



Lipari School on Computational Complex Systems

Jacob T. Schwartz International School for Scientific Research

Università di Catania



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August 2, 2014*

Smart Cities:

New Ideas about Data-Driven Modelling, Visualisation,
Simulation, Prediction and Design

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<http://www.complexcity.info/>

<http://www.spatialcomplexity.info/>



Centre for Advanced Spatial Analysis



Outline

- Some Preliminary Remarks about Cities
- Smart Cities: A New Paradigm?
- *An Old Exemplar 1: Land Use Transport Modelling*
- *An Old Exemplar 2: 2D into 3D – Symbolic into Iconic*
- *Exemplar 3: Public Transport Networks & Flows*
- *Exemplar 4: Public Bike Schemes: Local Routing and Local Models of Movement*
- *Exemplar 5: Crowd-Sourcing & Social Media*
- Where Do We Go From Here? The Next 50 Years

Some Preliminary Remarks about Cities

Three topics: smart cities, land use transport models, and size and scaling in cities

Smart cities deal with short term issues – mobility, energy etc

Land Use Transport Models deal with long term more aggregative issues, prediction in cities

Size and Scaling deal with complexity in cities

These topics not seamlessly connected but all define aspects of the new digital world in cities

These all sit in an enormous sea of knowledge about cities and their planning reflecting many disciplines

Let me begin

- A couple of examples about what smart cities are all about
- Real time, streamed big data
- An example from public transport in London where smart card data is now key

Smart Card Data

Oyster Card Taps

Tap at **start** and **end** of train journeys

Tap at **start only** on buses

Accepted at 695 Underground and rail stations, and on thousands of buses

991 million Oyster Card taps over Summer 2012 – this is big data



And how can we make sense of this



<http://www.simulacra.info/>



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Plane Finder 3D x

3d.planefinder.net/flight/U21525

planefinder

Plane Finder 7 - Out Now!

Plane Finder 7 YouTube

Available on the App Store

Close

planefinder

Features Screenshots Video How to Buy

Plane Finder 3D

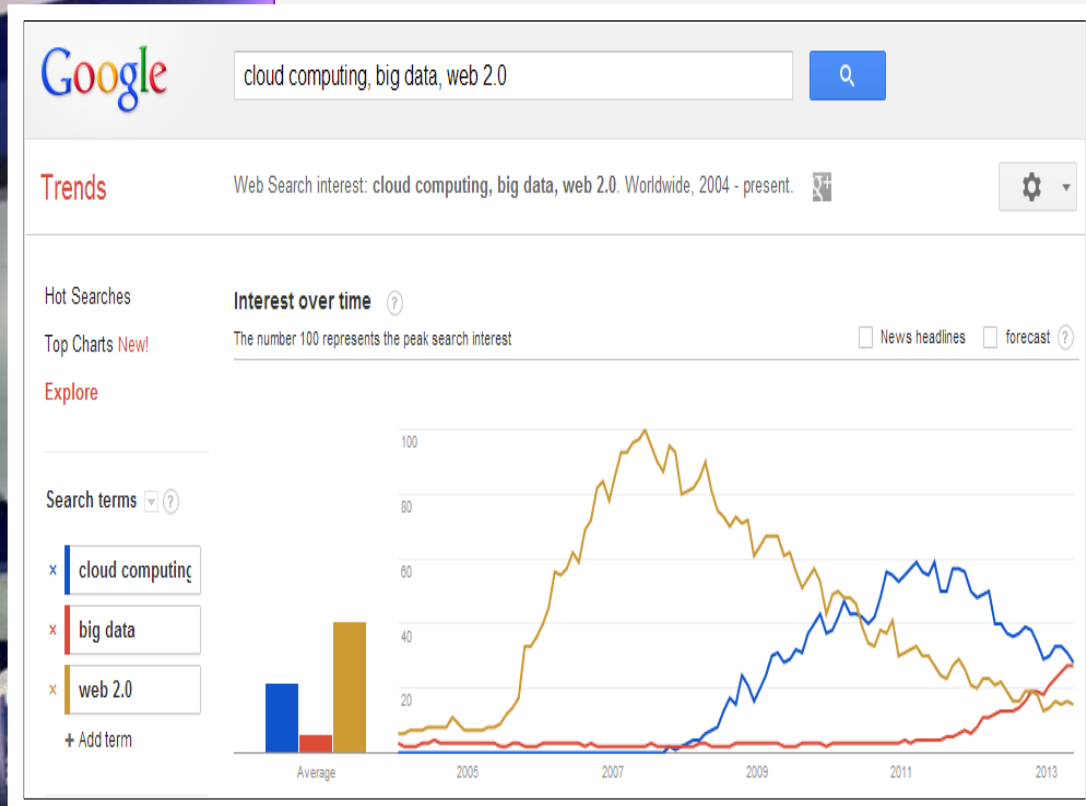
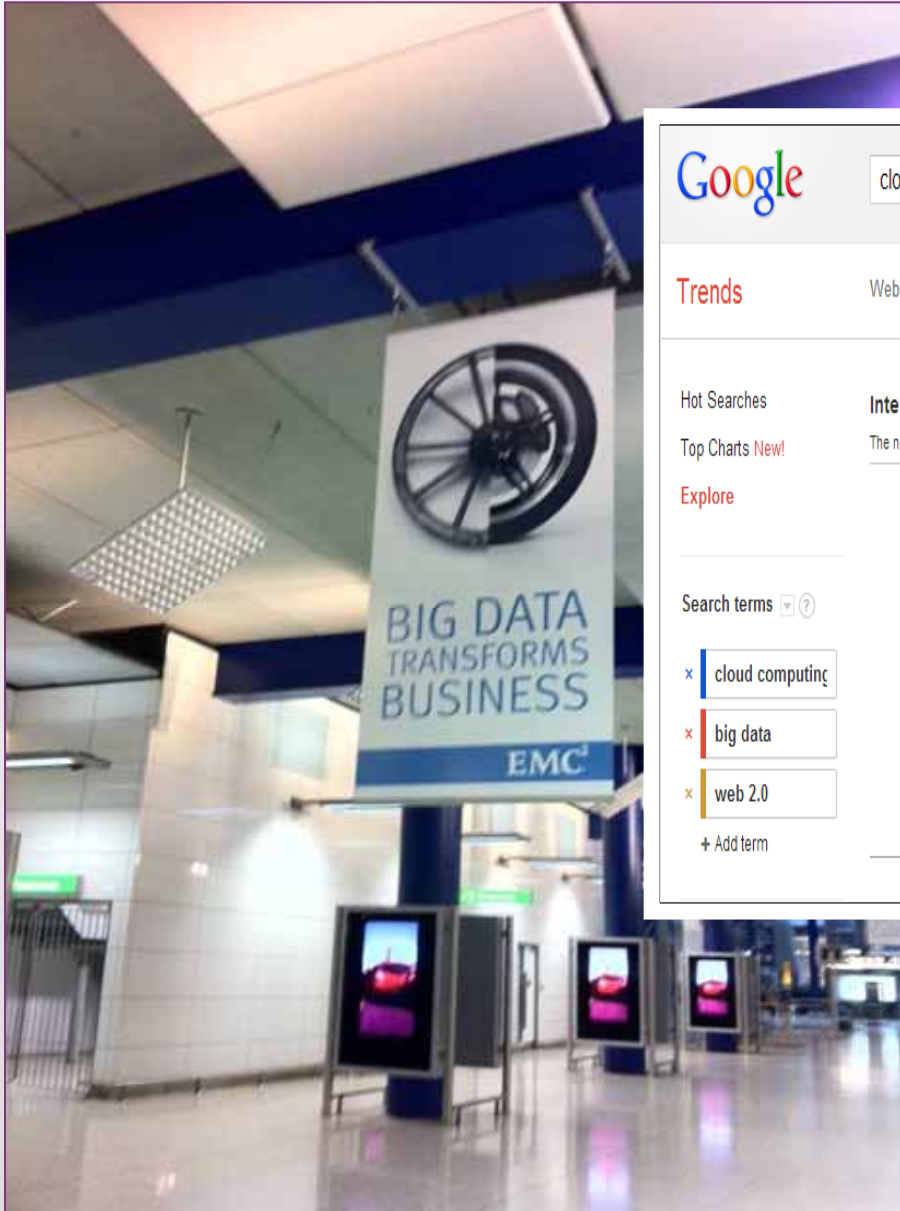
The only 3D live plane tracking App.

Google Earth

Per Ogni Tua Tappa c'è Una Mappa. Installa Gratuitamente

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Squawking 7700: SE-DSU <http://t.co/oME0gyYq3h> #PF7700



Smart Cities: A New Paradigm

What then is the smart city? This is a peculiarly American word

Well cities where computers are being used to make them more efficient, and perhaps more equitable

Essentially computers have moved out of the corporate and individual domains into the collective domain of the city – to control things and to deliver services

They are also used to help our understanding and planning the city – and this is the idea that we used them to understand how they are being used

What is happening is that we are getting a much better sense of the short term changes in the city. Much of our geographic science of the city is about how it changes over the long term – the very long term like the rise of cities over years and decades

But the *smart city is about what happens in the next 5 minutes or the next 5 hours or even the next 5 days*

This is changing our ability to respond and it is also changing our abilities to function in cities – our behaviour. This lecture is an example - informed by my access to the web and pulling down things like my bikes example for London which I will show later

By putting sensors into the built environment and also linking them to ourselves, then great streams of data are being released

This is Big Data: a Billion Oyster card records in 3 months – now you can't use an Excel spreadsheet to analyse that

Smart Cities and Big Data are strongly related. If this then is the Future of Cities, we need to dig a little behind the hype and the media spin. So what have we learnt and what are we learning? What is the geography of the smart city? Let us see through my examples most taken from London.

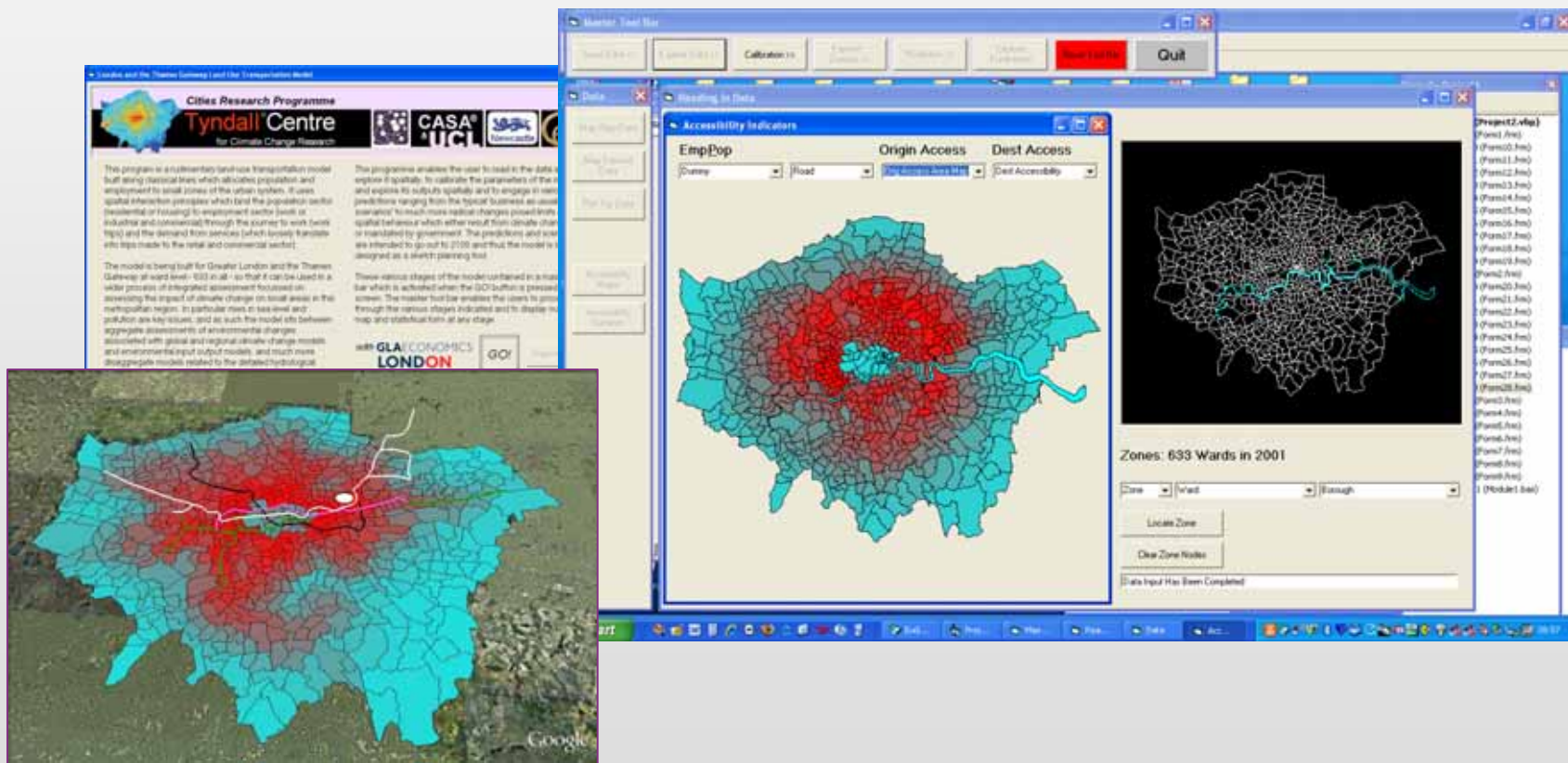
I will begin with two old examples of what we can do with new technologies in terms of simulating and visualising the city.

First we have been building land use transportation models for a long time but now we can visualise their simulations, their data, how big they are, and how we can quickly we can generate ‘what if?’ scenarios

Second, visualisation is not now about simply maps in GIS which is now routine but 3-d geometry that is becoming routine – the virtual city that we can use as a visual set of filing cabinets to which we can add content – and not just render but real attribute data.

An Old Exemplar 1: Land Use Transport Modelling

Our core expertise is in land use transportation modelling and we have several such models for the London region:



MASTER TOOL BAR: The London and Thames Gateway Land Use Transportation Model

Tyndall Centre CITIES

Input Data >> Normalise Data >> Explore Data >> Choose Model >> Calibration >> Explore Outputs >> Prediction >> Explore Predictions >> Reset Tool Bar Quit

Data Reading in Data

Mapping Location Data

Employment Population Work Trips

Employment Bar Map Population Maps Interzonal Trip Flow Map Road

Employment Density Pop Density Area Map Trip Density 6

Click to Save the Thematic Map to Display in Google Earth

Google Earth

File Edit View Tools Add Help

© 2009

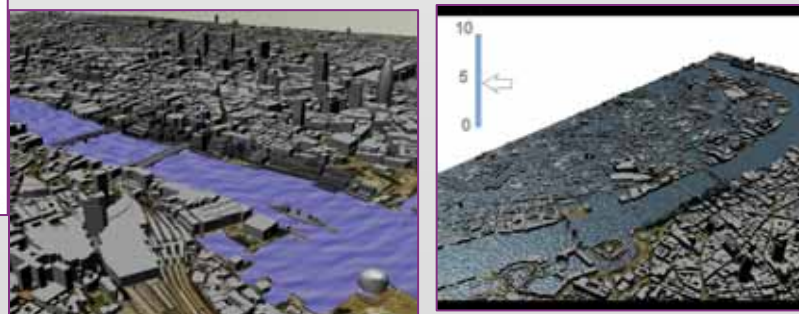
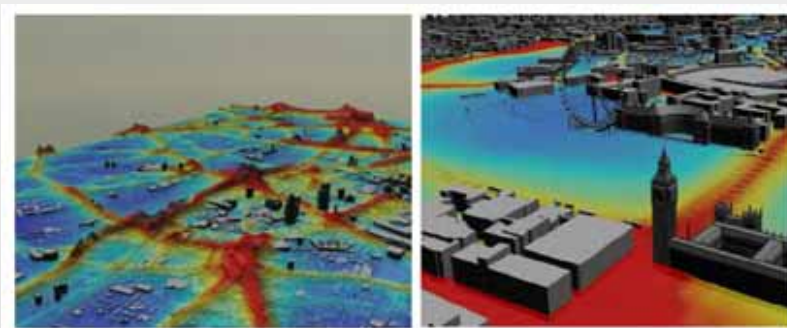
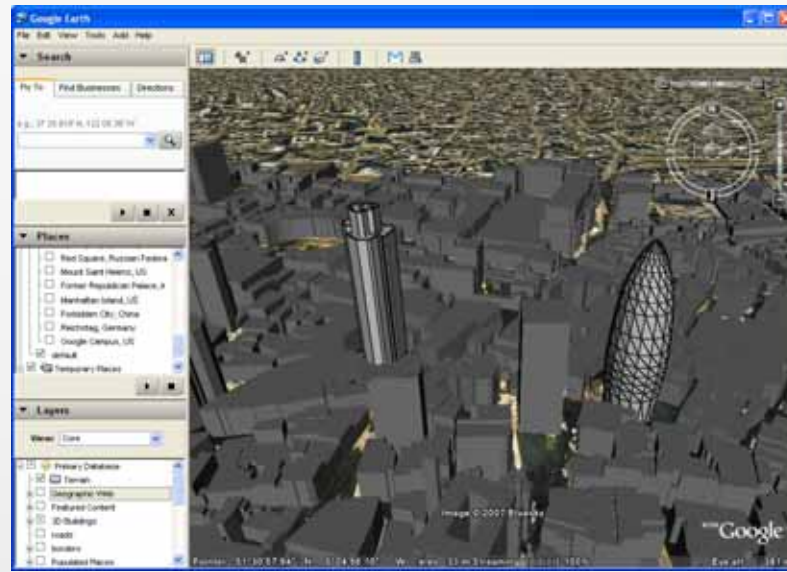
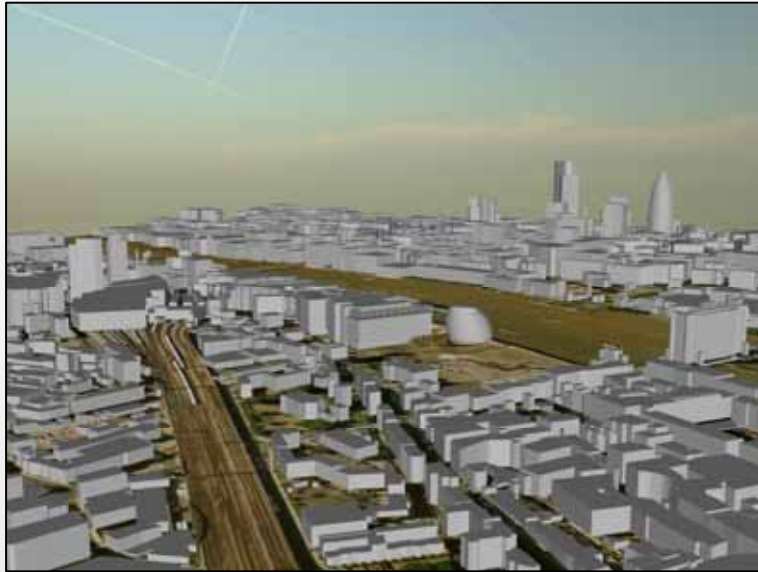
<http://www.casa.ucl.ac.uk/movies-weblog/GoogleEarth.mov>

An Old Exemplar 2: 2D into 3D – Symbolic into Iconic

We have built a large scale 3-D model for London based on RS data at parcel levels. The model is different from our LUT models – requiring different skills

The models are being tagged with socio-economic data. We have used it for flooding, visualising air pollution, we have looked at the morphology of building form, and used it to visualise 2D to 3D design proposals.

What is intriguing is the way *iconic and symbolic models are beginning to merge* – land use transport models with virtual city models. We are not yet in the realms of the smart city but you can see how our computers are beginning to help us understand and communicate ideas better across the web.



<http://www.londonair.org.uk/>

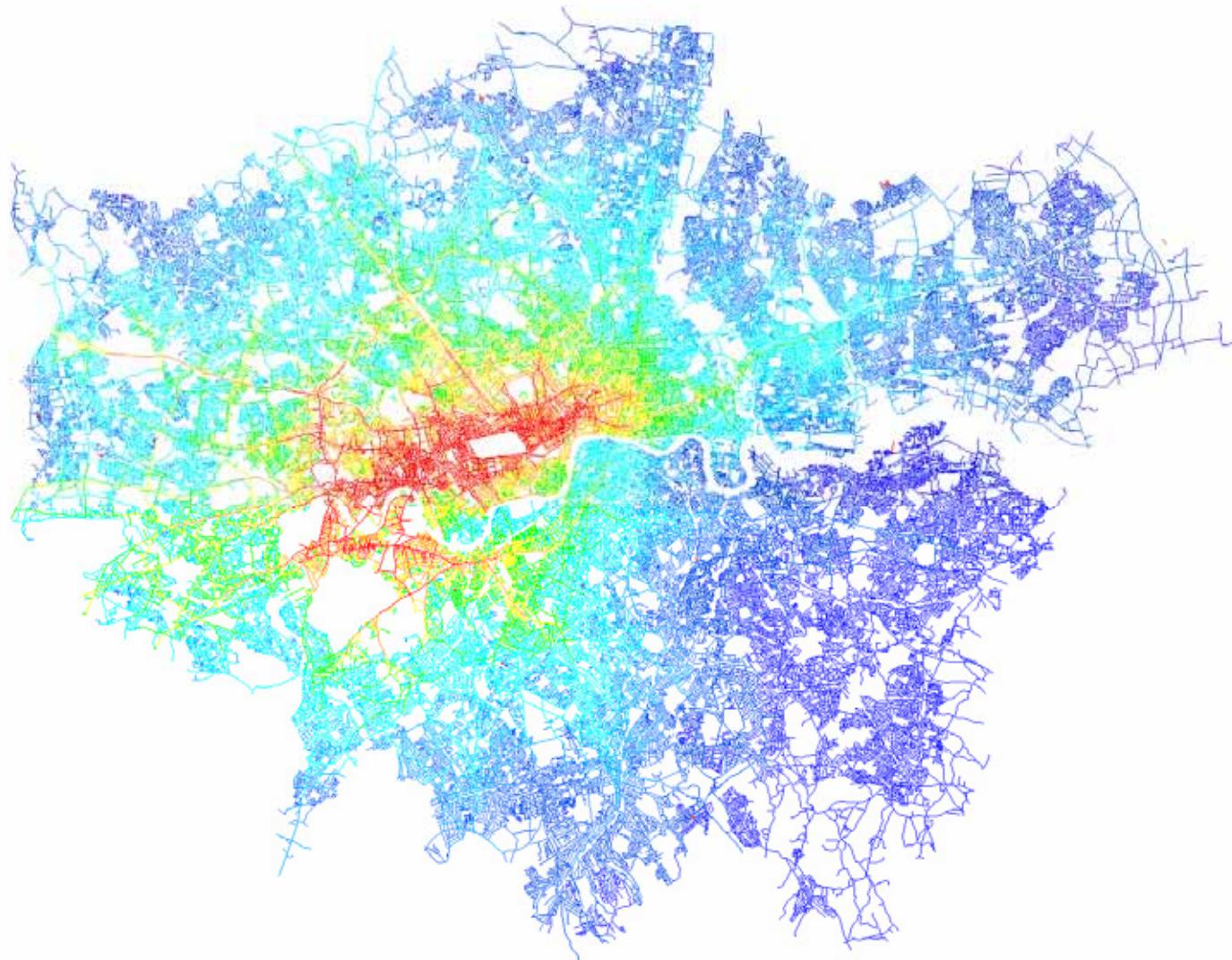
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Flooding from our
3D Virtual London Model





Shifts in Traffic Accessibility if all Bridges across the Thames are Inoperable as far West as Hammersmith

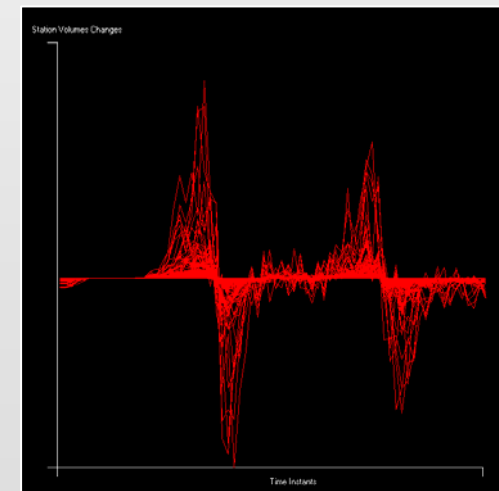
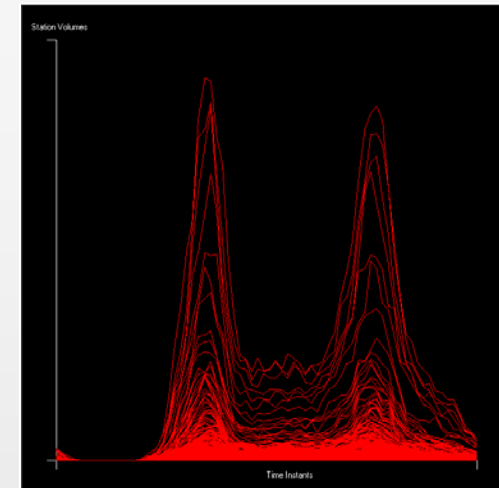
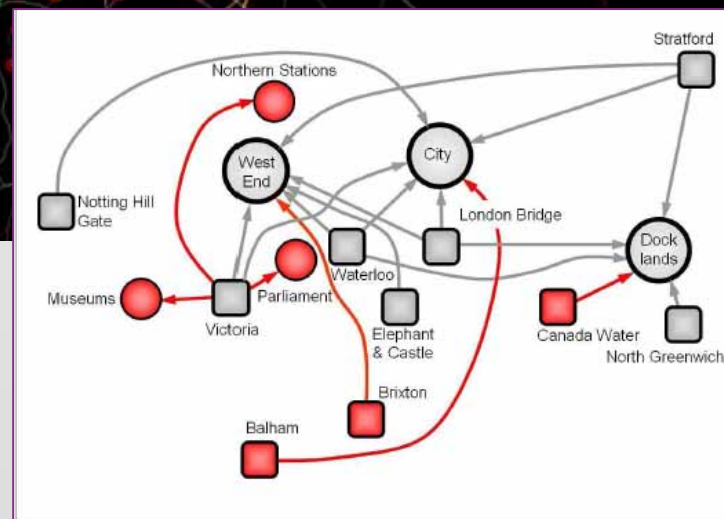
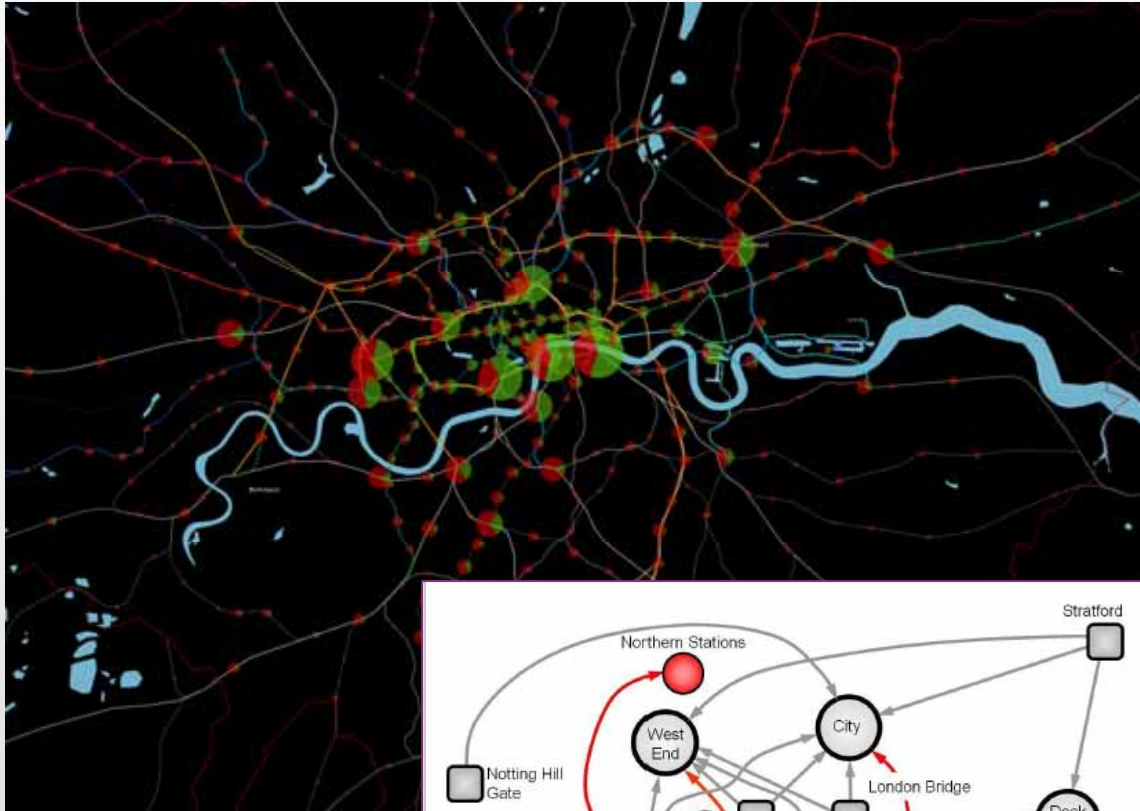
Exemplar 3: Public Transport Networks & Flows

Many new sources of network data now exist, much of coming from digital sources and we are working with mining this data and extracting functionality from it

Our key data sets are telecoms data (landline) for the UK, the online travel card data (Oyster) for public transport schemes in London which is massive, really massive and the online bike movement data for the London bikes scheme. These are big data sets that record every phone call, trip etc over a period of days with each object time stamped. Let me show some more of the smart card Oyster project first

I have shown you the flows but there are many things we can do with all this – like work out disruption on the network and inform travellers – eventually in real time

Oyster Card Data – interpreting urban structure, multitrips, etc.

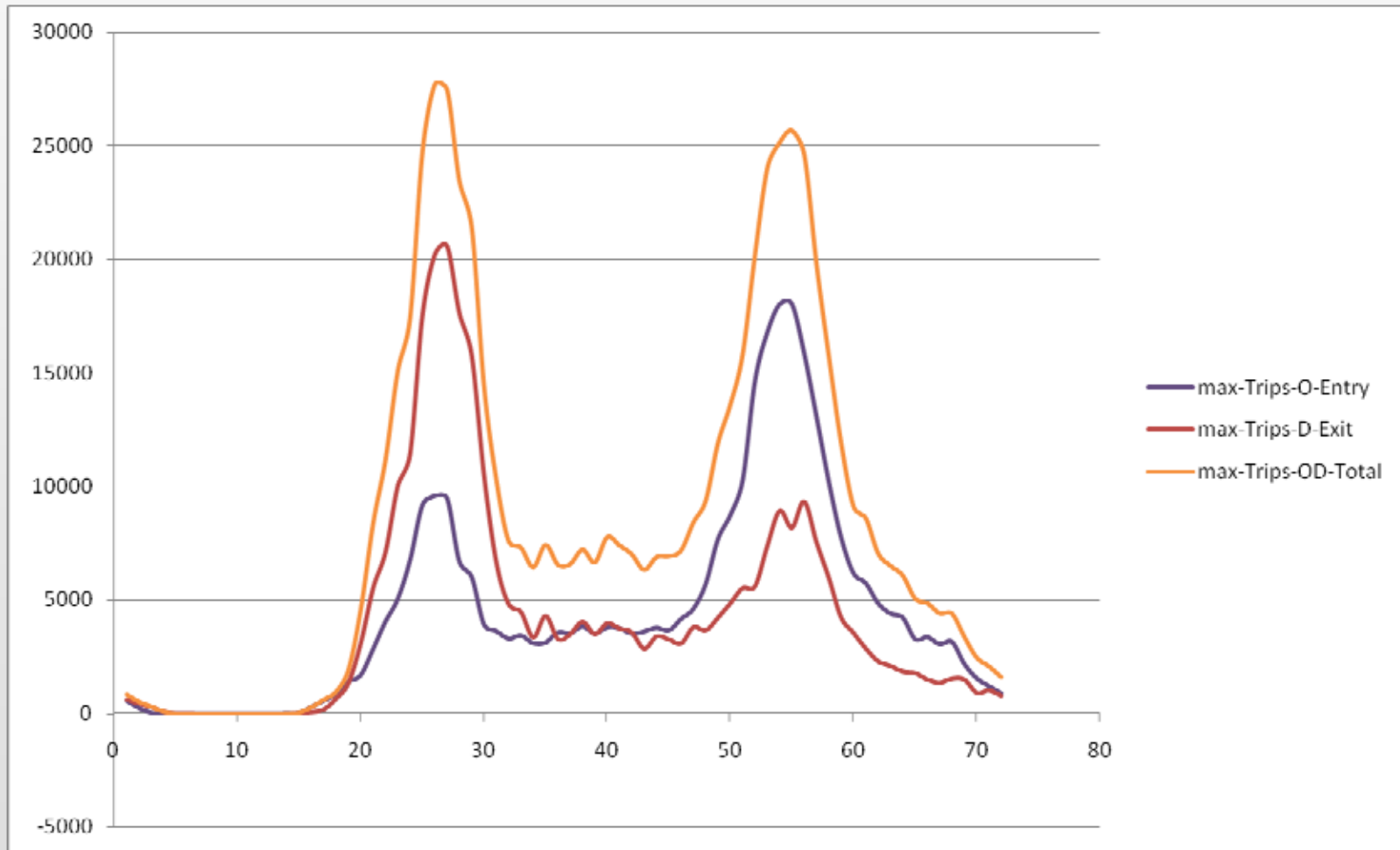


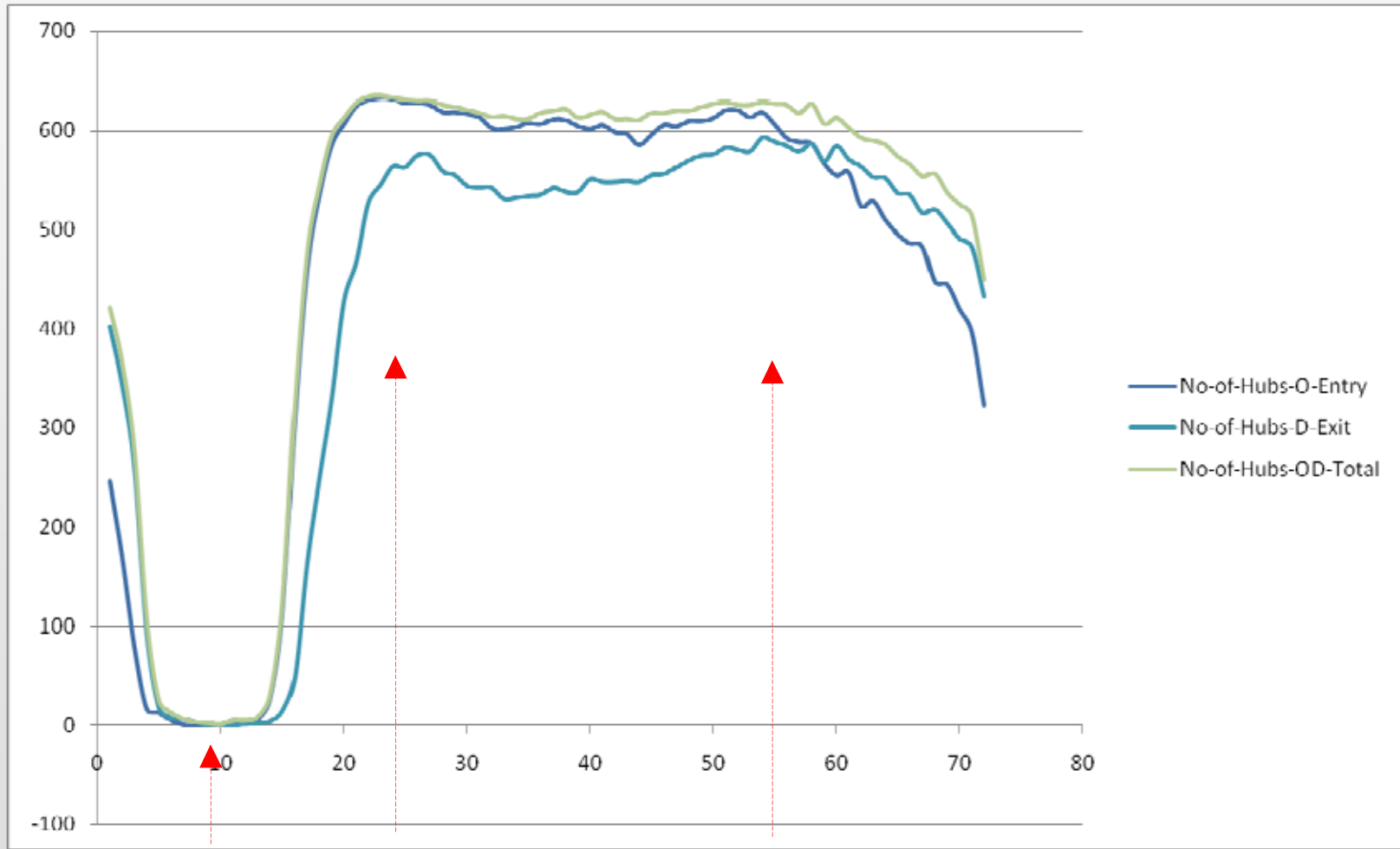
We can examine origins volumes, destination volumes separately and we are doing but here we will simply add these together as total volumes – in this sense they will not have meaning any longer as trips

	A	B	C
1	1	London-Bridge	599568
2	2	Victoria	502127
3	3	Waterloo	486861
4	4	Liverpool-Street	437658
5	5	Kings-Cross	395919
6	6	Shepherd's-Bush	346027
7	7	Hammersmith	274623
8	8	Wimbledon	198913
9	9	Paddington	196067
10	10	Vauxhall	180411
11	11	Stratford	177964
12	12	Oxford-Circus	150704
13	13	Charing-Cross	149290
14	14	Ealing-Broadway	139911
15	15	Euston	138394
16	16	Canary-Wharf	132206
17	17	Barking	112842
18	18	Balham	111090
19	19	Brixton	108814
20	20	London-Terminals	93026

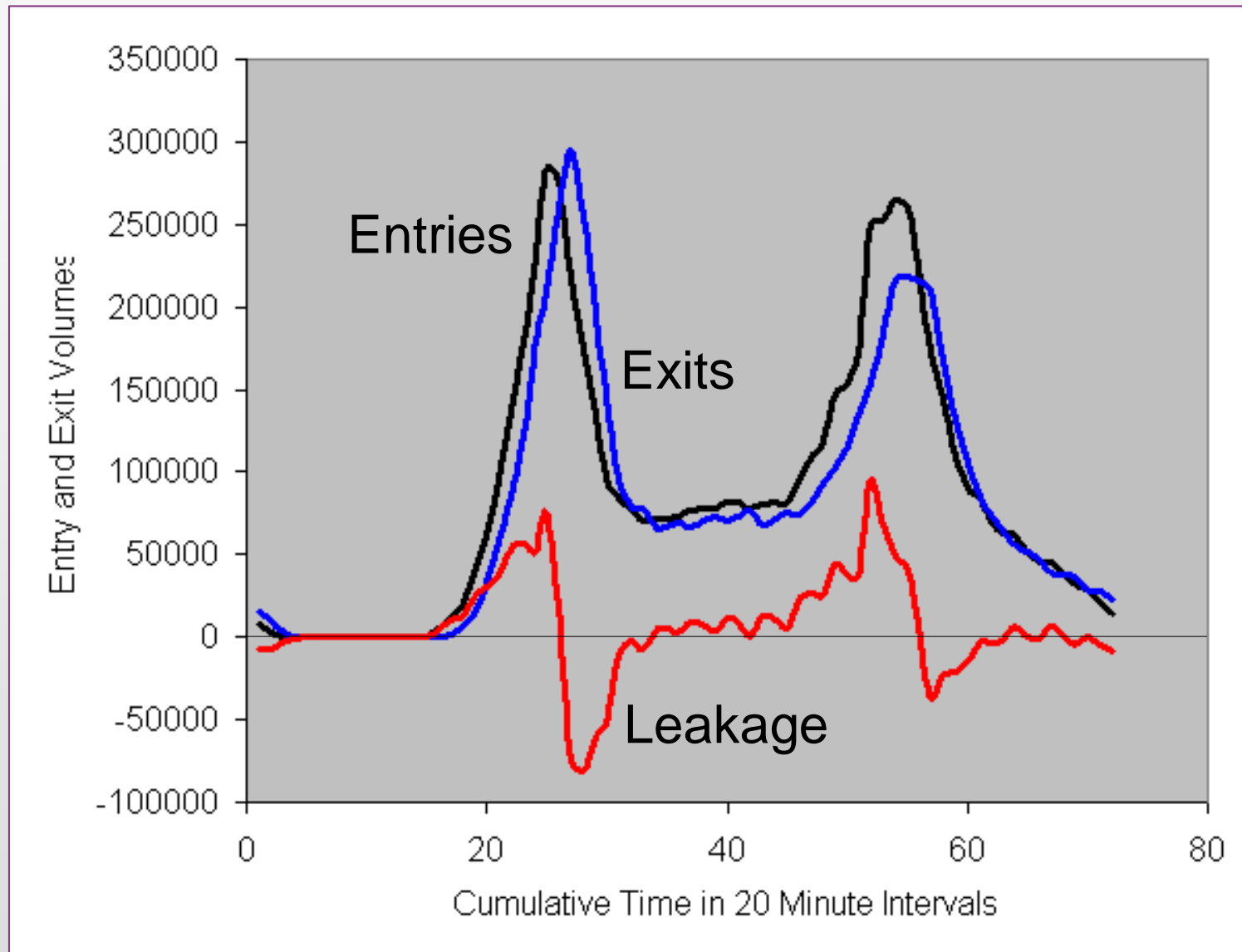
We will now examine the profiles of behaviour during the 24 hour day to provide some sense of the problem

Examining the Dynamics of the Hub Volumes

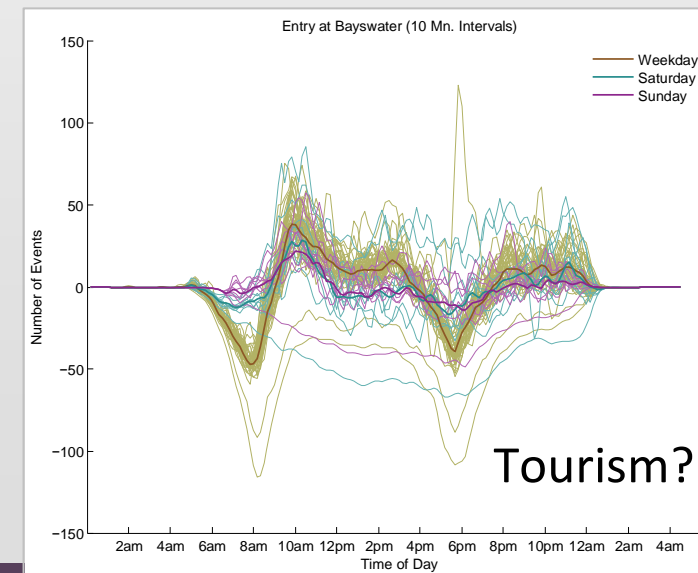
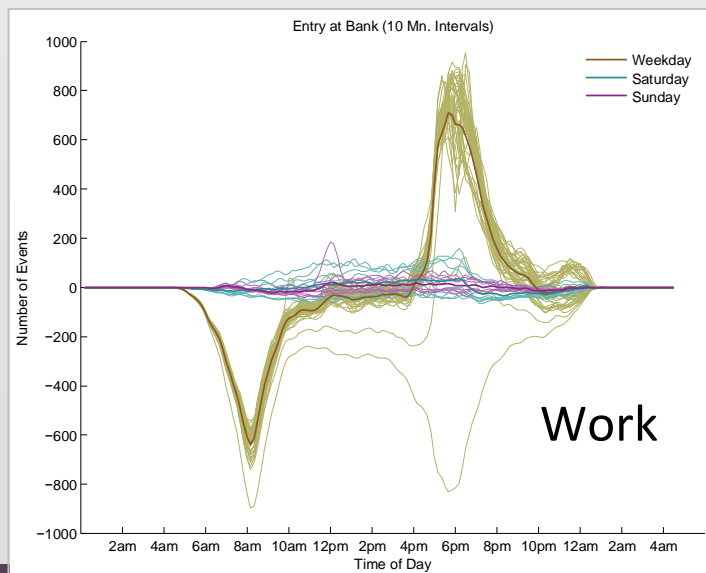
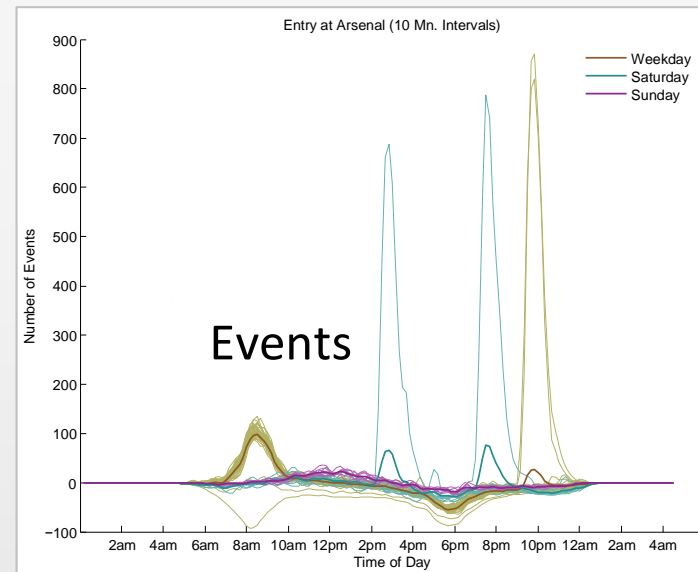
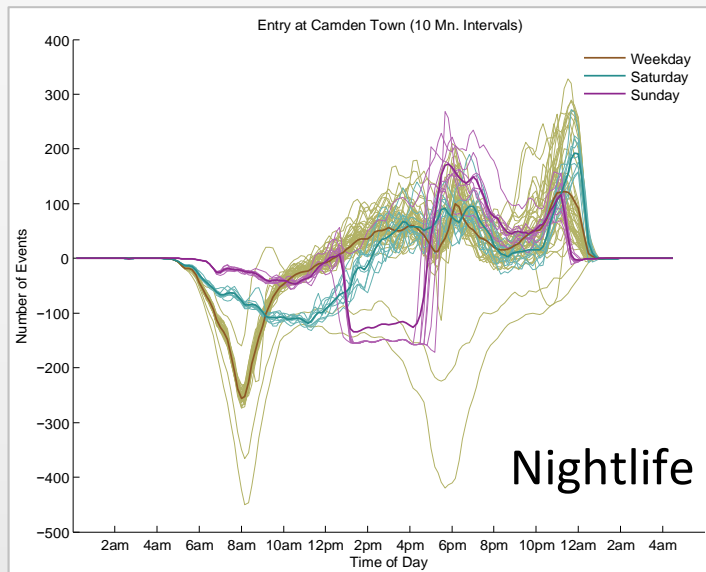


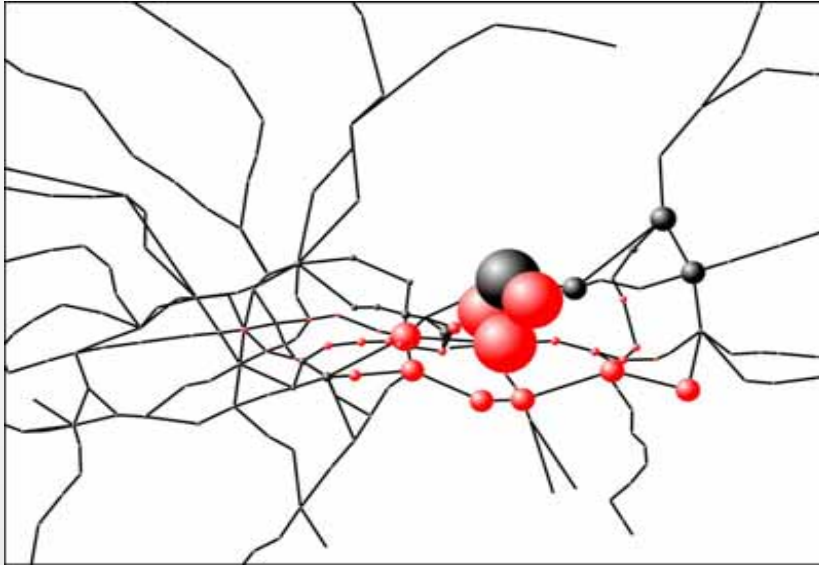


Night am peak pm peak

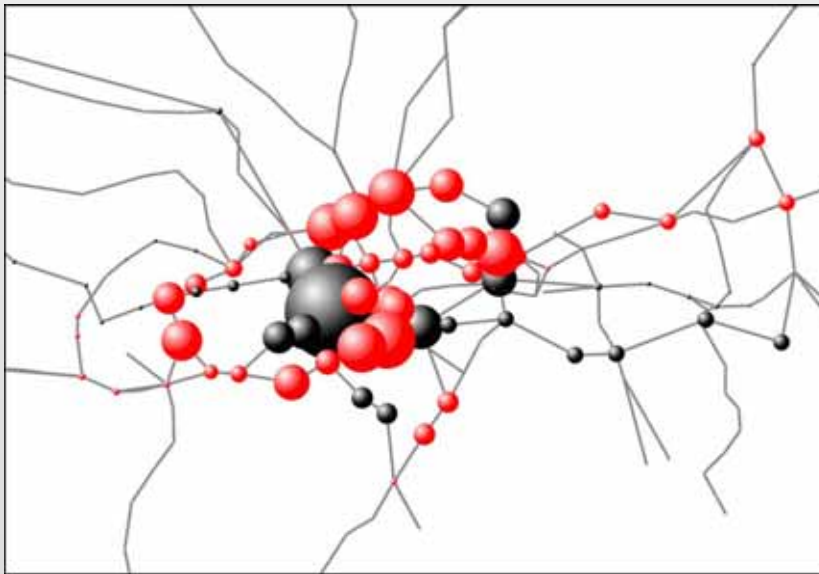


Particular Events: Weekdays, Saturdays and Sundays

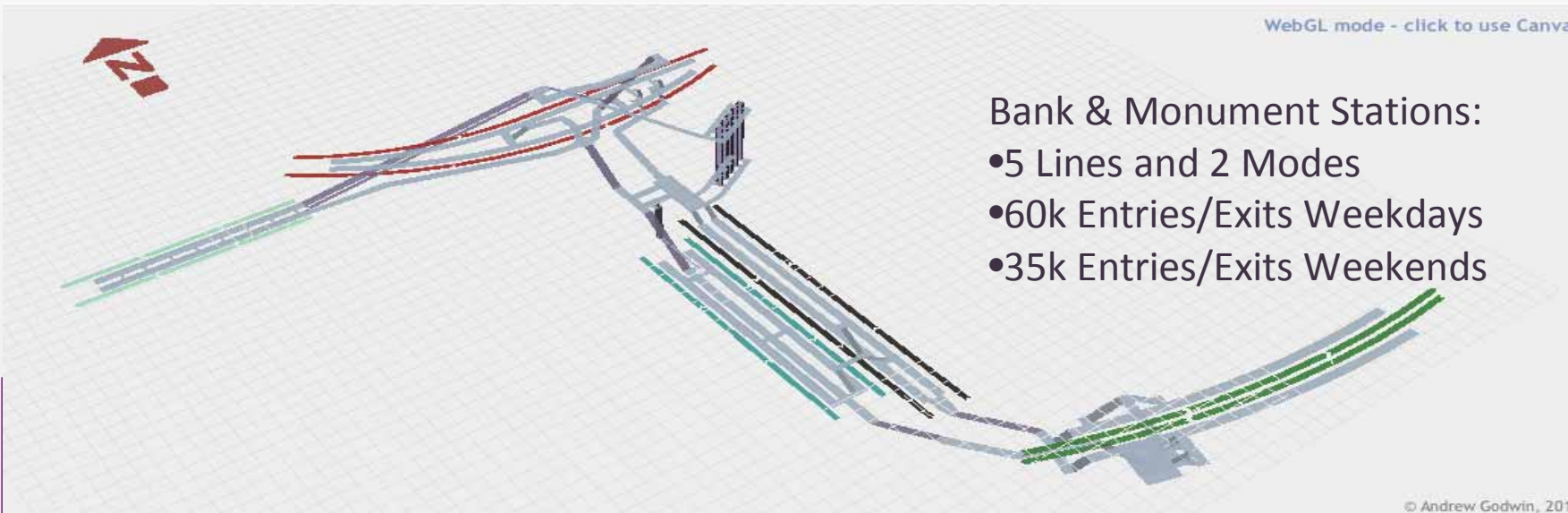




Disruption caused by closing Liverpool Street in terms of the graph of the tube network



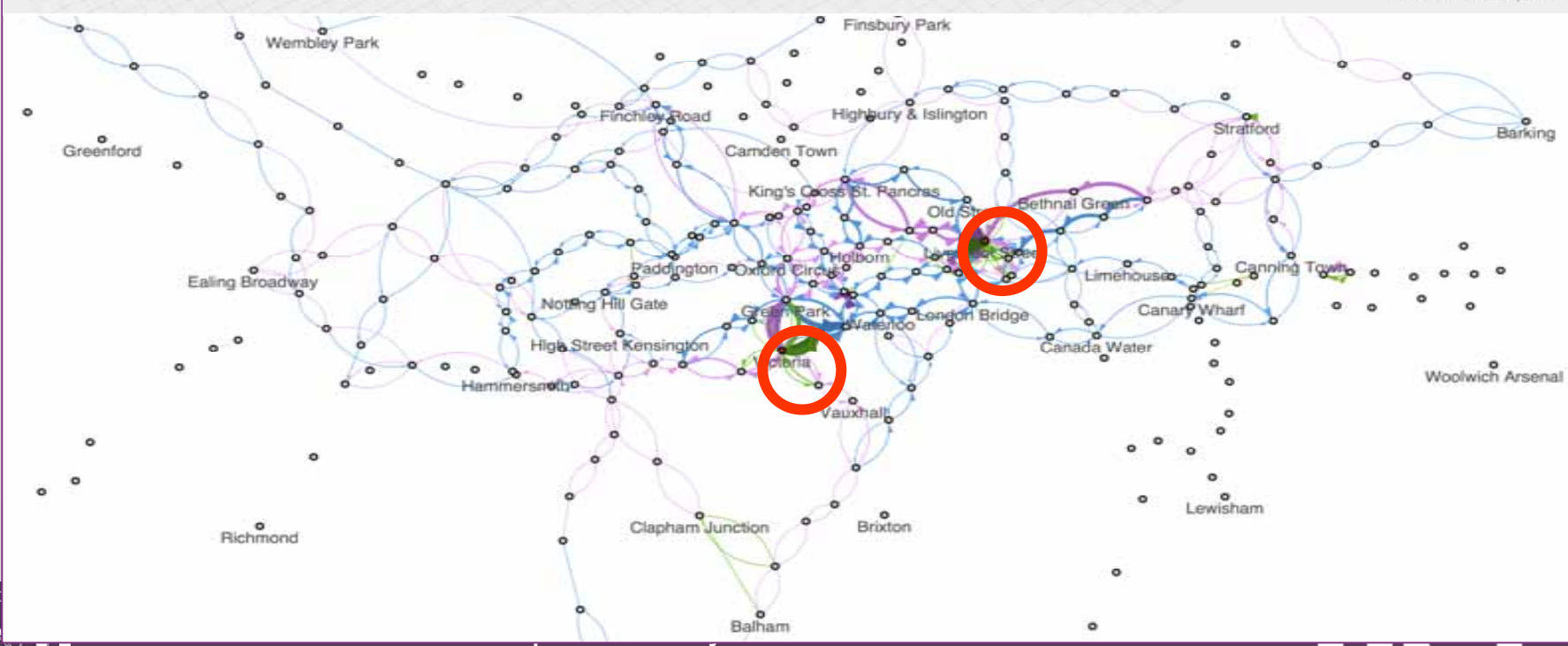
Closing Green Park – shifts in betweenness centrality

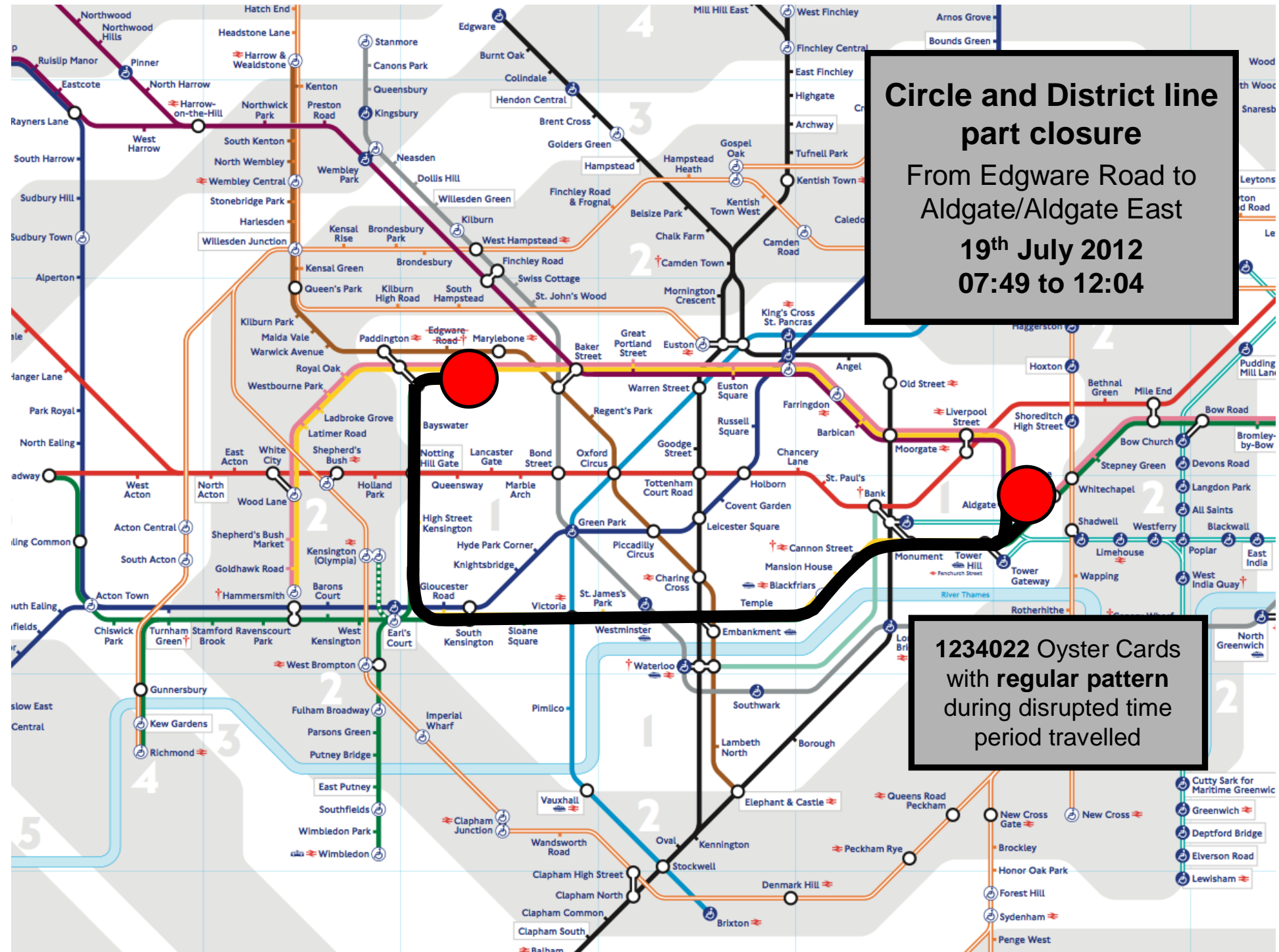


Bank & Monument Stations:

- 5 Lines and 2 Modes
- 60k Entries/Exits Weekdays
- 35k Entries/Exits Weekends

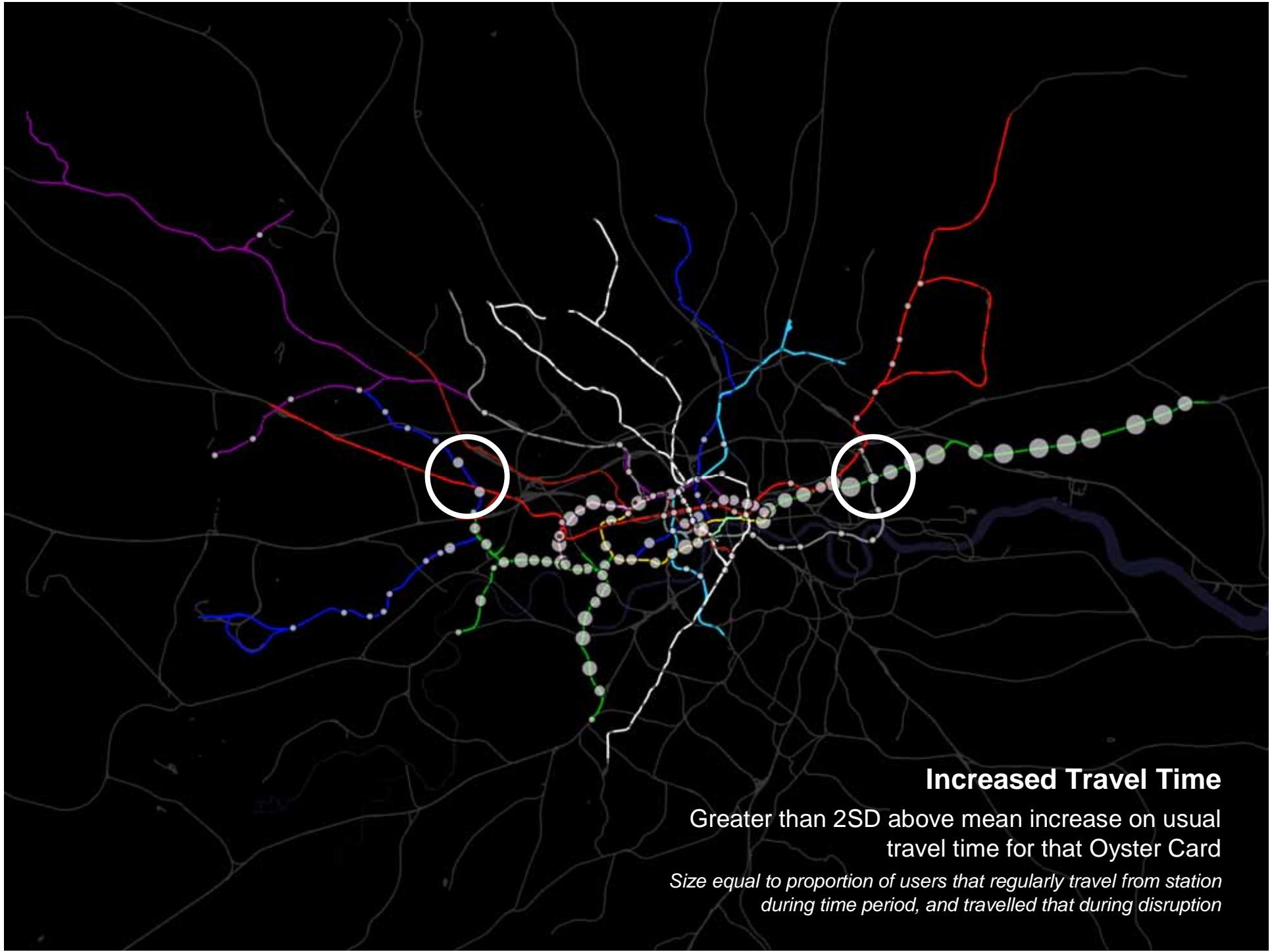
© Andrew Godwin, 2012





**Circle and District line
part closure**
From Edgware Road to
Aldgate/Aldgate East
19th July 2012
07:49 to 12:04

1234022 Oyster Cards
with **regular pattern**
during disrupted time
period travelled

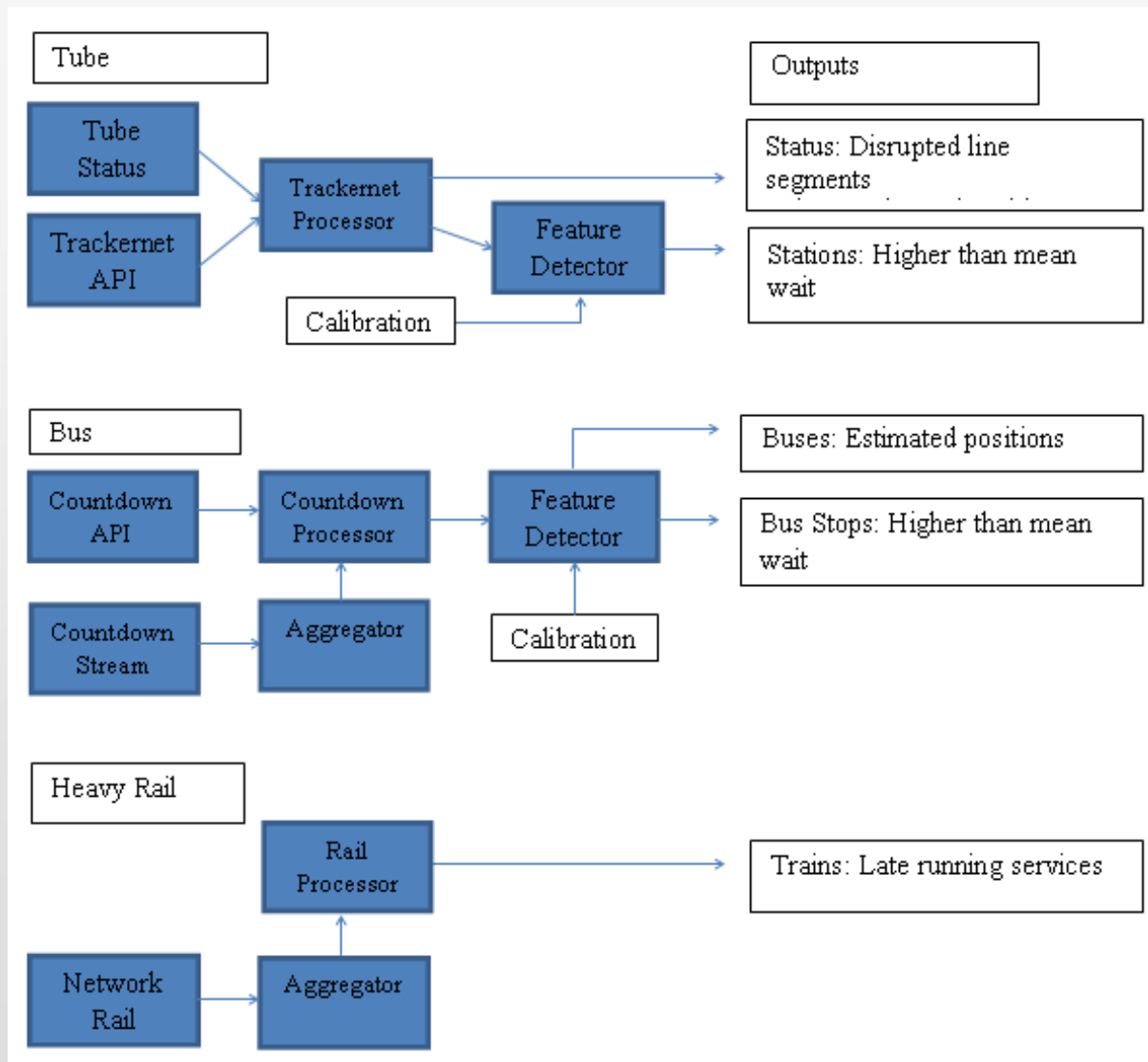


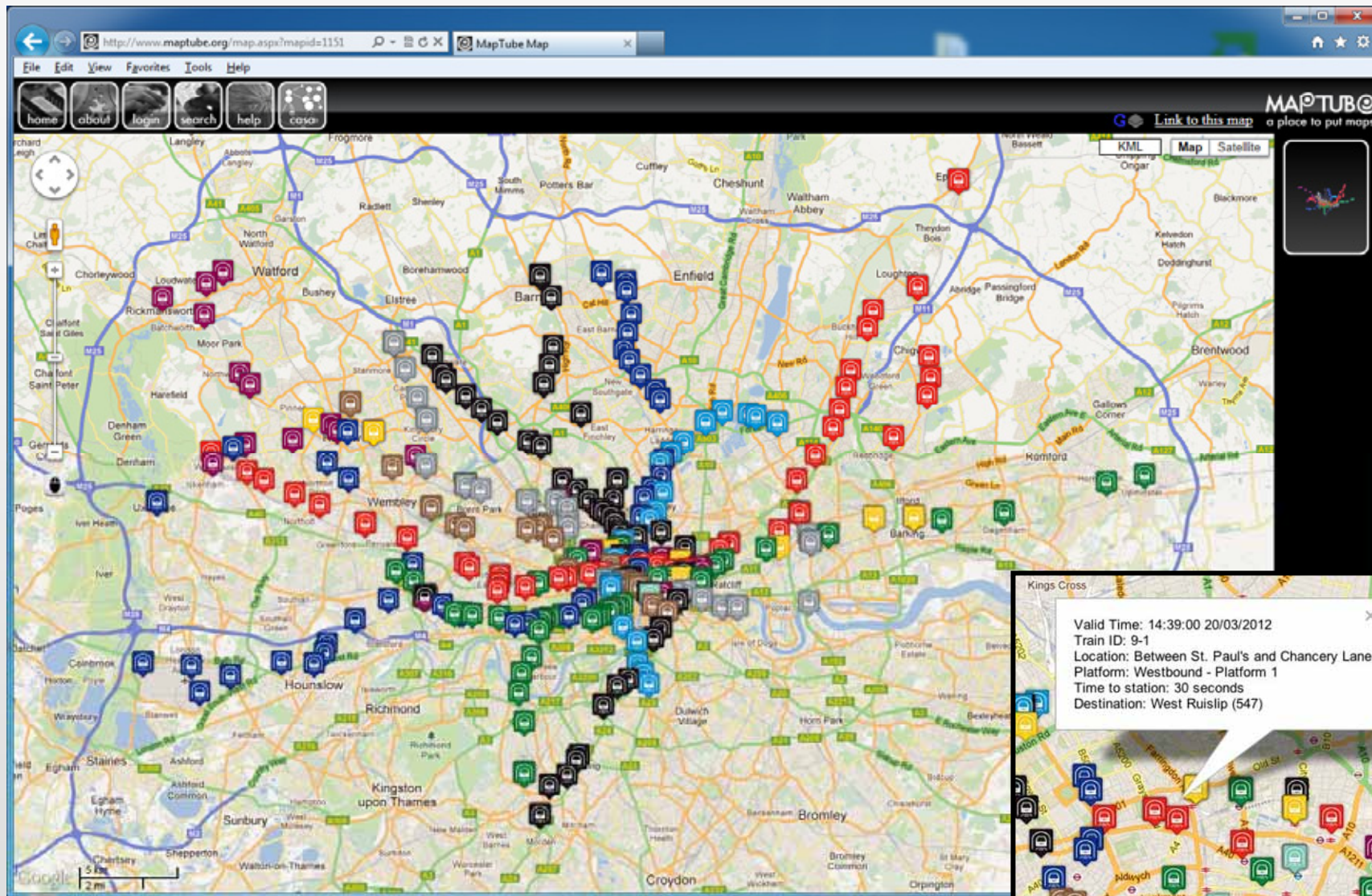
Increased Travel Time

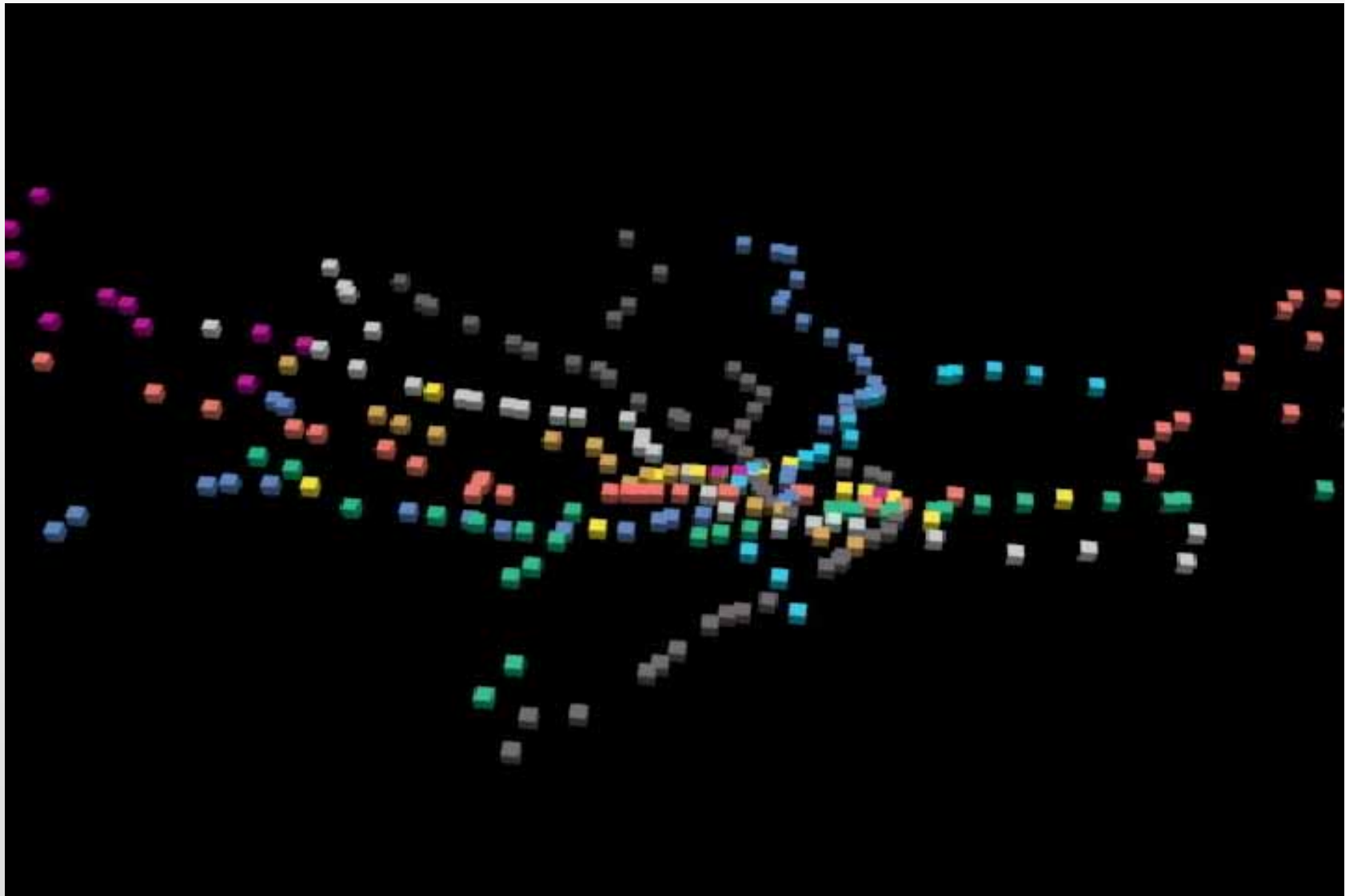
Greater than 2SD above mean increase on usual travel time for that Oyster Card

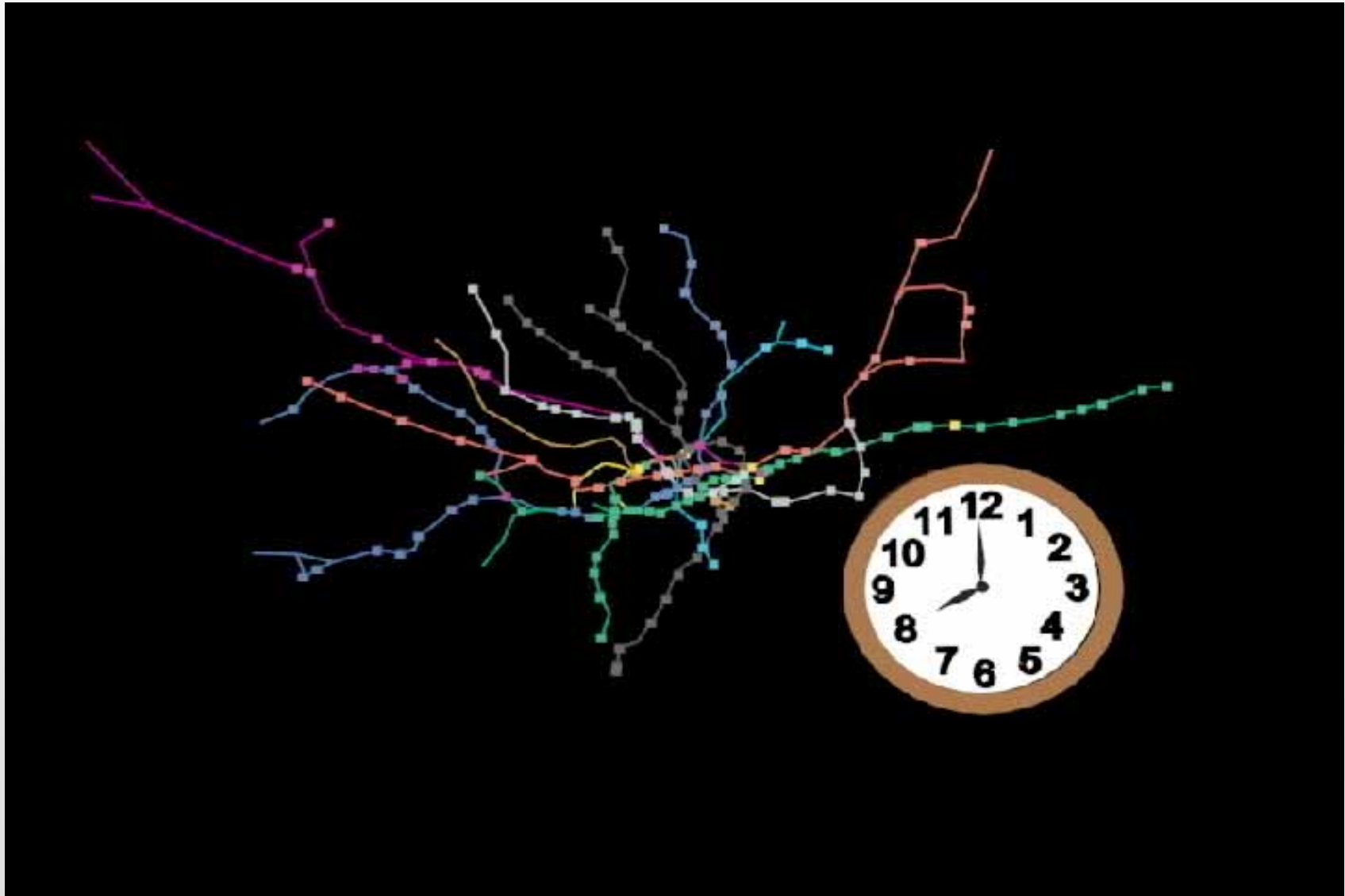
Size equal to proportion of users that regularly travel from station during time period, and travelled that during disruption

The Public Transport System in Terms of Vehicle Flows

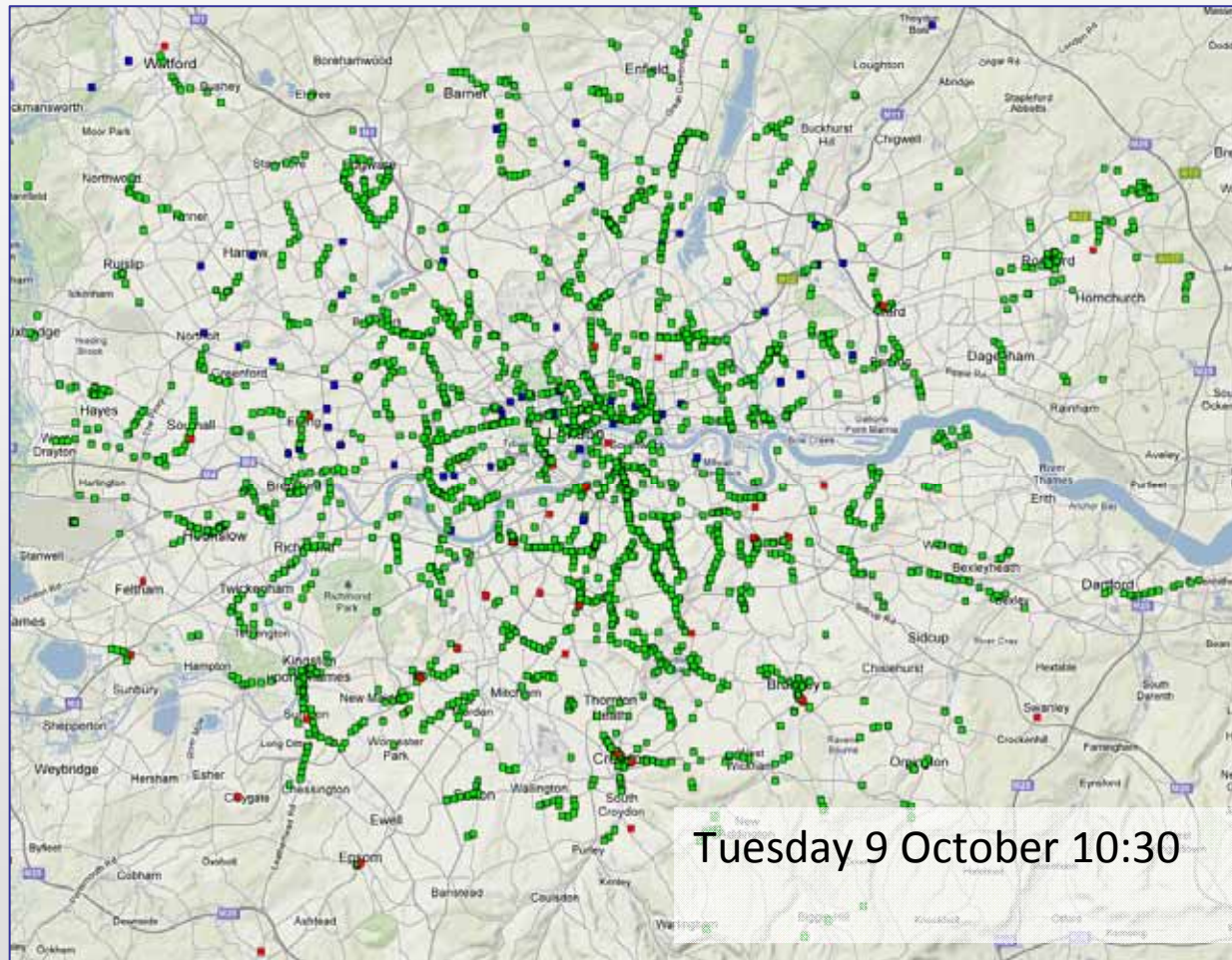











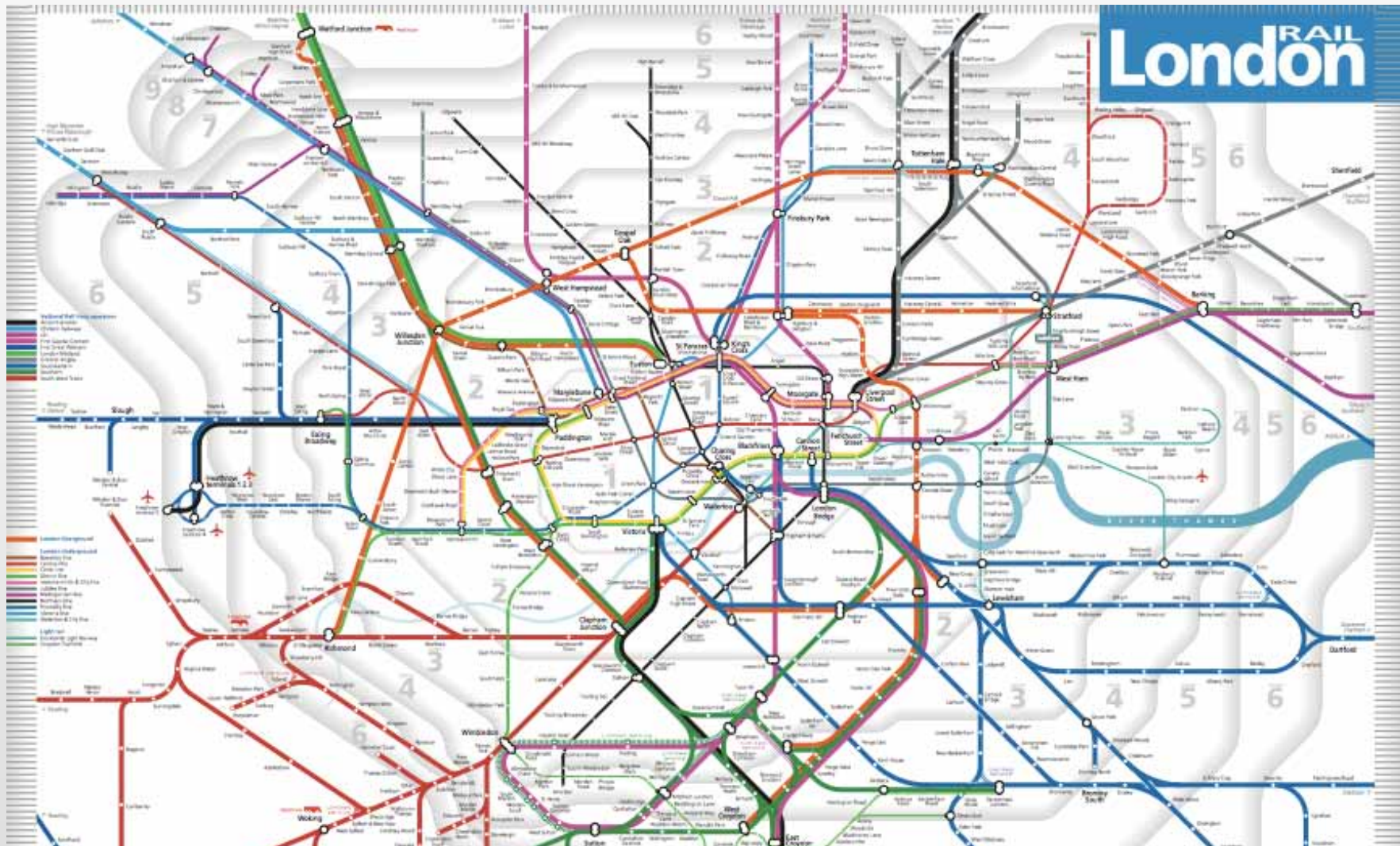
Delays from Tube, National Rail and Bus Fused



Key

-  National Rail more than 5 minutes late
-  Tube stations showing a wait time 15% above expected
-  Bus stops showing a wait time 20% above expected

Tube delays from the TfL status feed are also plotted as lines

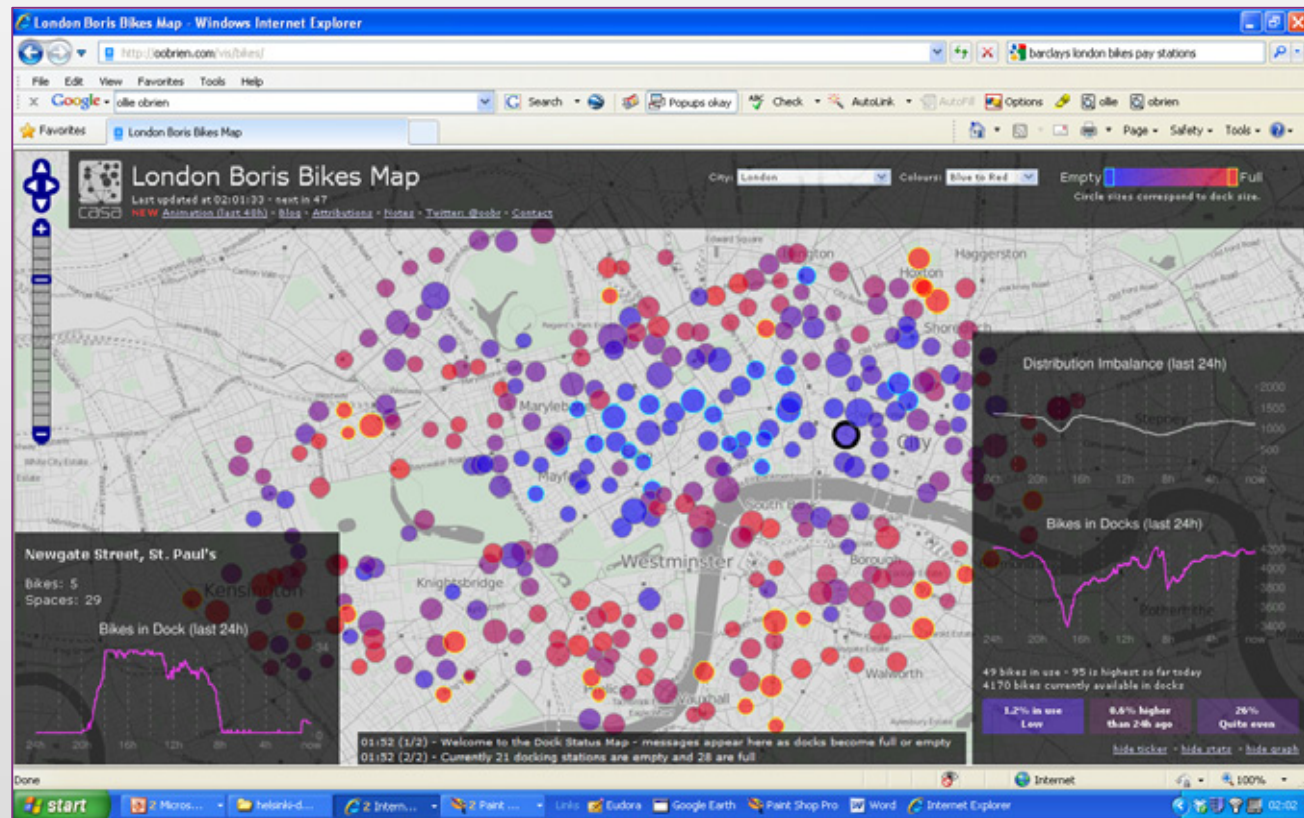


Tube, Overground and National Rail Networks in London
where Oyster cards can be used

Exemplar 4: The Public Bike Scheme: Local Routing and Local Models of Movement



Bikes Data – 4200 bikes, started Nov 2010, all the data– everything – all trips, all times, all stations/docks





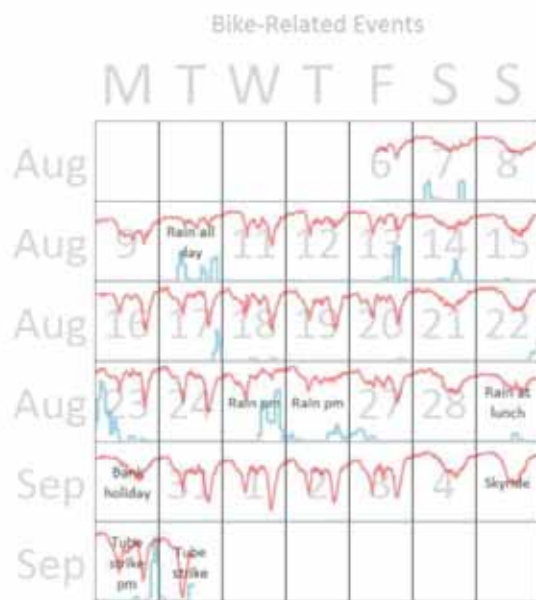
Animations of Public Bike Movements



Animations of Changes in the Bike Nodes: Docking

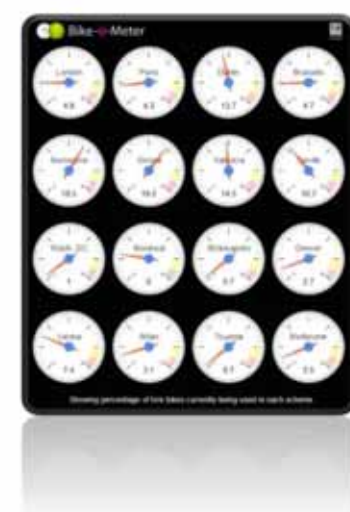
More Analysis

- **London**
- Graph shows number of bikes available to hire
- Effect of rain
 - Using the CASA weather station
- Effect of the tube strikes



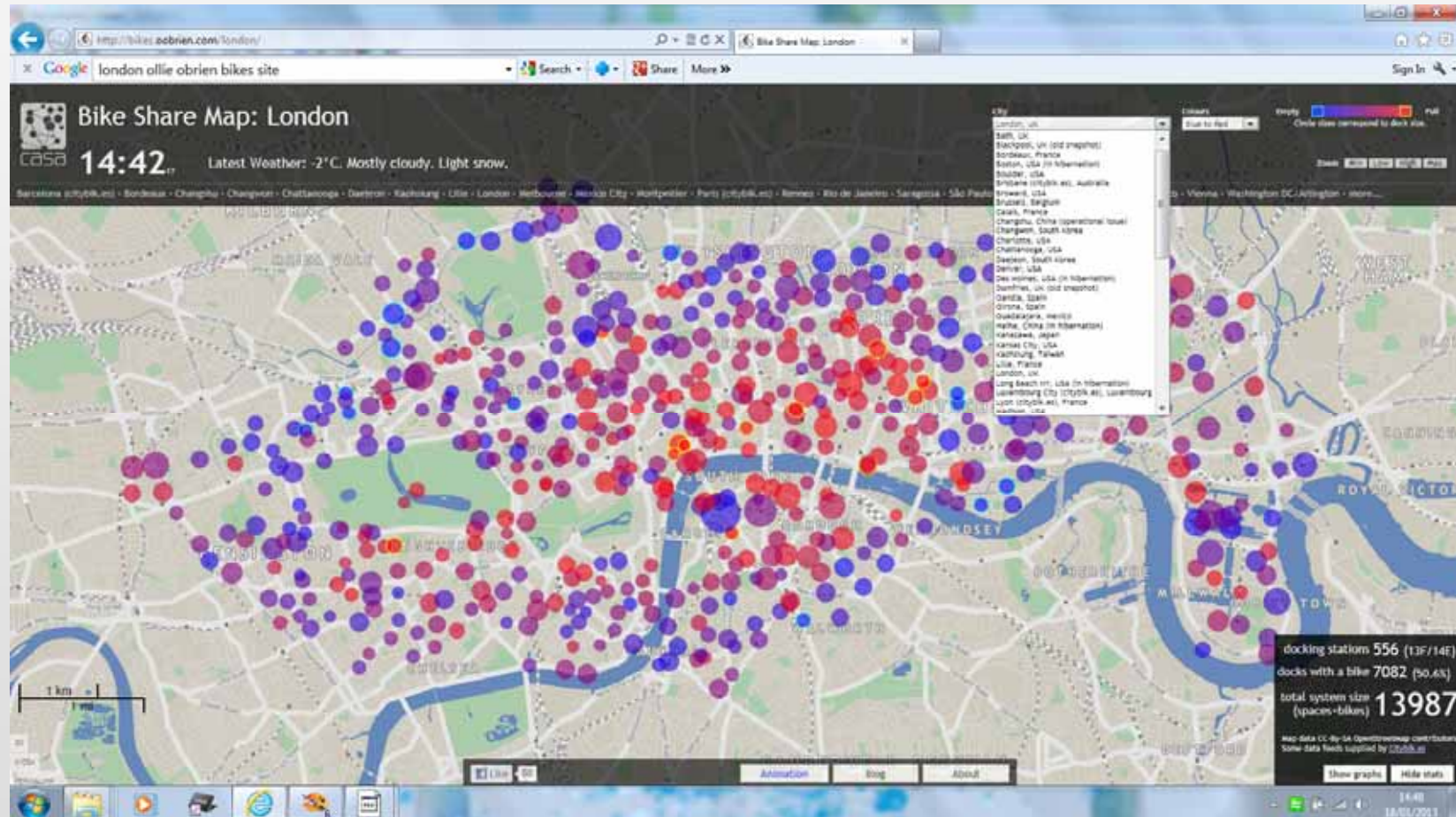
Bike-o-Meter casa.ucl.ac.uk/bom

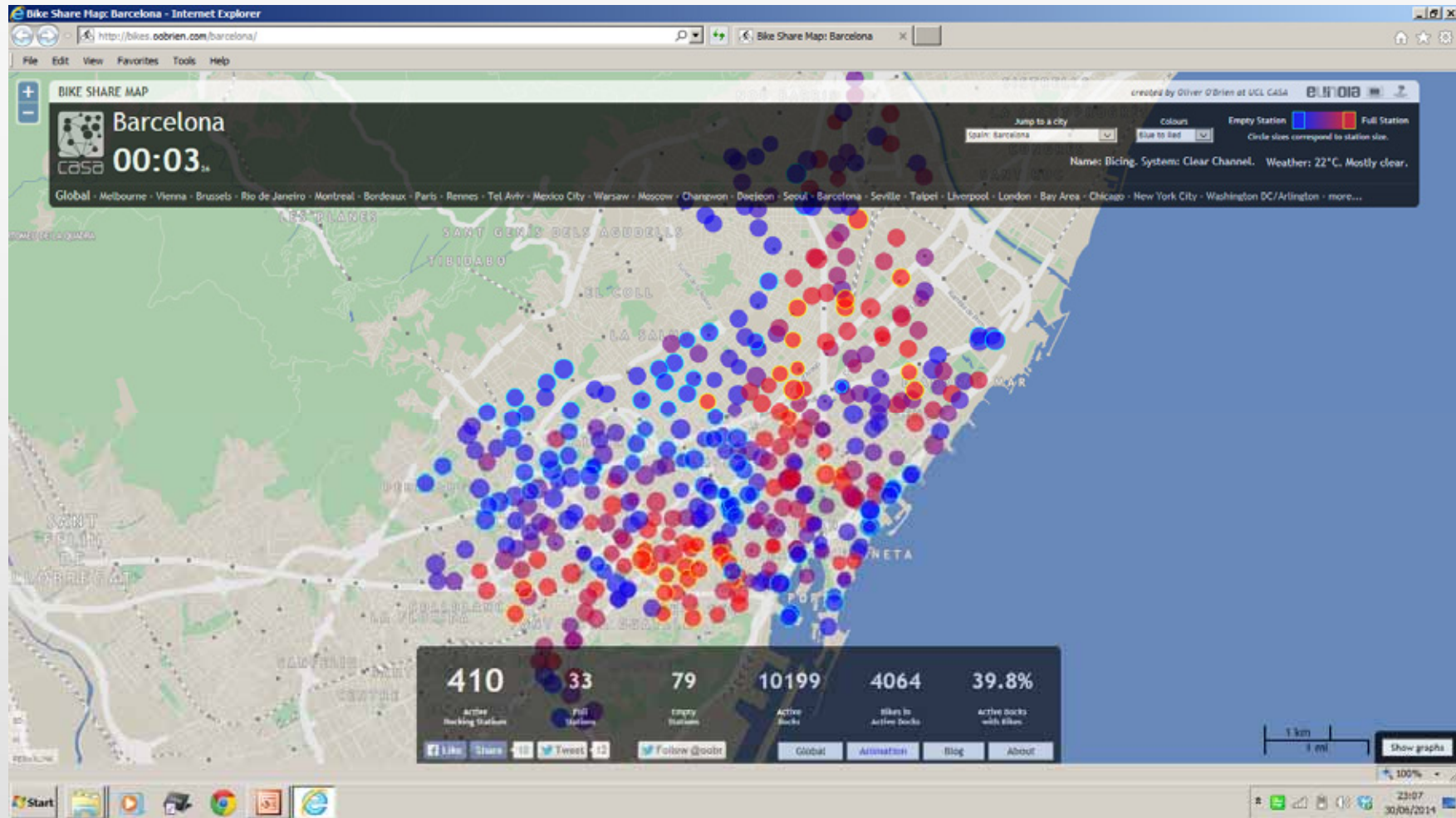
- Tweet-o-Meter for bikes
 - Steven Gray (@frogo)
 - Using Google Gauges
- See the real life Tweet-o-Meters at the new British Library "Growing Knowledge" exhibition
 - Should be easy to hack to show the Bike-o-Meters instead 😊



The Website: Real Time Visualisation of Origins and Destinations Activity

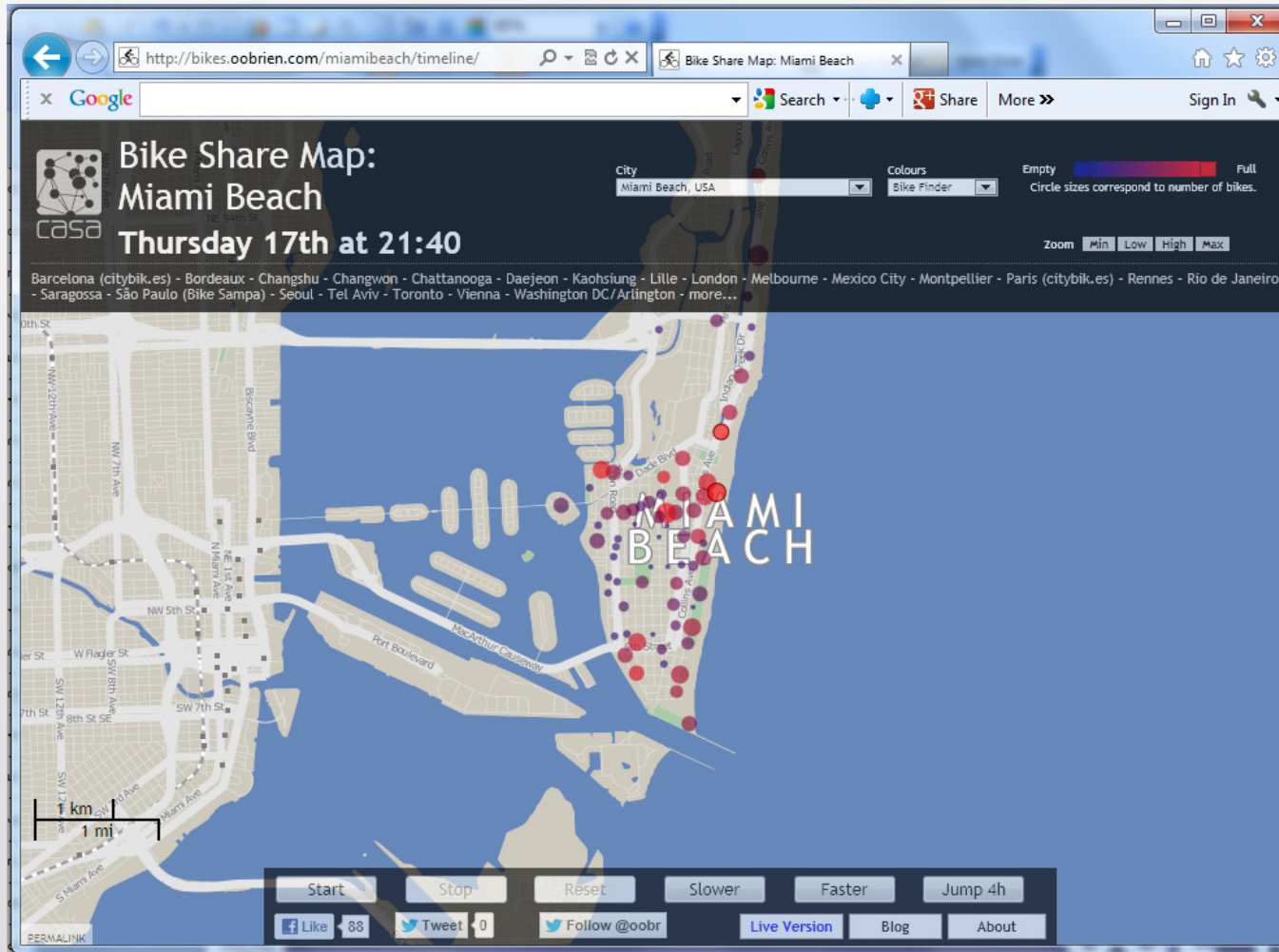
<http://bikes.oobrien.com/london/>





<http://bikes.oobrien.com/barcelona/>

You can play back the last couple of days from the animator for many of the cities where the data is captured online



We have shown a lot of data and examples of flow data which is 'big data' taken from streaming in real time

What has become very popular is the notion of the dashboard – a way of presenting all this streamed data in terms of a one stop shop – a portal that gives access to the streams all arranged to provide an instant picture of what is happening.

Some of these focus on the performance of cities and are evaluative but these will evolve in time and as everywhere with new information technologies, these glimpses of the state of things will become widespread. Here is our contribution.

London

51.51 N, 0.13 W

Mon 30 Jun @ 20:47:27

[Go to Map](#) - [Go to Grid](#) - [Change City](#)

WEATHER STATIONS (MULTIPLE SOURCES)

STATION	WIND SPEED	WIND GUSTS	DIRECTION	TEMPERATURE	HUMIDITY	RAIN TODAY	PRESSURE	FORECAST
CASA Office: Bloomsbury W1	1.8 mph	1 mph	NW ↘	19.2 °C	63%	1.3 mm	1016.4 mbar	Dry Clear
Lambeth Meters: Brixton SW9	4.1 mph	4.1 mph	SE ↘	16.8 °C	79%	1.2 mm	1016.9 mbar	Dry Clear
Kampstead NW3	1.6 mph	0 mph	W →	15.2 °C	80%	0.7 mm	1017.0 mbar	Hard Rain

WEATHER (METAR)

London City Airport
Mostly clear
Cumulonimbus clouds observed
ESE at 9 mph 17 C

FORECAST (YAHOO! WTH)

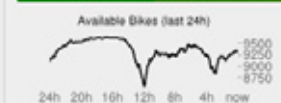
Mon	Tue
21 C Showers Early	21 C Mostly Sunny

TUBE LINE STATUS (TfL)

Bakerloo	Good Service
Central	Good Service
Circle	Good Service
District	Good Service
H & C	Good Service
Jubilee	Good Service
Metropolitan	Good Service
Northern	Good Service
Piccadilly	Good Service
Victoria	Severe Delays more
W & C	Good Service
Overground	Good Service
DLR	Good Service

LONDON CYCLE HIRE (TfL)

2.9 % Stations Full	8 % Stations Empty
9321 Bikes Available	381 Bikes or Docks Faulty



IN SERVICE (TfL)

3903 London buses
374 Underground trains

BICYCLES (LBH)

Goldsmiths' Row
2073 yesterday

AIR POLLUTION (DEFRA)

µg/m ³ Tsp. 24hr	Ozone	NO ₂	SO ₂	PM _{2.5}	PM ₁₀
Bloomsbury	53	41	3	9	12
Marylebone Rd	14	11	10	12	16
N Kensington	68	42	10	?	16

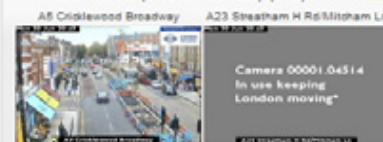
RIVER LEVEL (PLA)

Thames (Tower Pier)
2.55 metres

STOCKS (YAHOO)

FTSE 100 Index
6743.94 -13.83 (-0.21%)

TRAFFIC CAMERAS (TWO AT RANDOM) (TfL)



BBC LONDON NEWS (BBC)



OPENSTREETMAP UPDATES (OSM)



ELECTRICITY (N Grid)

Demand (Great Britain)
34988

MOOD (LSE HAPPINESS)

5% unhappier than the long term average for here	3% happier than the whole country right now
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TWITTER TRENDS FOR LONDON

Data unavailable

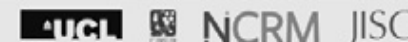
LONDON NEWS AND EVENTS (TWITTER)

Data unavailable

LONDON UNIVERSITIES (TWITTER)

Data unavailable

[Tweet](#) 1,383 [About](#)

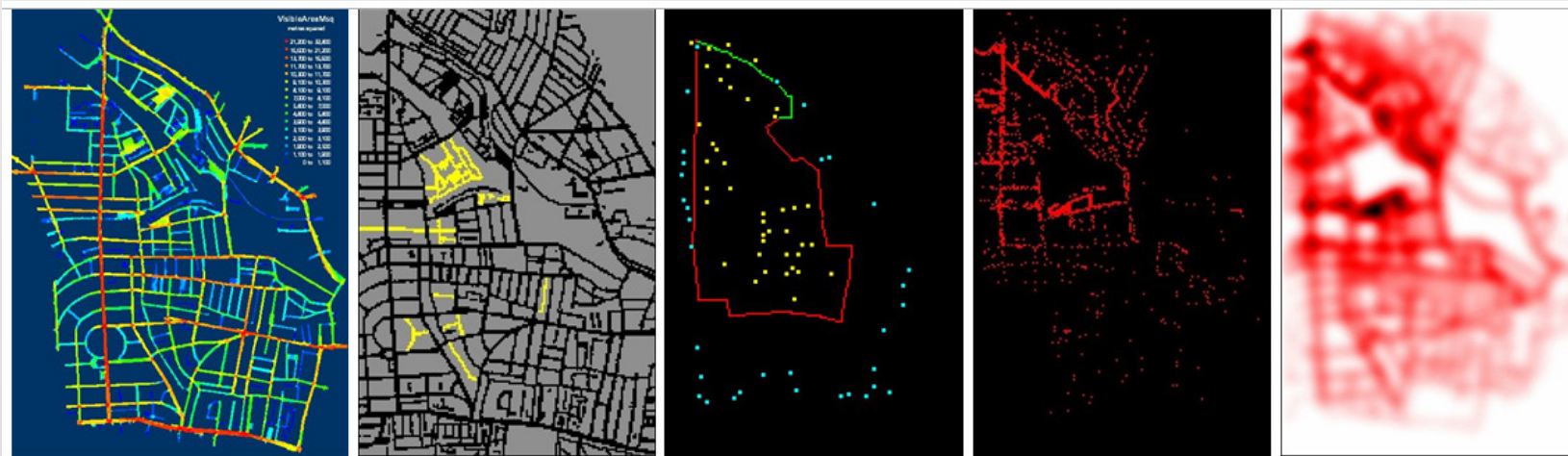


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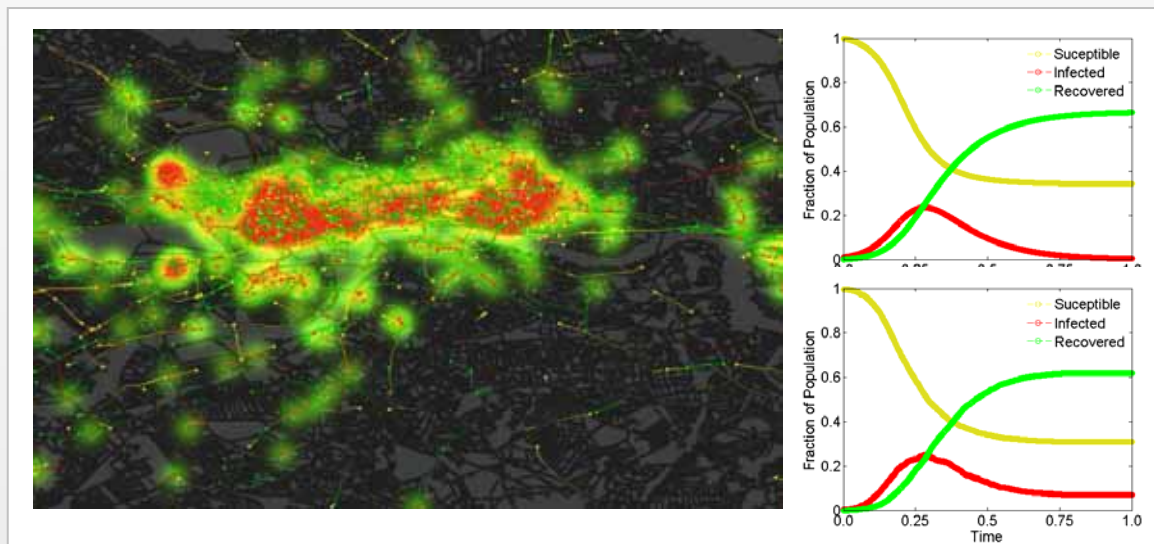


Simulating Crowds: Fine Scale Modelling and Sensing

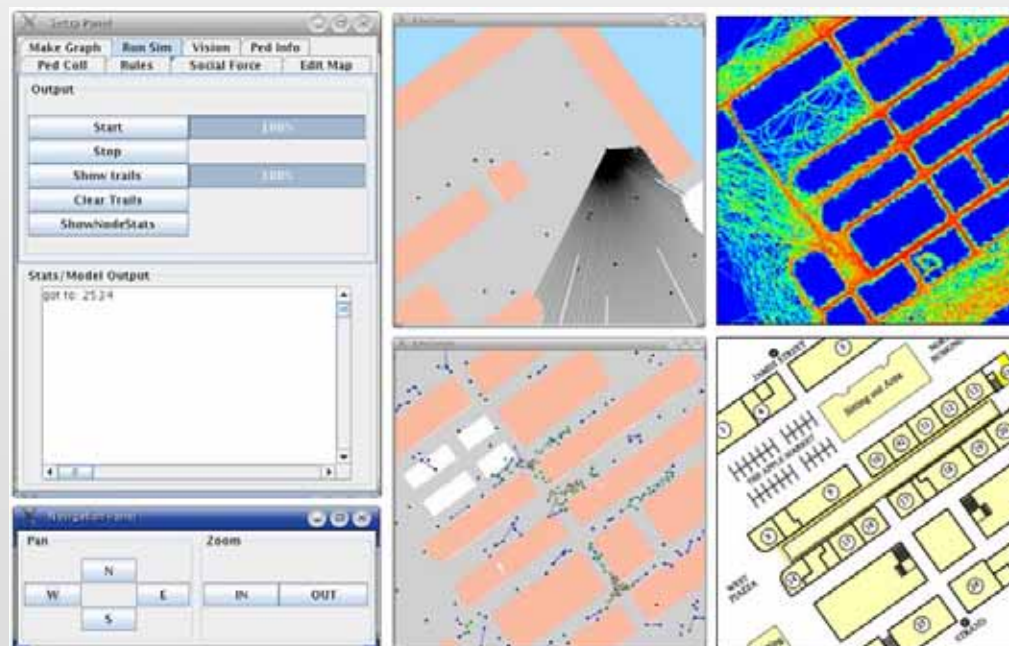
In a different tradition but one which is rapidly converging with our interests in sensing and networks, we have developed a number of pedestrian models, first for the Notting Hill Carnival, and then for many town centres



We are now working on fine scale models which are mirror diffusion and spread in situations ranging from epidemics to evacuation and shopping.



We have a simple model of epidemics on networks in London and we are looking at evacuations of major shopping centres such as Covent Garden (right)



Let us change tack from sensing to mapping

Exemplar 5: Crowd-Sourcing and New Data: Sources from Social Media

We have a number of mapping projects using Web 2 and these involve using these online mapping systems to elicit simple data from the crowd – but data that is geotagged, hence the production of online maps of the crowdsourced data in real time

We have looked at Manchester congestion charge, anti social behaviour and credit crunch where in all cases we have used the BBC to broadcast the questions and provide the forum for response while our servers and software have produced the maps.



MAPTUBE
a place to put maps



Radio 4: Mapping the Credit Crunch

Welcome to Radio 4 Listeners, below is the Credit Crunch question, simply select an option and then input the first part of your postcode - for example RG11

MapTube will then take your answer and every hour automatically create a map of the nation's mood.

What single factor is hurting you most about the credit crunch?

- Mortgage or Rent
- Petrol
- Food Prices
- Job Security
- Utility Bills
- Not Affected

Enter the first part of your postcode:

Submit

Centre for Advanced Spatial Analysis - University College London - 1-19 Torrington Place - London - WC1E 7HB - ☎ +44 (0)20 7679 1782 - Fax +44 (0)20 7813 2843 - Email casa@ucl.ac.uk Copyright © 1999-2008 UCL

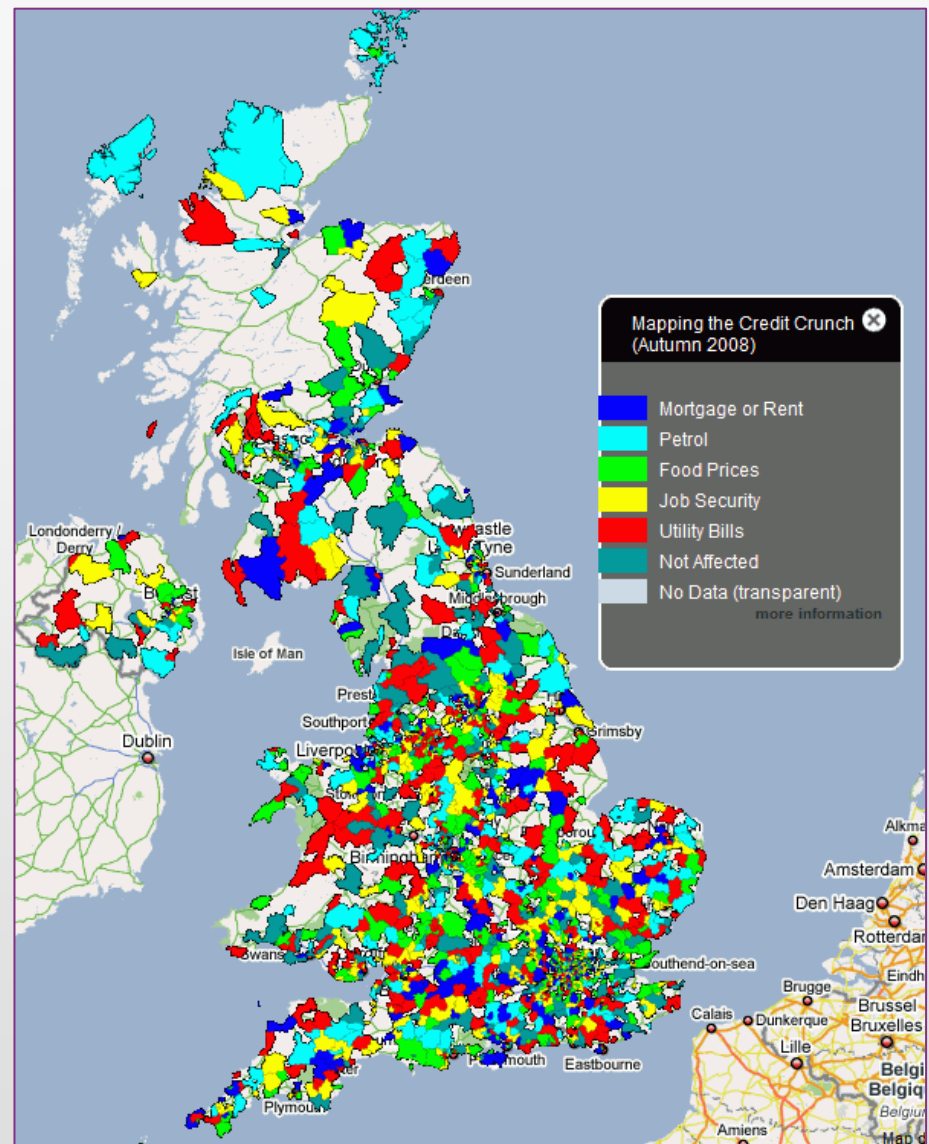
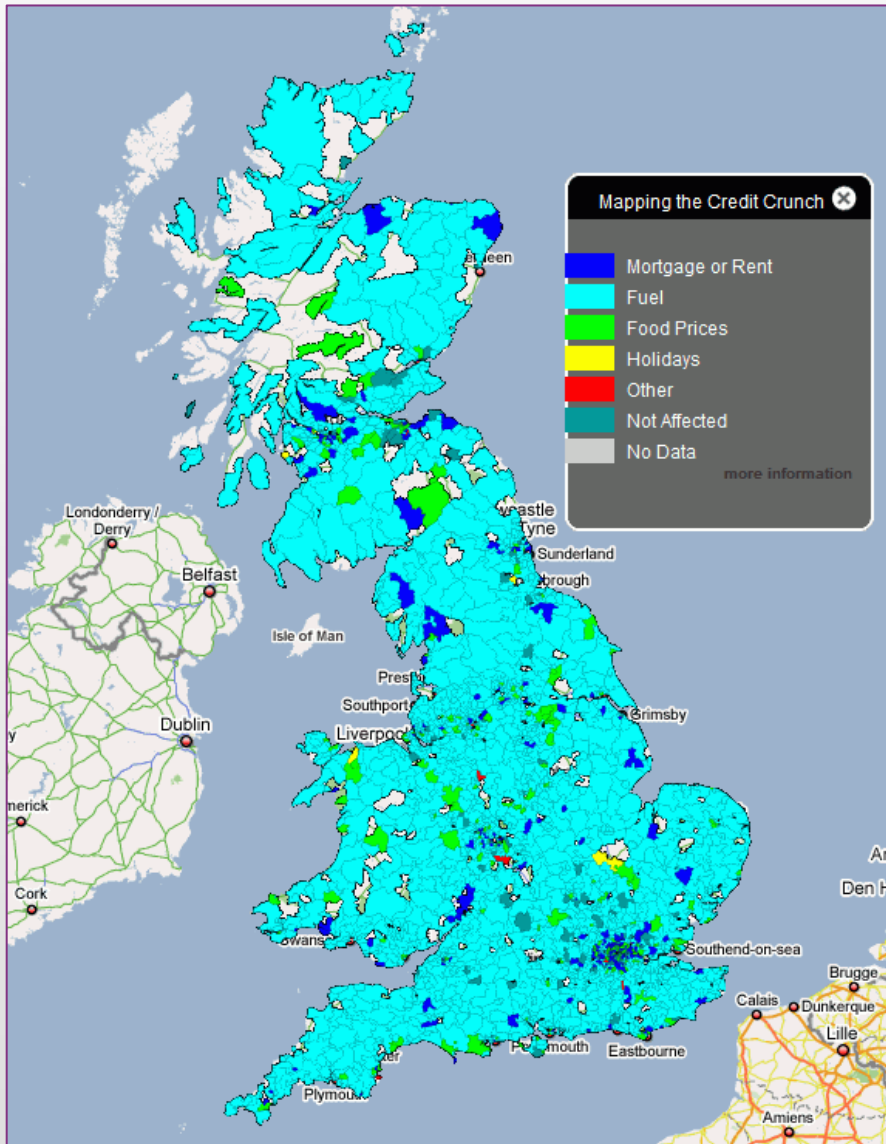
23,475 responses
April, May, June 2008

A new credit crunch survey started in October and currently has 3,802 responses.



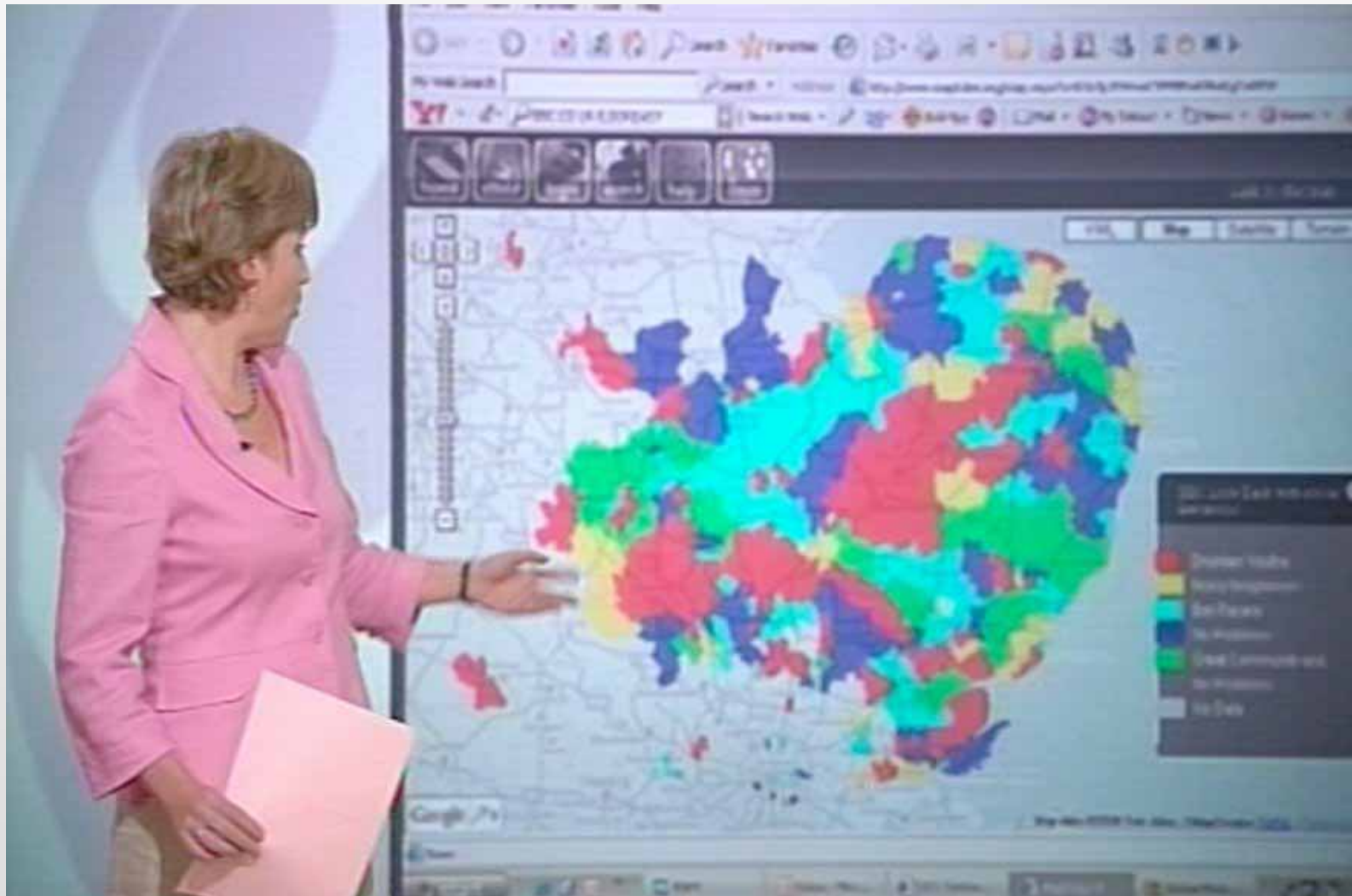
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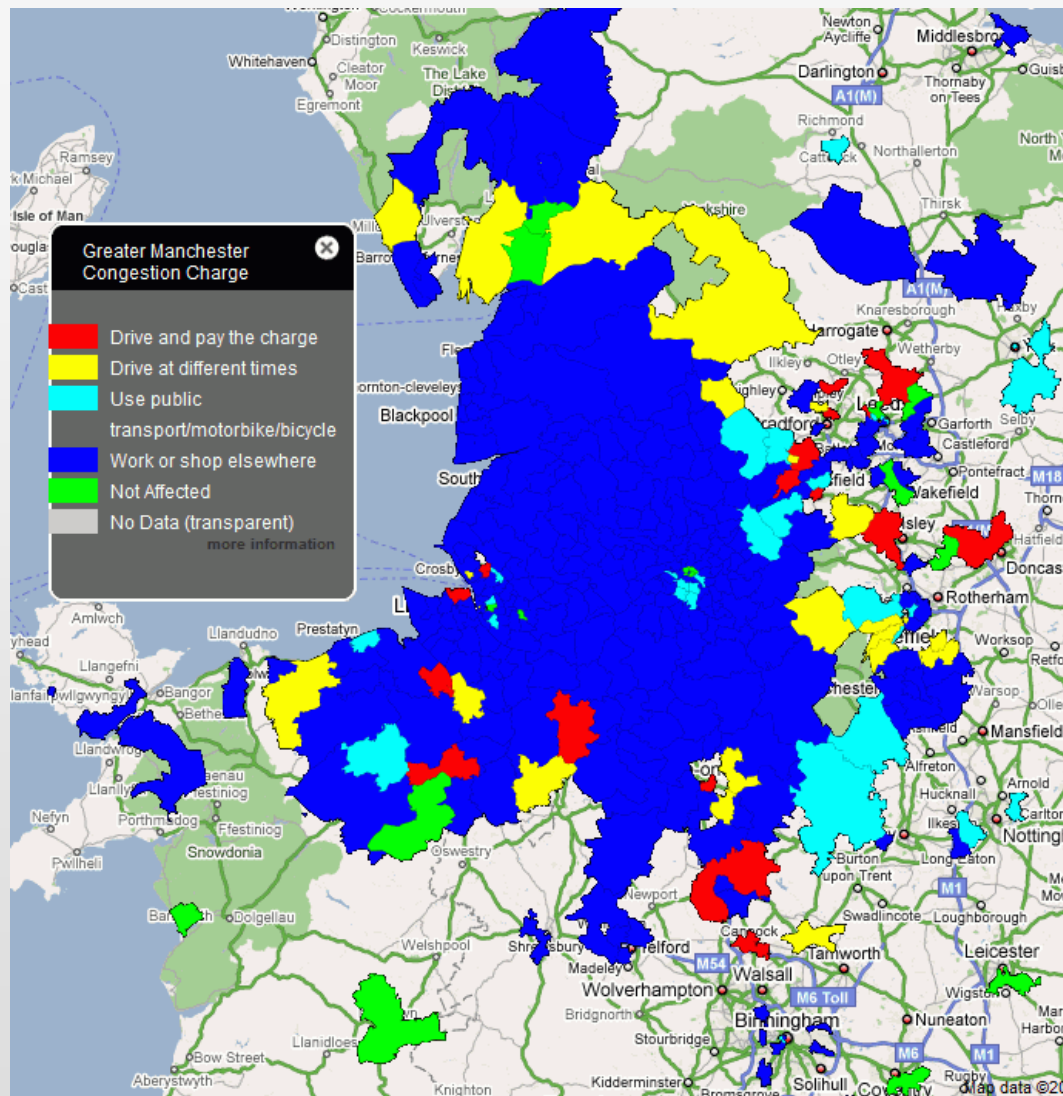
<http://www.maptube.org/creditcrunch/>

BBC Look East: Anti-Social Behaviour

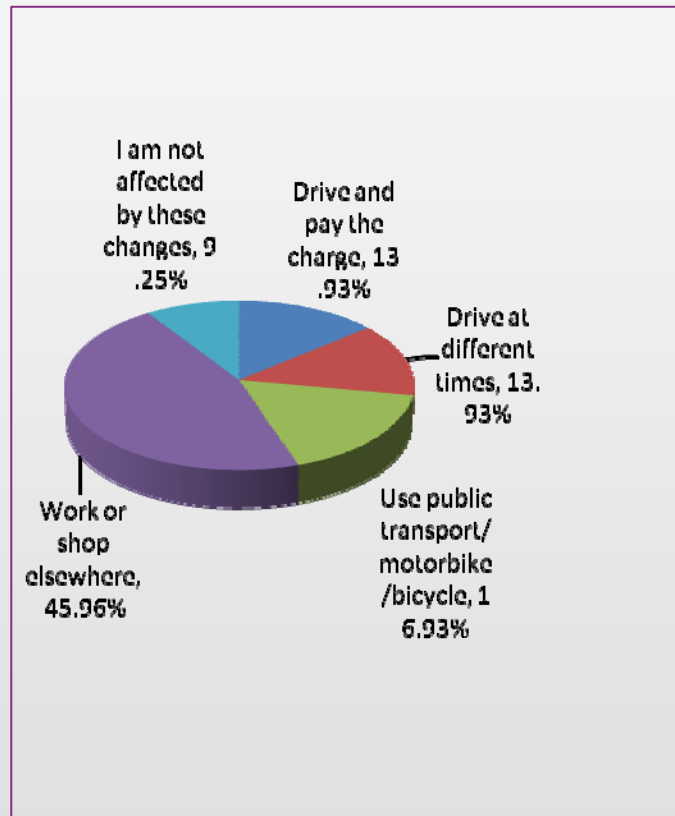


<http://www.maptube.org/lookeast>

Manchester Congestion Charge

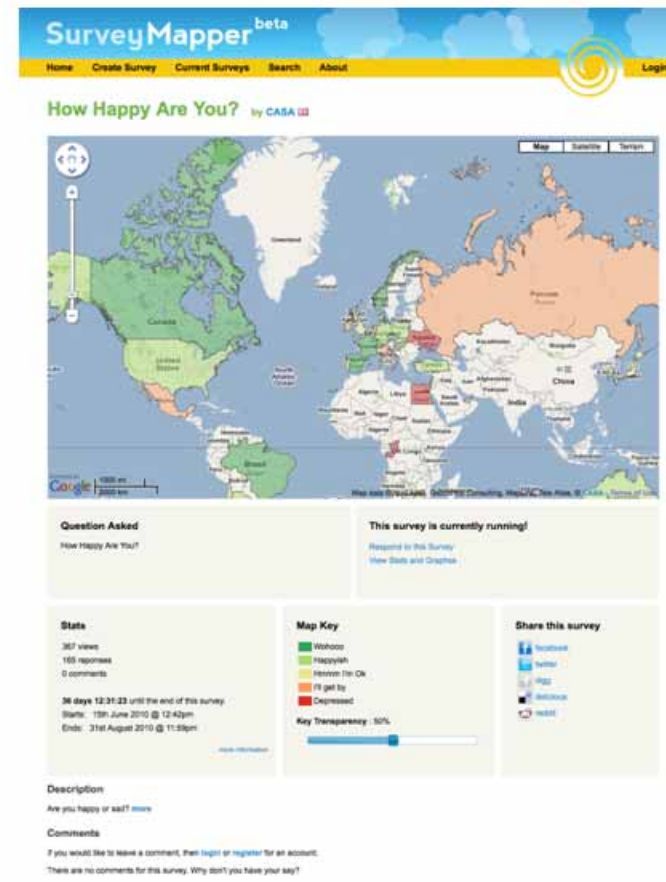


15,902 responses
October to December 2008

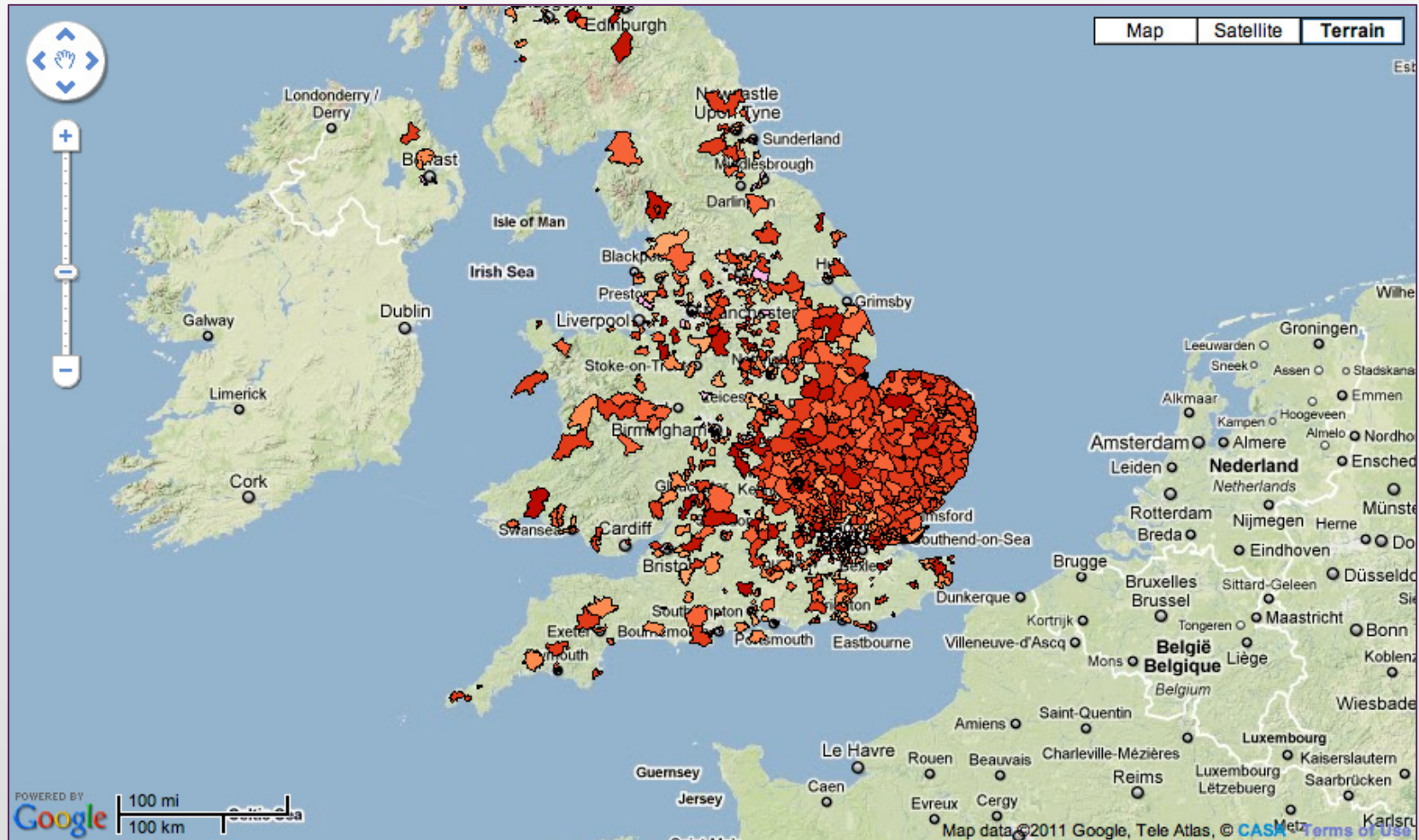


SurveyMapper

- Real-time Geographic survey tool.
- Up to 50 questions per survey
- Up to 50 answers per question
- Live stats and graphs
- Geographic Regions:
 - Worldwide Countries
 - European Countries
 - UK Counties
 - UK Postcode
 - Adding more soon
- Frequently updating regions



BBC Look East Survey - Broadband Speed Test



Extracting and Mapping Social Media

We have started to mine, map, interpret much social media because of the ease of its availability – and we have started looking at Short Text Messaging – Twitter data.

We have also begun to look at phone tracking data – from the iPhone for example but many of our data sets such as the bikes data, the Oyster card and such like data are really part of the same domain of new bottom up data. We have no control over this but some of the social media data we are mining we have greater control over. Here are some examples.

And Here is a Map of Tweets above London which uses our 3D model to visualise these data

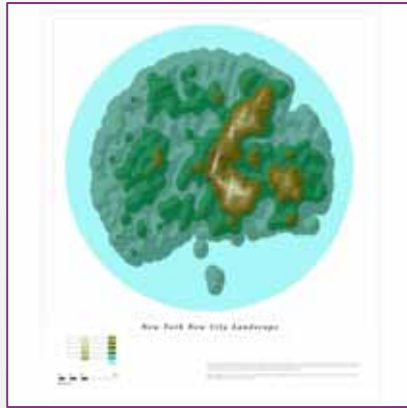


London Twitter Cloud

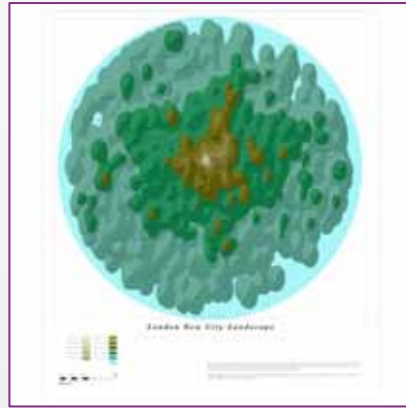


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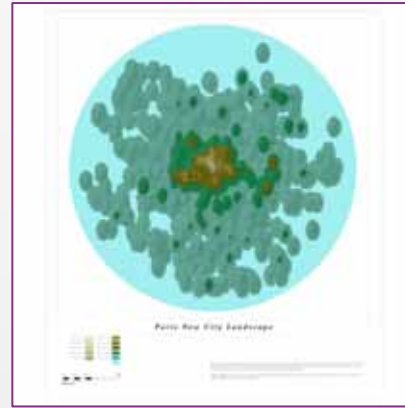




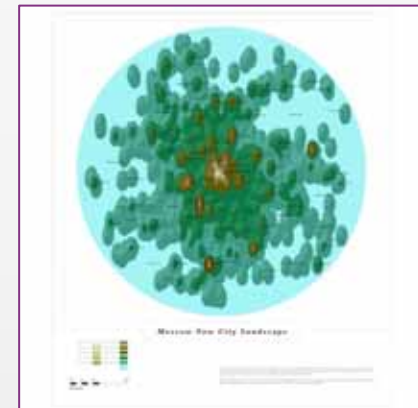
New York



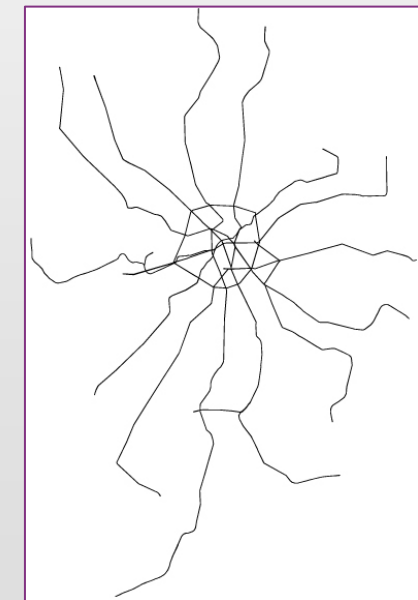
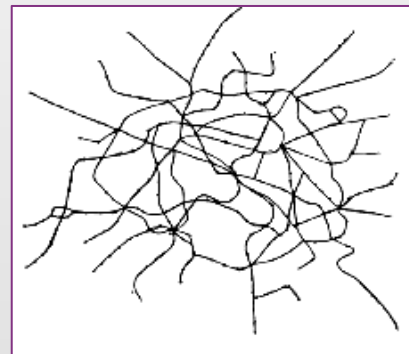
London

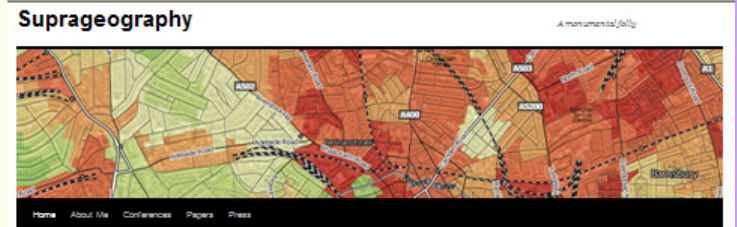
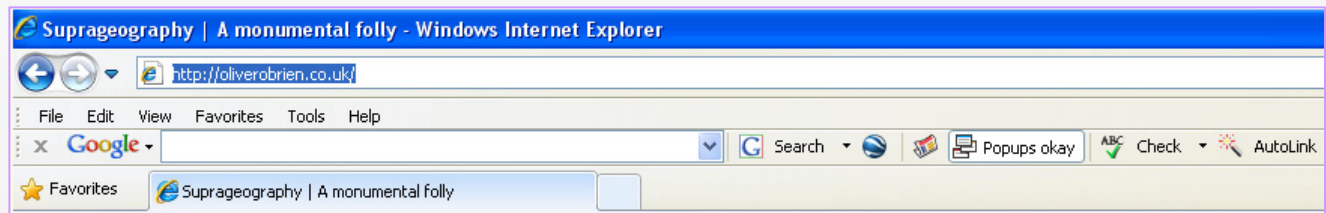


Paris



Moscow





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modelling, visualising and communicating urban environments

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2010-10-18

Bike-o-Meter Now Without Paris/Dublin/Brussels/Valencia/Seville/Vienna and Toyama

The world of data is changing, vast amounts of free and open data are enabling innovative visualisations. Our new Bike-o-Meter could be seen as a case in point, it provides at a glance a view of how bicycle rental schemes in cities around the world are performing. It even allows you to view the percentage of hire bikes that would need to be redistributed to balance each scheme and here may lie the problem - it allows under performing cities to be clearly identified using their own data.

3 [Tweet](#)

The image shows four circular gauges representing the Bike-o-Meter for different cities. The gauges are labeled: London (6.3), Paris (NaN), Dublin (NaN), and Brussels (NaN). Each gauge has a needle and a scale from 0 to 30. The London gauge shows a value of 6.3, while the others show NaN.

4689 readers
BY F49080818

LATEST NEWS

Data Mash-Ups and the Future of Mapping: JISC Report [Published](#)

TalesofThings in the [New York Times](#).

TalesofThings features in [Mashable's Spark of Genius Series](#), sponsored by Microsoft's BizSpark.

Our Digital Urban Booklet is now available as a [Free PDF](#).

Real Life Tweet-o-Meters

Posted on 2010-10-18 by [Giles](#)

The image shows three physical gauges mounted on a wall. They are labeled: "NEW YORK NEW YORK", "LONDON", and "SAN FRANCISCO". Each gauge has a needle and a scale from 0 to 30.

I was at the [British Library](#) yesterday for the launch of the [Growing Knowledge](#) exhibition of innovative research techniques. One installation has been built by Steve and Ben at CASA and is a real-life version of the [Tweet-o-Meters](#) (which were also the inspiration and technology for the [Bike-o-Meters](#) I mentioned yesterday.)

The installation has dials for nine cities around the world, showing the current level of Twitter activity (i.e. geo-located tweets) in these locations.

I love the "1930s retro" design of the installation. It is notable that all the other installations in the exhibition involve computer screens, in several cases these are used to display old maps (e.g. the New York Public Library rectification service) or historical paintings (using a Microsoft Surface screen.) I love the irony that the exhibition that is showing the data right now, i.e. coming live off Twitter from around the world, is the one which doesn't involve any computer screens at all - although they are of course computer-controlled

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October 2010

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- [Bike-o-Meter](#)
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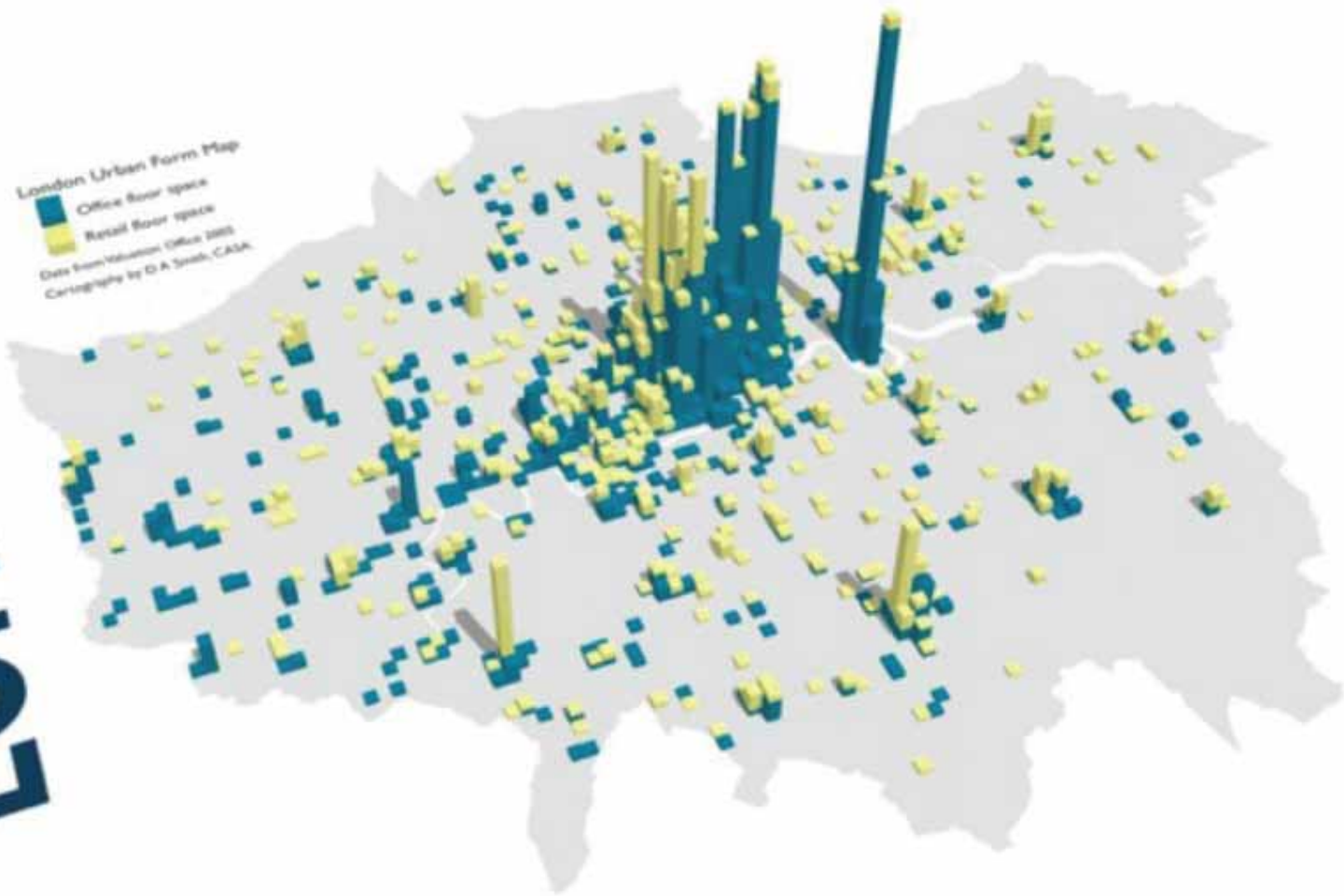
Returning to our old exemplars – these are being enriched with new tools and new data and new animations

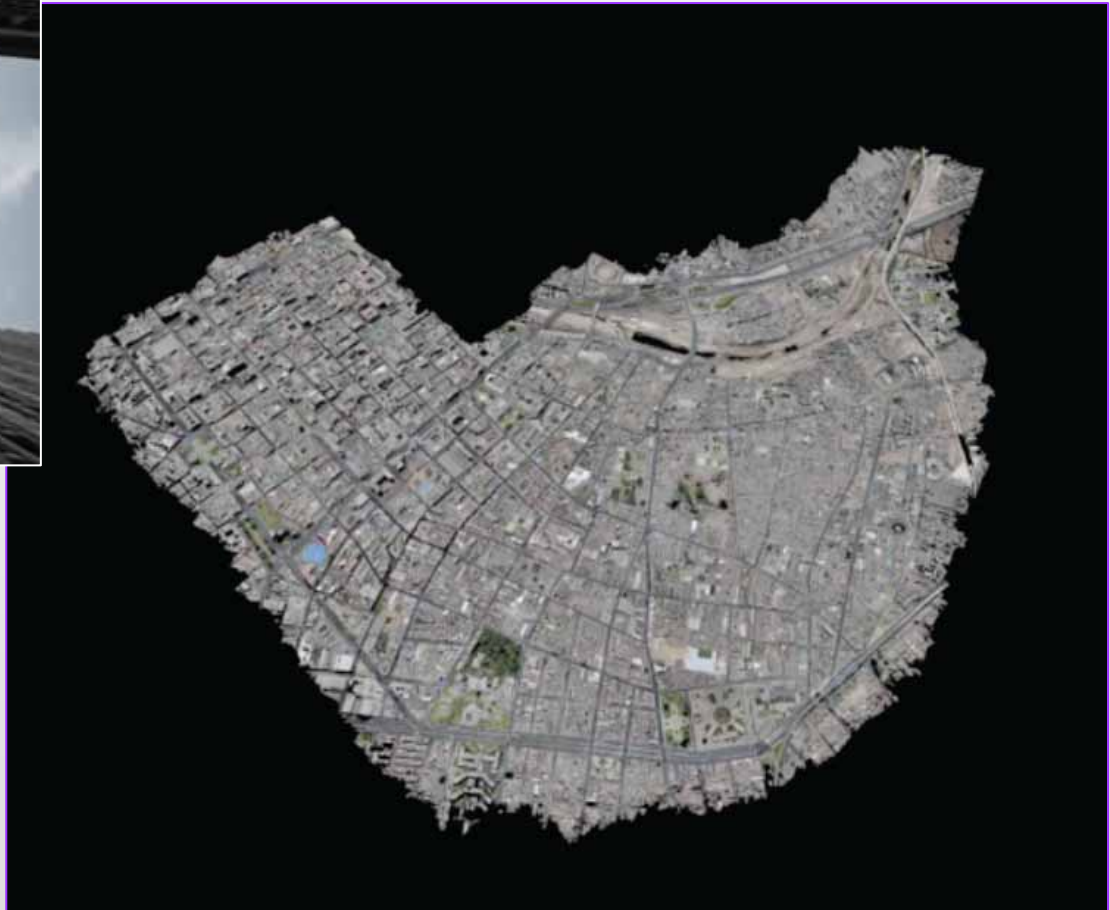
Our LUTI models are being informed by 3-d visualisation and can now be imported into 3-D in working form

Our 3-d visualisations are being enriched with new and rapid sensing technologies using everything from phones to drones and new data attributes in terms of social media.

LONDON

London Urban Form Map
Office floor space
Retail floor space
Data from Valuation Office 2005
Cartography by D.A. Smith, CASA







Where Do We Go From Here? The Next 100 Years

I have not mentioned that much of this is being ported to hand held devices – in fact this is obvious

I have not mentioned digital participation which is key to the smart cities movement, indeed reinforces the point you can't have smart cities without smart people.

I think we need to fashion a new science out of this and some of it is coming. This will be built on many ideas of the last century but a lot of new ones too across many different dimensions

Let me finish by saying what we are trying to do– to tie all this together in **A Science of Cities** and our progress in this will always be a moving target as cities continue to change as new technologies are invented which then change us.

Thanks

<http://www.spatialcomplexity.info/>

<http://www.complexcity.info/>

<http://www.mechanicty.info/>

<http://blogs.casa.ucl.ac.uk/>

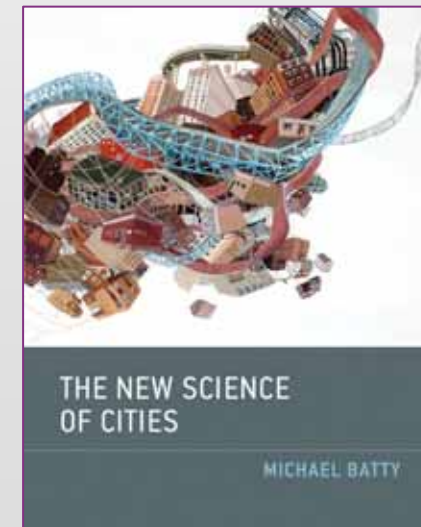
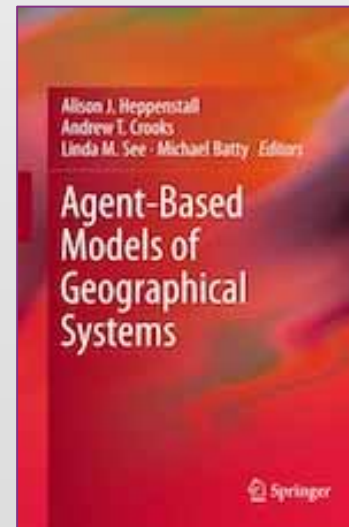
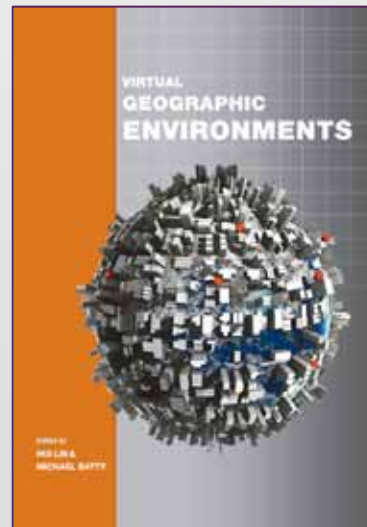
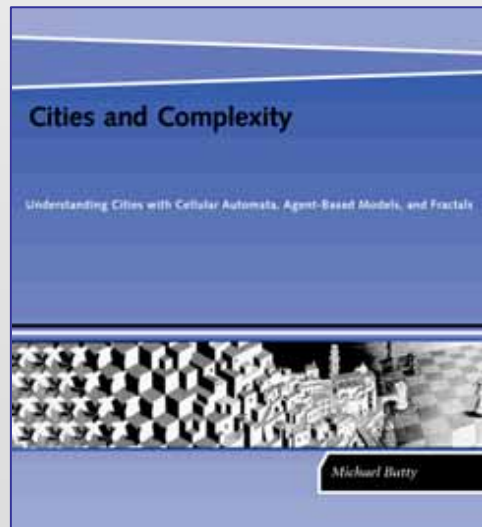
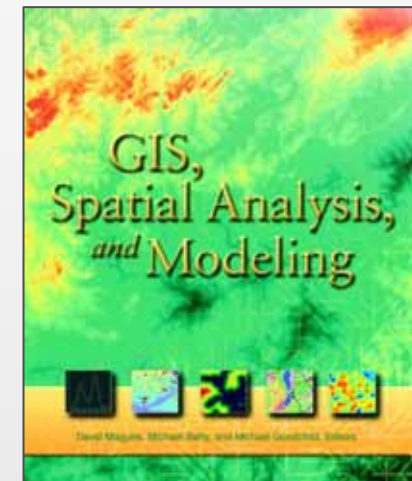
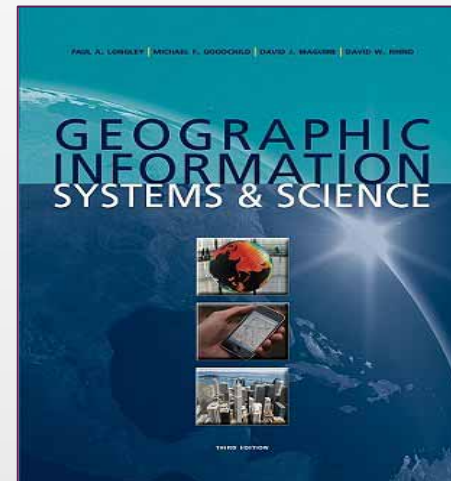
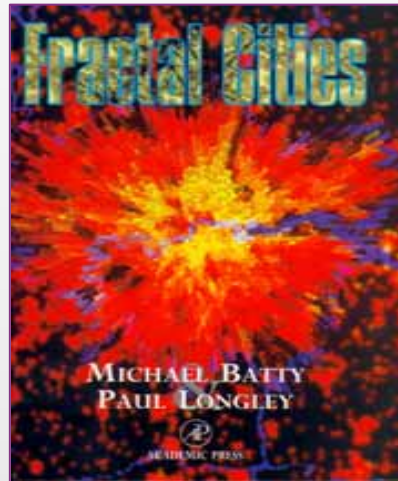
<http://www.casa.ucl.ac.uk/>

Acknowledgements

Andy Hudson-Smith, Richard Milton, Oliver O'Brien, Stephen Gray, Fabian Neuhaus, Pete Ferguson, Martin Austwick, Joan Serras, Camilo-Vargas-Ruiz, Paul Longley, Jon Reades, Ed Manley, Anders Johansson, Flora Roumpani and Stephan Hugel



Some of our books which are about some of this



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