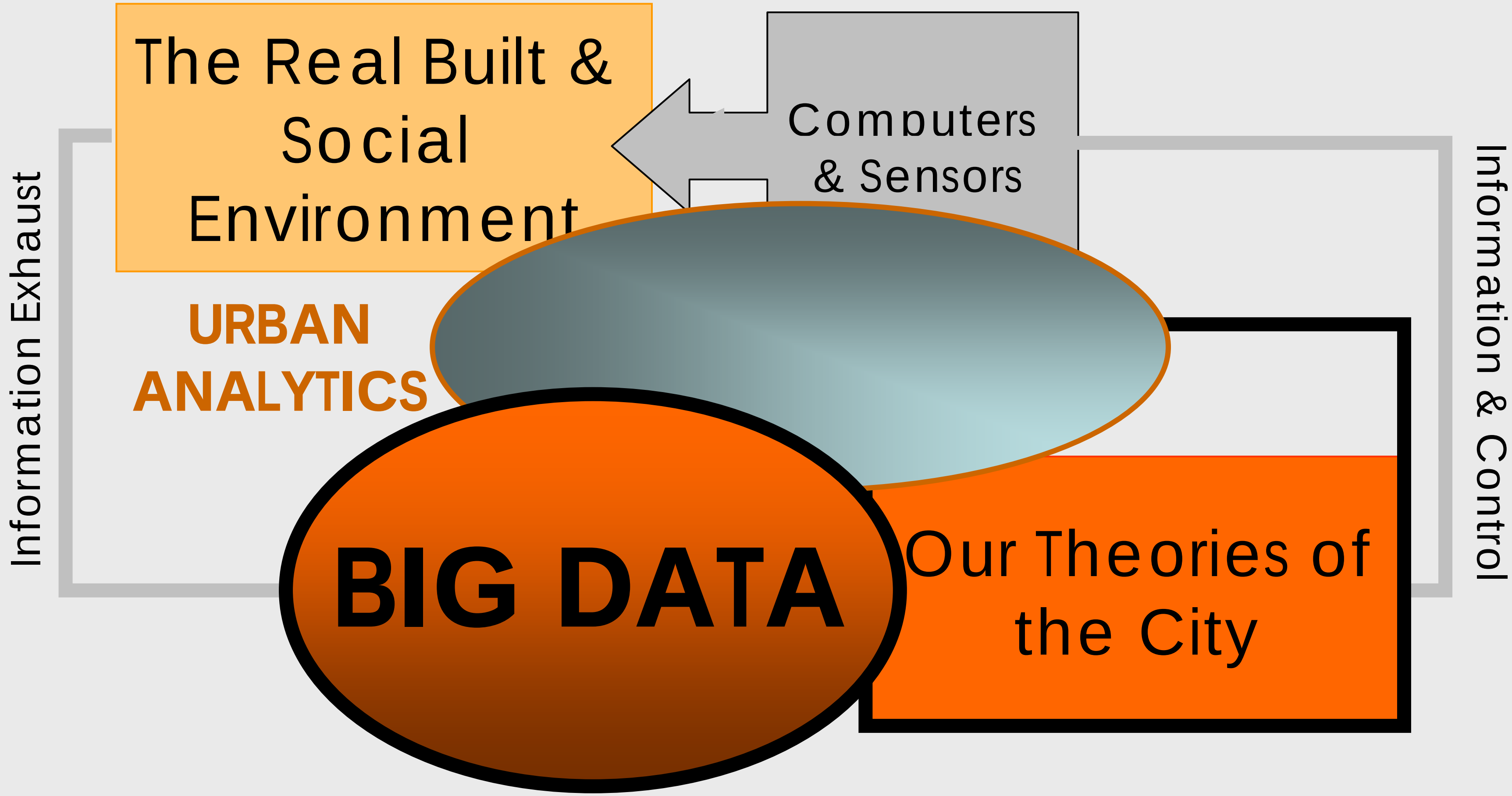
In fact there is a tendency for our methods and models and data to be clustered around the short term, fine spatial scale and the longer term, coarser spatial scale. So for example, the operation of routine movements and communications in the short term – second by second, minute by minute and so on – tends to be an the more individual level while our focus on the long term tends to be related to aggregates of such movements which pertain to bigger scale times and locations.

So we have a class of models and methods that pertain to short term fine scale and a different class that pertain to long term coarse scale. Important to note that both classes of models have existed for a long while but the more routine are being reinvigorated through modern ICT

So urban operations research models for emergency services, police, fire, crime and so on are examples of the more routine while transportation planning models, land use and housing market models are examples of the longer term more strategic.

We are tending these days in the smart cities movement to call models and methods ‘analytics’ while the other feature is data – and in this context ‘big’ and ‘open’ data have become significant. Essentially this is because computers are being embedded into the physical fabric of the environment – not only are we using models to manage and plan and improve the environment, computers are being used to control it and it is these that are generating streams of real time data – this is big data where time is the key dimension.

In this sense we might portray our focus on smart cities as follows



Now we can position our focus on the smart city across this set of domains. But before we do so and move to thinking about communications, let us focus on different definitions of the term smart city.

Generally the big IT companies define smart cities as digital technologies meaning software services being embedded or used in cities – this covers all aspects of our figure but in fact it tends to be nearest the routine built environment end of the spectrum

In the history of smart cities, the notion of the **wired city** came first and these were close to the 1980s conceptions of cable and Telephone services in cities. Then this concept was broadened into the **intelligent city** and some times this was notated as the **information city**. Castells was key in this.

In parallel to this as cities were being modelled in terms of their physical form, the **virtual city** came on stream – with cities being pictured as virtual realities. These grew out of 3D mapping and CAD, and thence virtual environments became significant in which the user could interact with the virtual city itself.

These virtual environment were in distinction to other models of cities that were more abstract and in a sense still remain on the edge of these conceptions.

As we proceed we will fill in the history and the picture of the contemporary smart cities movement; and in the next talk, we will begin with thinking about cities in terms of communications.

University College London

Session 2: Smart Cities Are About Information, Hardware And Software

2. Data and Technology: Big Data, Open Data, Data Infrastructures

Michael Batty

http://www.spatialcomplexity.info/

June 30, 2017

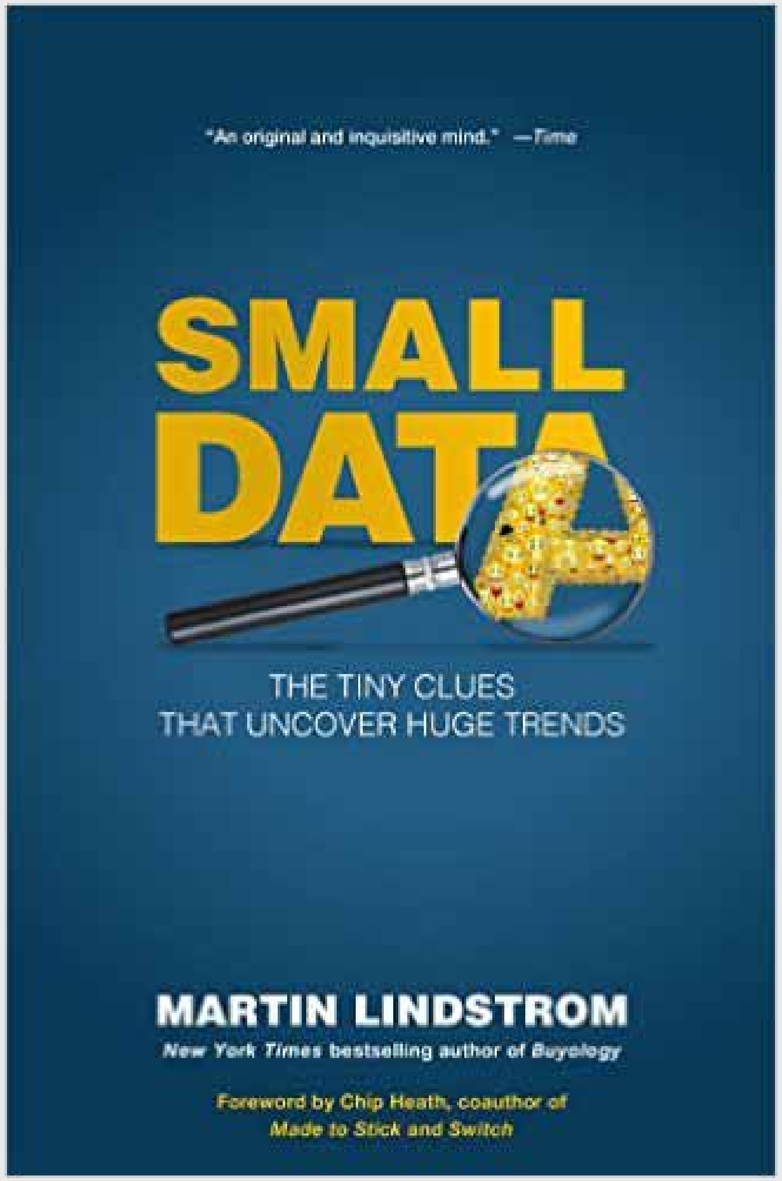
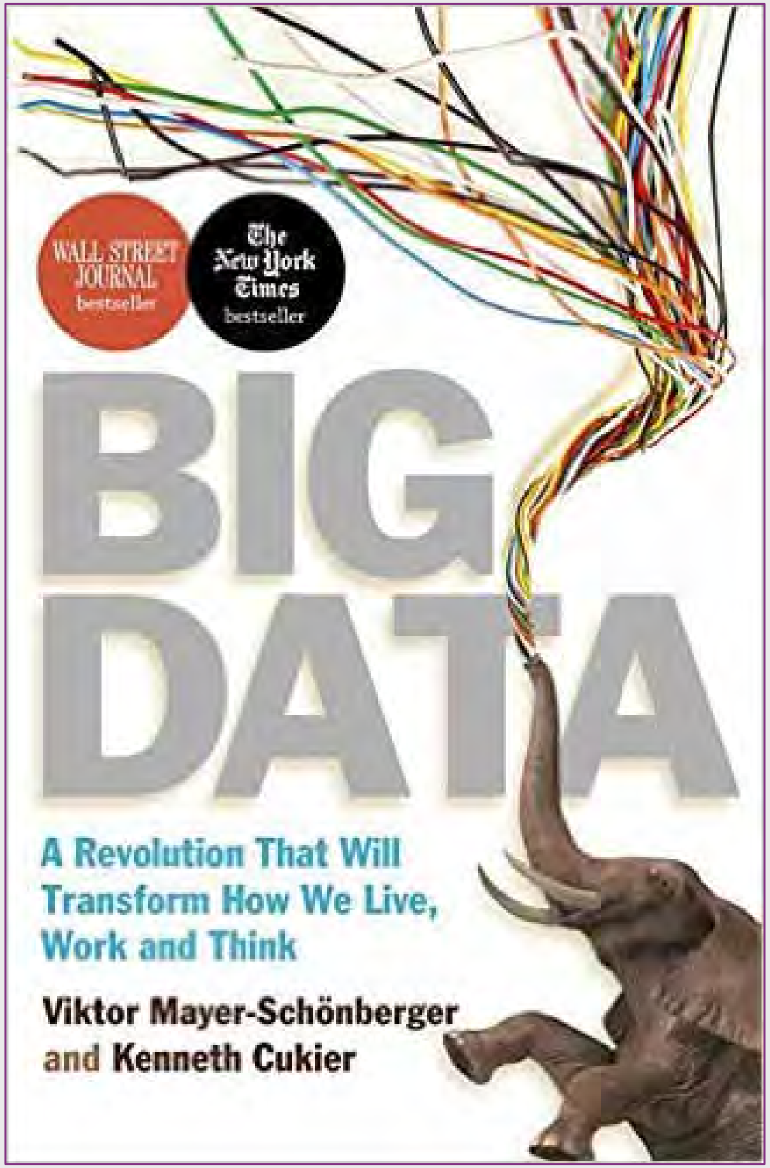
Let me point you at www.spatialcomplexity.info

where I will add the material under the menu item

Shanghai

There you will find

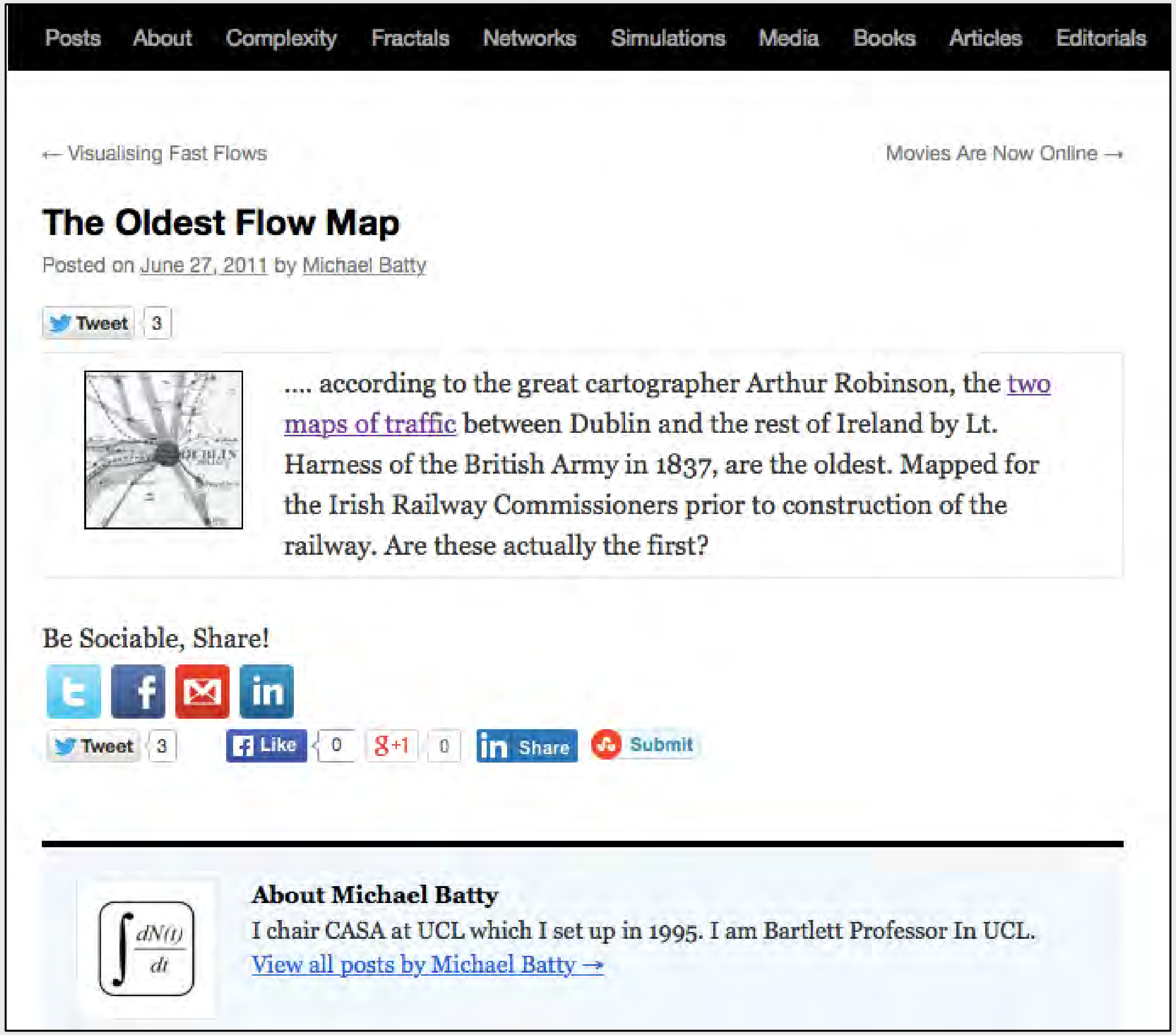
- **The Journal Publication: Big Data and the City**
- **Shanghai Smart Cities Lectures 1, 2, 3, and 4**


"An original and inquisitive mind." —Time
SMALL DATA
THE TINY CLUES THAT UNCOVER HUGE TRENDS
MARTIN LINDSTROM
New York Times bestselling author of Buyology
Foreword by Chip Heath, coauthor of Made to Stick and Switch

WALL STREET JOURNAL bestseller
The New York Times bestseller
BIG DATA
A Revolution That Will Transform How We Live, Work and Think
Viktor Mayer-Schönberger and Kenneth Cukier

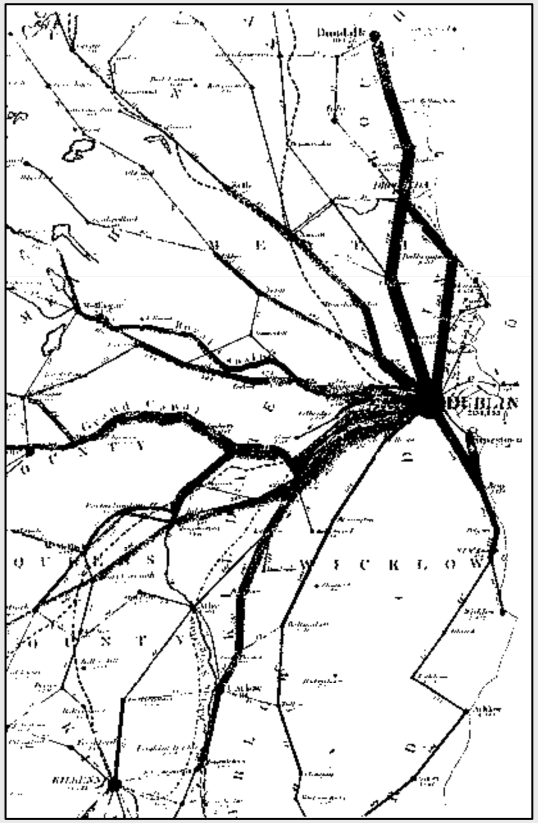
How Big is Data? Big Can Be Small & Small Big

- Data is big with respect to its volume. I know there are other definitions – velocity, variety etc. but to me, data is big if it requires large use of computer memory implying volume.
- In cities, data usually implies numbers of locations and their attributes but locations imply interactions.
- Thus data are relations between locations and in essence if we have ***n locations***, we have ***n^2 interactions***. Thus small data can become big. EG:

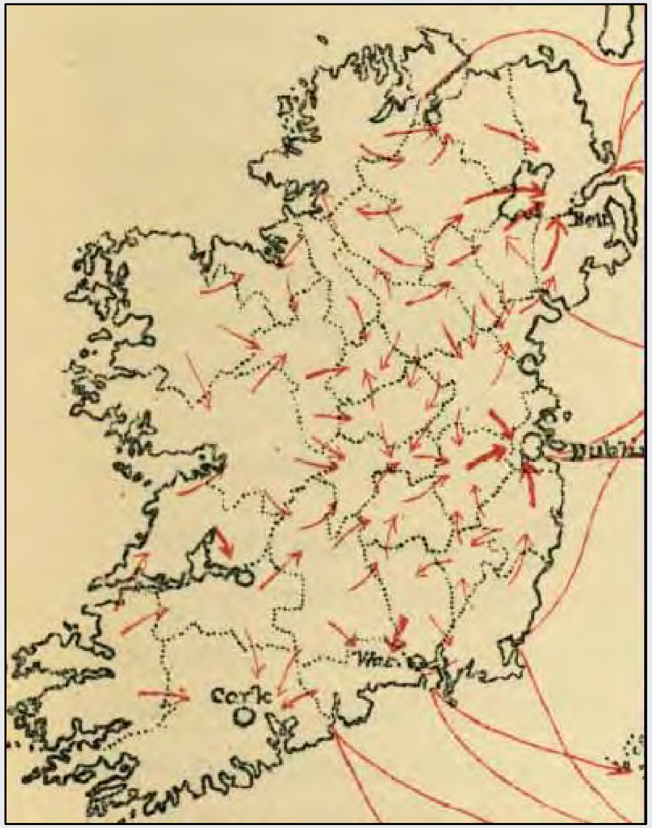
Examples: Dublin 1837, Ireland 1888, London 1953



Examples: Dublin 1837, Ireland 1888, London 1955



Harness, 1837



Ravenstein 1888

https://www.youtube.com/watch?v=pcBJfkE5UwU

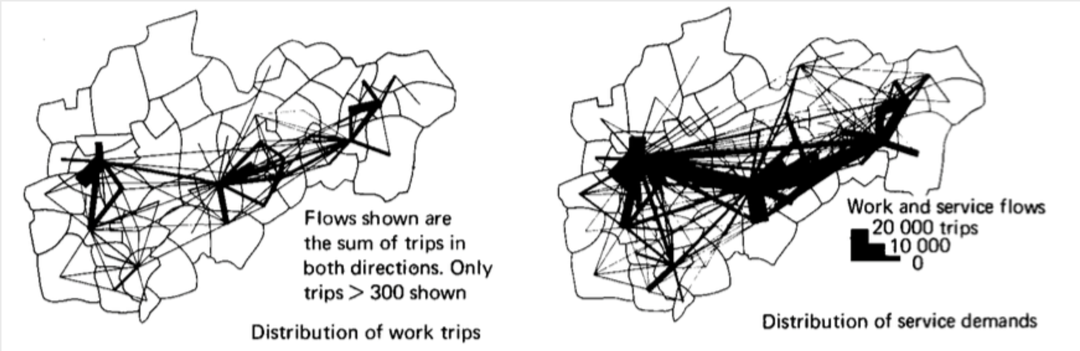
Locations and Interactions: Flow Systems in Cities

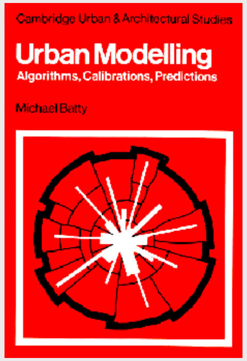
Elsewhere I have argued that we should treat cities as flow systems – as networks. This has been a focus for a long time in transport and land use and we have always been up against the problem of big data.

So let me begin my illustration of this dilemma and how we are thinking about it with some problems that have very small data. Problems of spatial interaction where our numbers of locations is small < 100, ~ 50

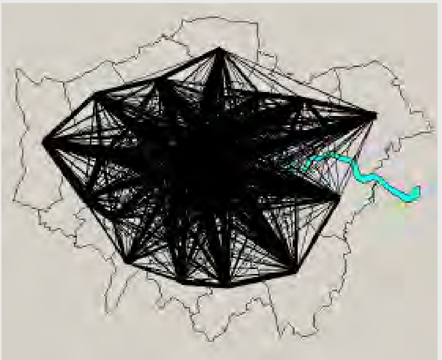
Understanding and Visualising Flows

An early model circa 1967-8 Central and NE Lancs

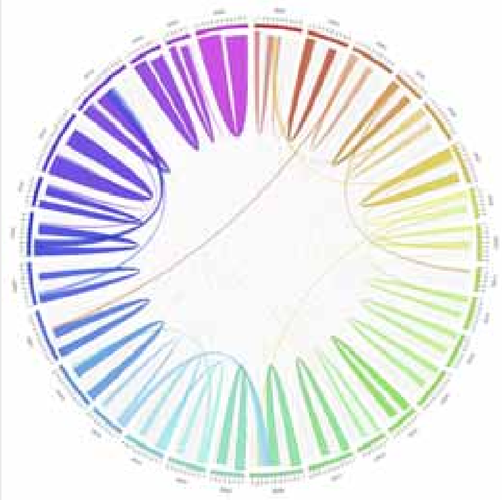


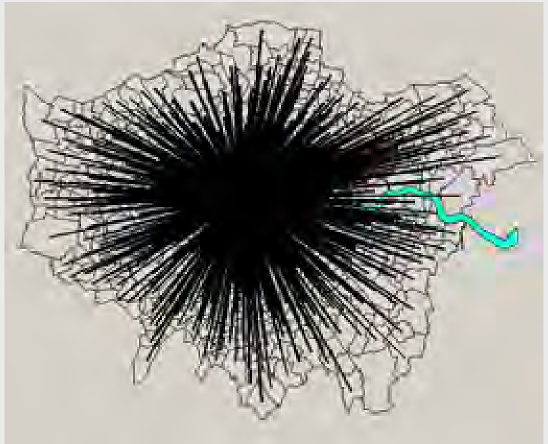


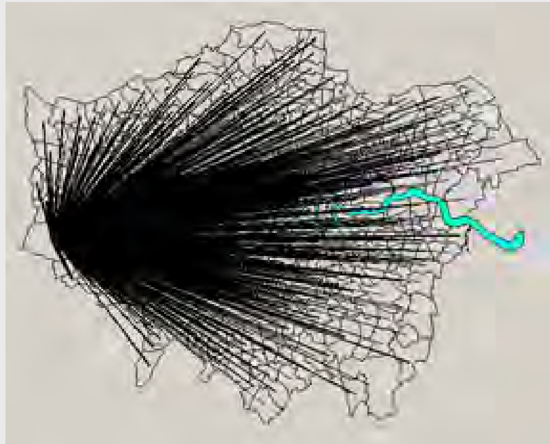
M. Batty (1976)
Urban Modelling
Cambridge UP



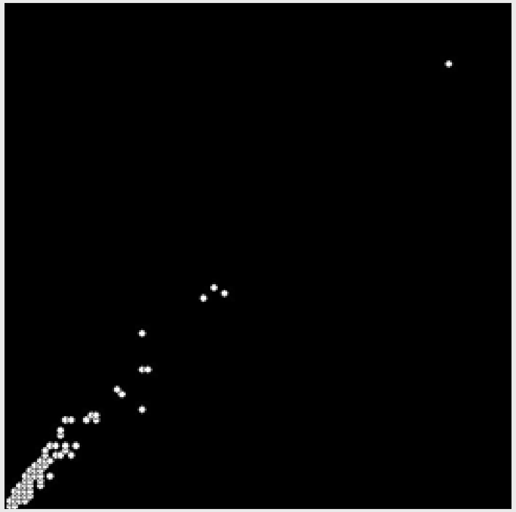
$n^2=33^2=1089$, not so big but hard to visualise

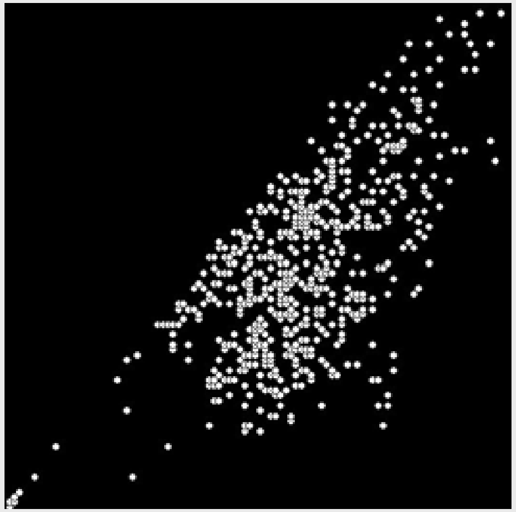


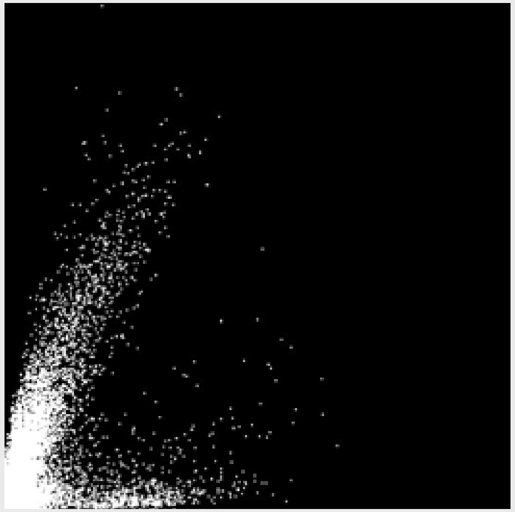


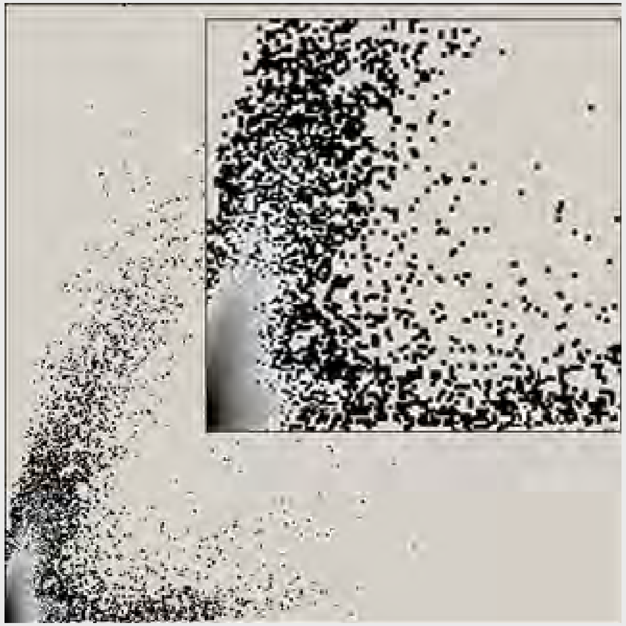


$n^2 = 633^2 = 400{,}689$, bigger but impossible to visualise





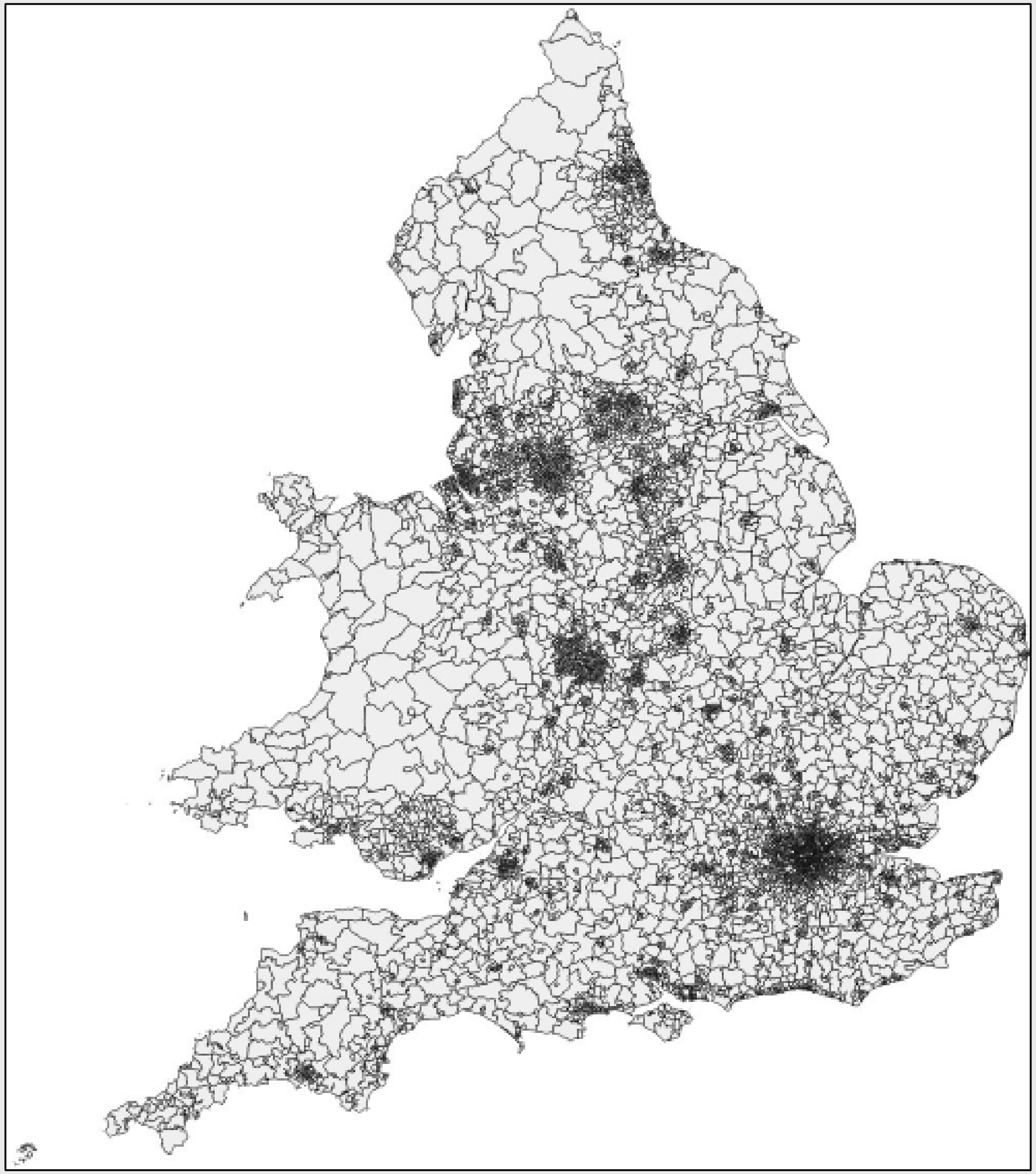




Even our statistics breaks down when we get large numbers like over several thousand as you can see on the left and above right for 400K data points where the pattern is highly convoluted. This is from a gravity model.

Now what happens when we really do scale up to the level of MSOAs of which there are 7201 in the UK – do we partition and argue we don't need to scale up to $n^2=7201^2=51{,}854{,}401$.

Circa 52 million points is an issue but our models run in a matter of seconds but that is a lot of data to store – ok it is sparse but sparsity isn't structured so we can't easily partition and in any case we want to compute any possible flows between central London say and Newcastle. Here is the problems scaled up and this is what we are grappling with at present.



(a) MSOA (A=7201) (b) LSOA (A=34753) (c) OA (A=181408)

Figure 8.2: ONS Geographies for MSOA, LSOA and OA levels.

The Web and the Desktop: Users are also Data

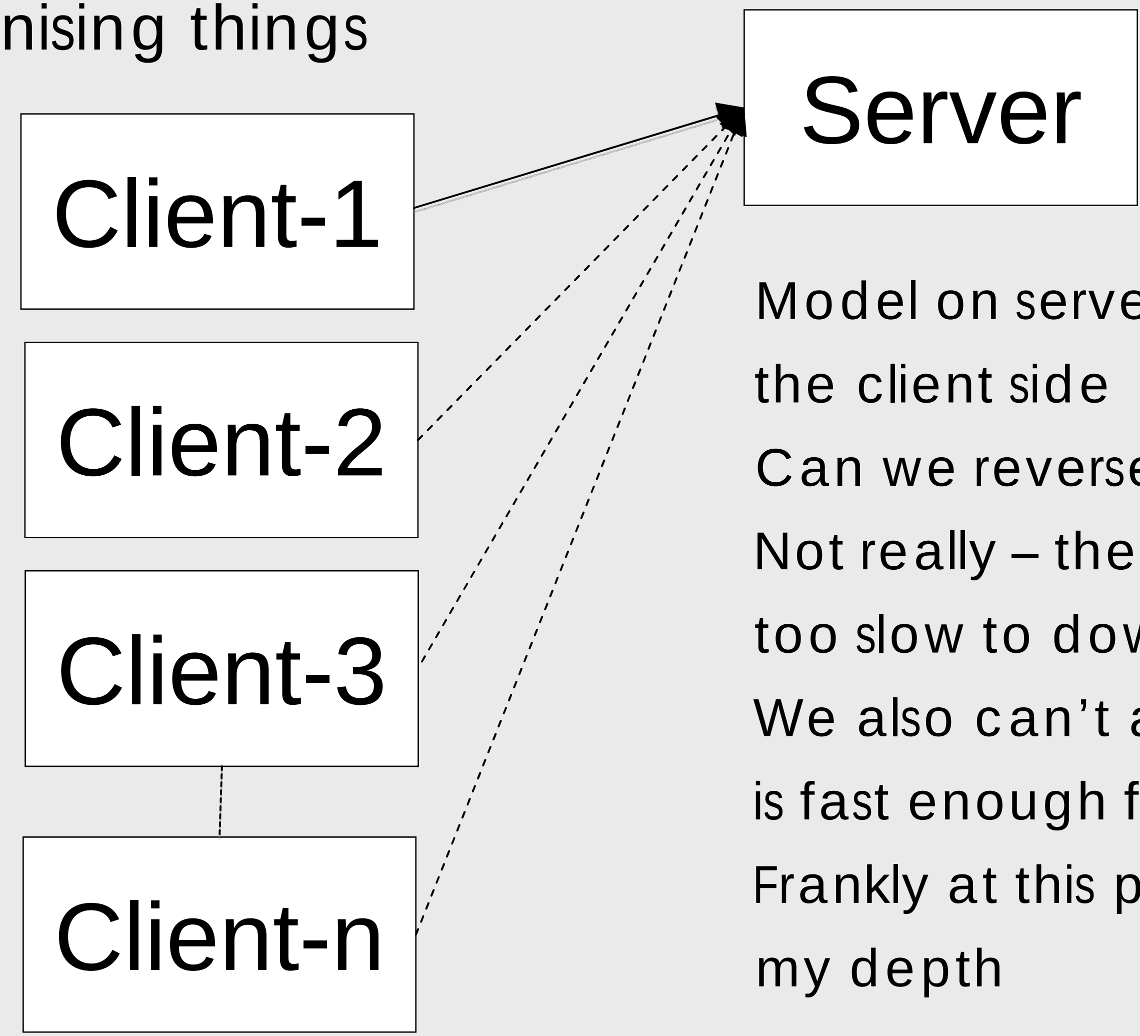
We are building a model of the UK – well E&W at present – we will add Scotland before long – which is of the nature we have been implying – Without going into details, the model takes a few seconds to run – it will take a lot longer when finished as we will add sectors and of course the number of big data we have to hold in RAM might be very large – currently we need to hold 4 such 52 million sized matrices – we may need to go up to 8 in time and that will involve a lot of packing and moving in and out of core, I think

But the real issue is users – if our model is this large, and we have many users, then our data problem is exploded by the users –

Our big data is our original and predicted data from the model, times the number of users. Why are users data ? Well because they are using data differently – they are making their own predictions and thus scaling up the data.

We could have one model for each users but we don’t know who the users are? We thus want them to access this on the web. This is where it all hits the fan ..

Here is a block diagram of how we are currently organising things



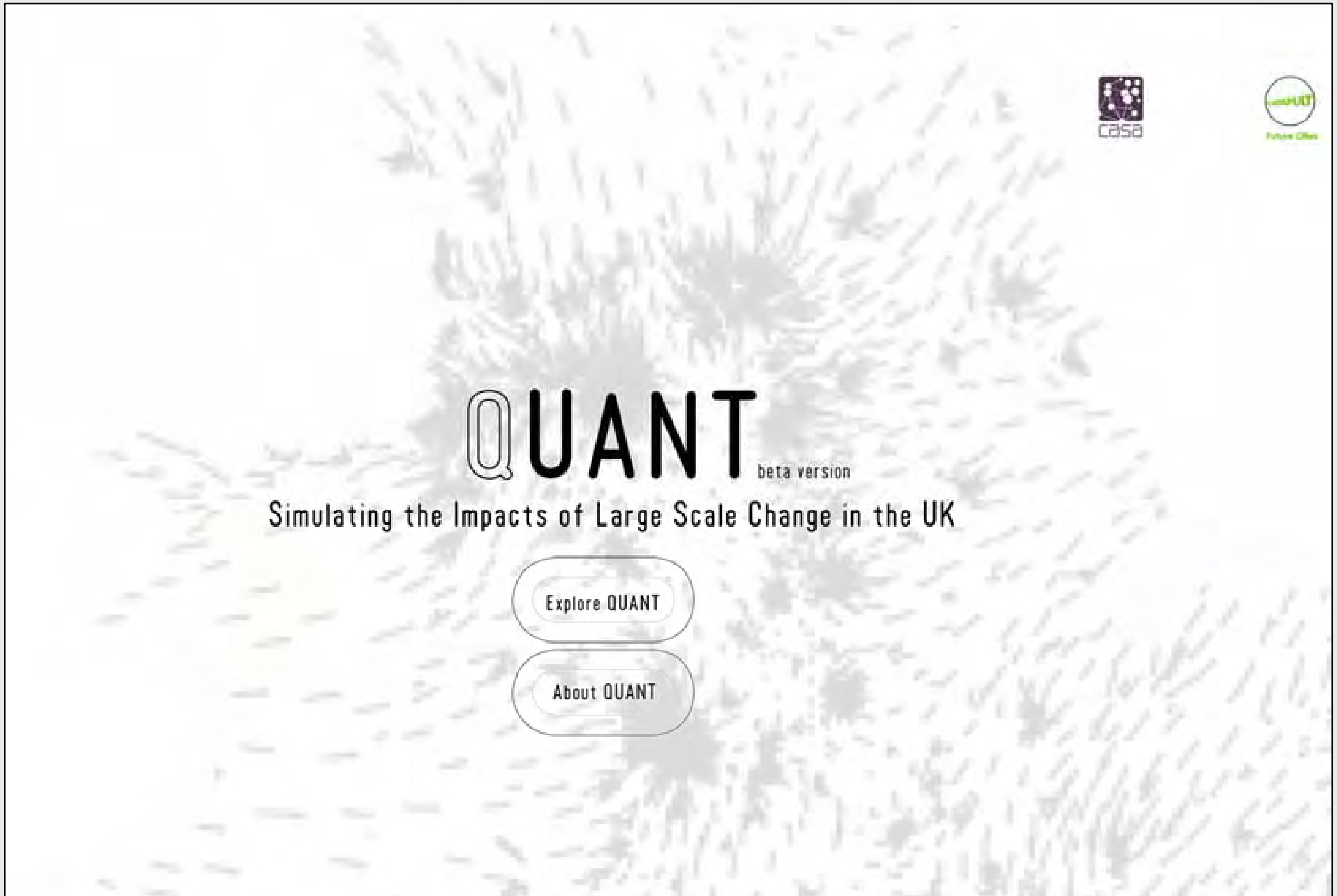
Model on server side; Maps on the client side

Can we reverse this?

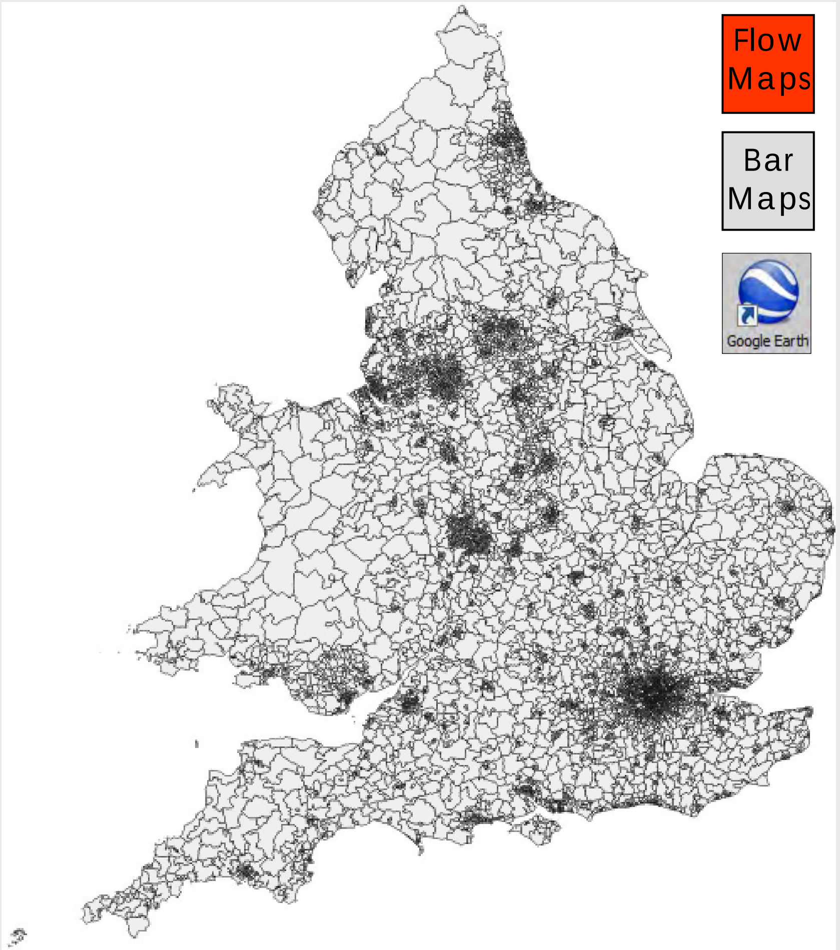
Not really – the matrices are too slow to download to client?

We also can't assume the client is fast enough for computation.

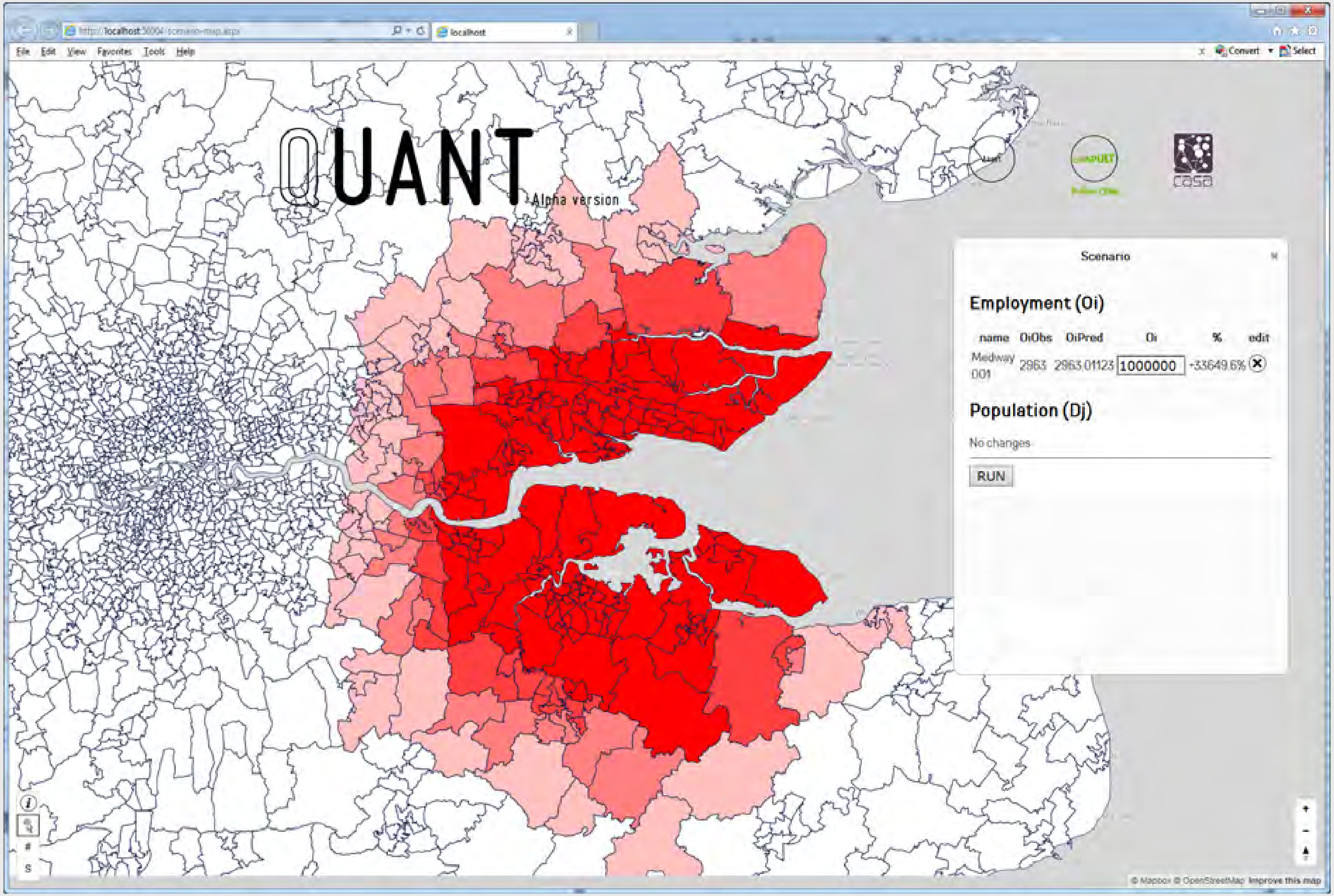
Frankly at this point, I am out of my depth



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



$$[x_i, y_i] = [[x_i, y_i], \left[\left[x_i + \frac{\sum_j T_{ij}\,[x_i - x_j]}{n}\right], \left[y_i + \frac{\sum_j T_{ij}\,[y_i - yy_j]}{n}\right]\right]]$$


QUANT
Alpha version
Scenario
Employment (Oi)
name OiObs OiPred Oi % edit
Medway 001 2963 2963.01123 1000000 -33649.6%
Population (Dj)
No changes
RUN
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