Smart Cities, Data and Big Data

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@jmichaelbatty

http://www.complexcity.info/
http://www.spatialcomplexity.info/

FIRST DATA, THEN BIG DATA

DATA

Numeric, Ordinal, Nominal

Quantitative, Qualitative

Spatial, Non-Spatial, People, Places

Individual or Aggregated

Collected by Questionnaire or by Sensor

Large Scale, Small Scale Individual

Urban Analytics: to process data

Databases – Excel, SQL and so on

GIS – geographic information systems

Statistical methods for developing summaries of data – insights into data and also patterns in data

Data mining – multivariate technical

Spatial scale

Archives, Portals, Depositories, Servers,

BIG DATA

AFirst couple of examples about what smart cities are all about

Real time, streamed data and this is ‘big’

First, An example from public transport in London where smart card data is now key

Second, about online aircraft flight data

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

UCL ENGINEERING
Change the world

Menu +

Home – Projects – Oyster gives up pearls

OYSTER GIVES UP PEARLS

How studying millions of Oyster Card journeys reveals London's 'polycentres'

Researchers from UCL have analysed millions of Oyster Card journeys in a bid to understand how, why and where we travel in London.

Professor Michael Batty (UCL Centre for Advanced Spatial Analysis) and Dr Soong Kang (UCL Management Science and Innovation) applied the techniques of statistical physics to their mountain of raw data.

The pair joined forces with a computational social scientist and a physicist, both based in Paris, to explore patterns of commuting by tube into central London.

They used Transport for London's database of 11 million records taken over one week from the Oyster Card electronic ticketing system.

Latest news from UCL Engineering

New web privacy system could revolutionise the safety of surfing

UCL host Google Girls Coding Programme with Generating Genius and University of West indies

Professor Polina Bayvel to Give Royal Society Lecture

Twitter feed

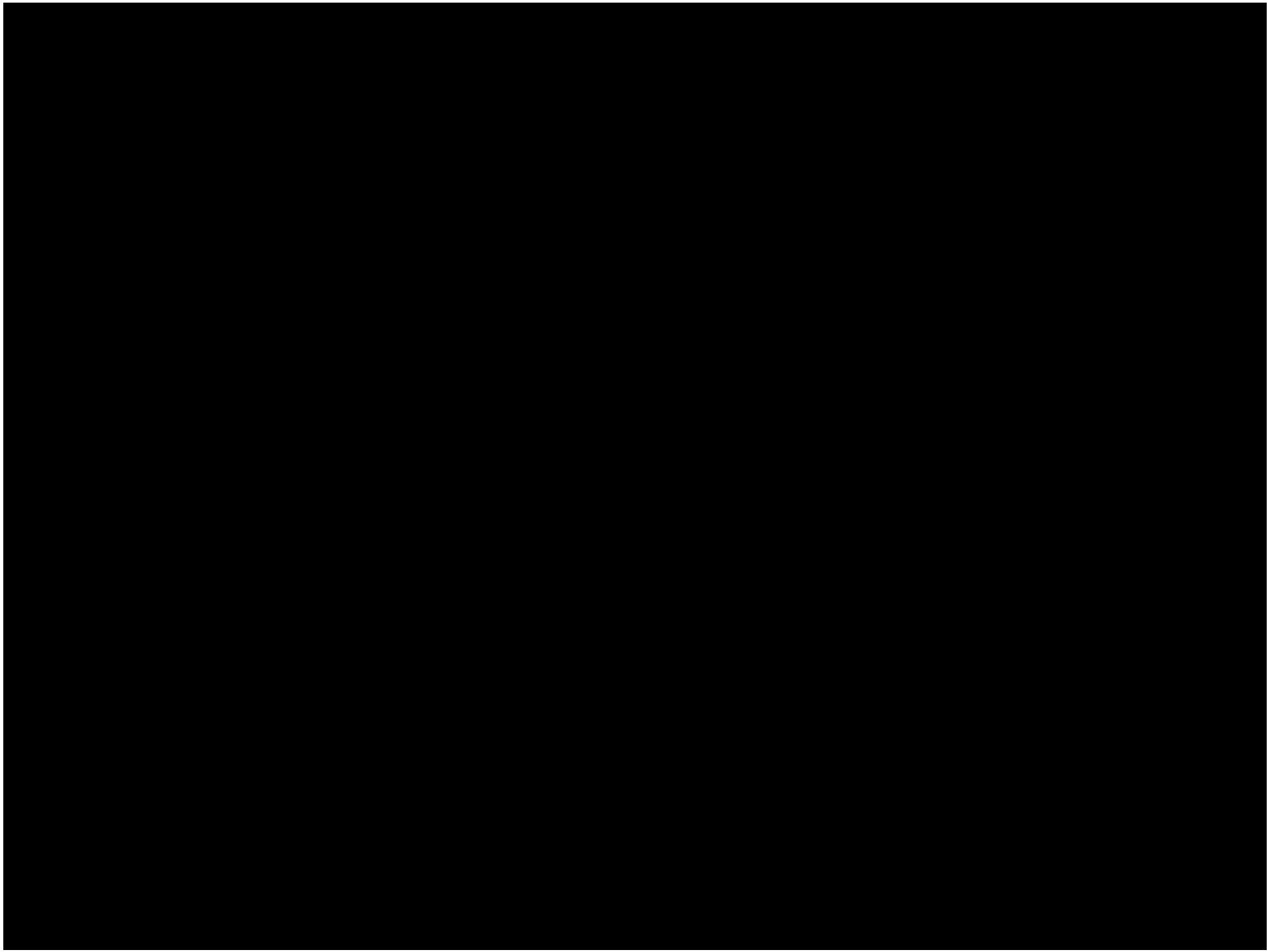
RT @markmiodownik: Am giving a ENGins seminar today for @UCLEngineering @UCLENGins all UCL engineers welcome - Roberts G06, 6:30pm. http:/...

8:58am Thu 9th October 2014

RT @Centre4EngEdu: We're hiring! Multi-talented Centre Administrator required to help us launch and expand! bit.ly/ZsERSM

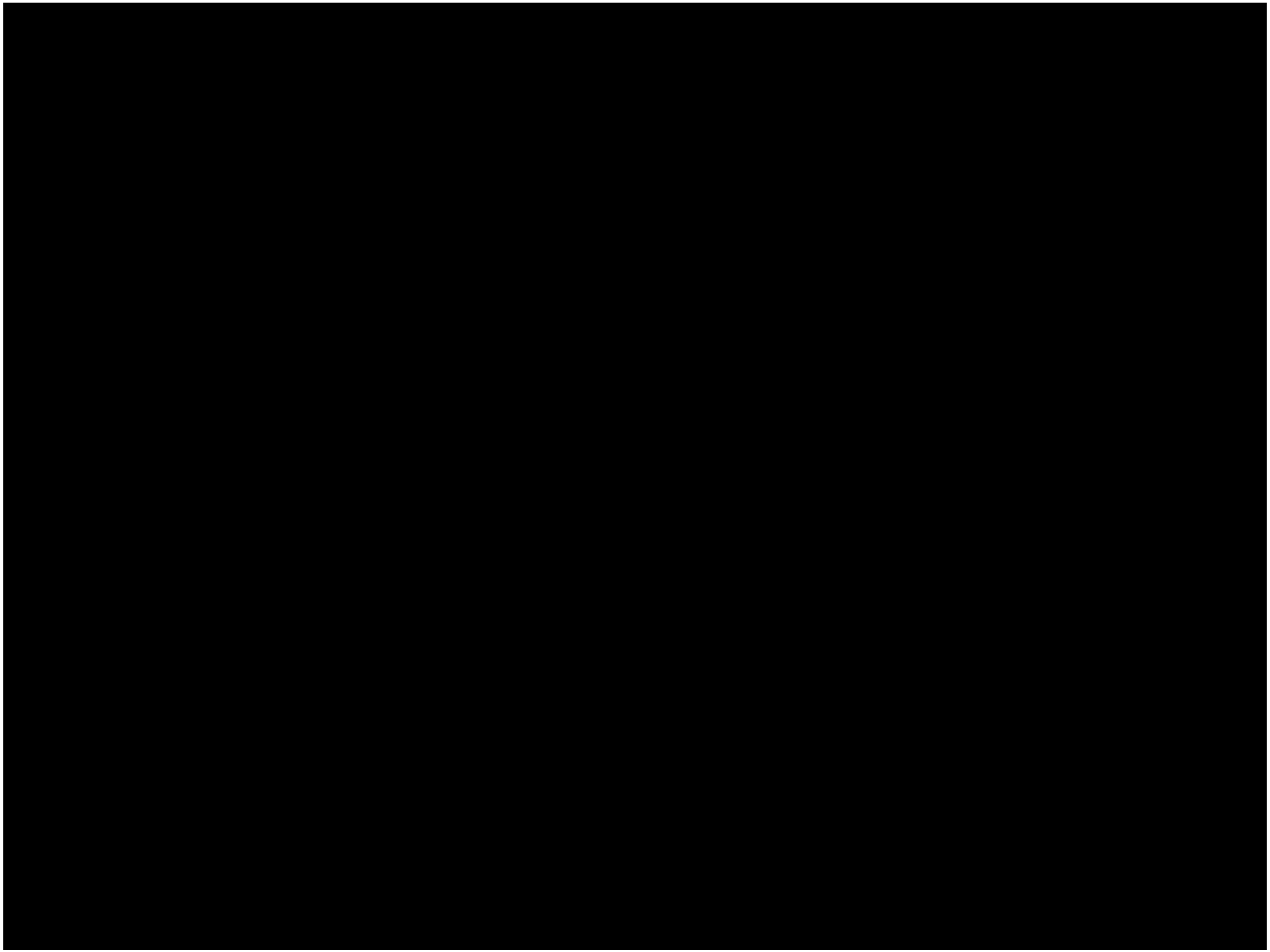
10:54am Wed 8th October 2014

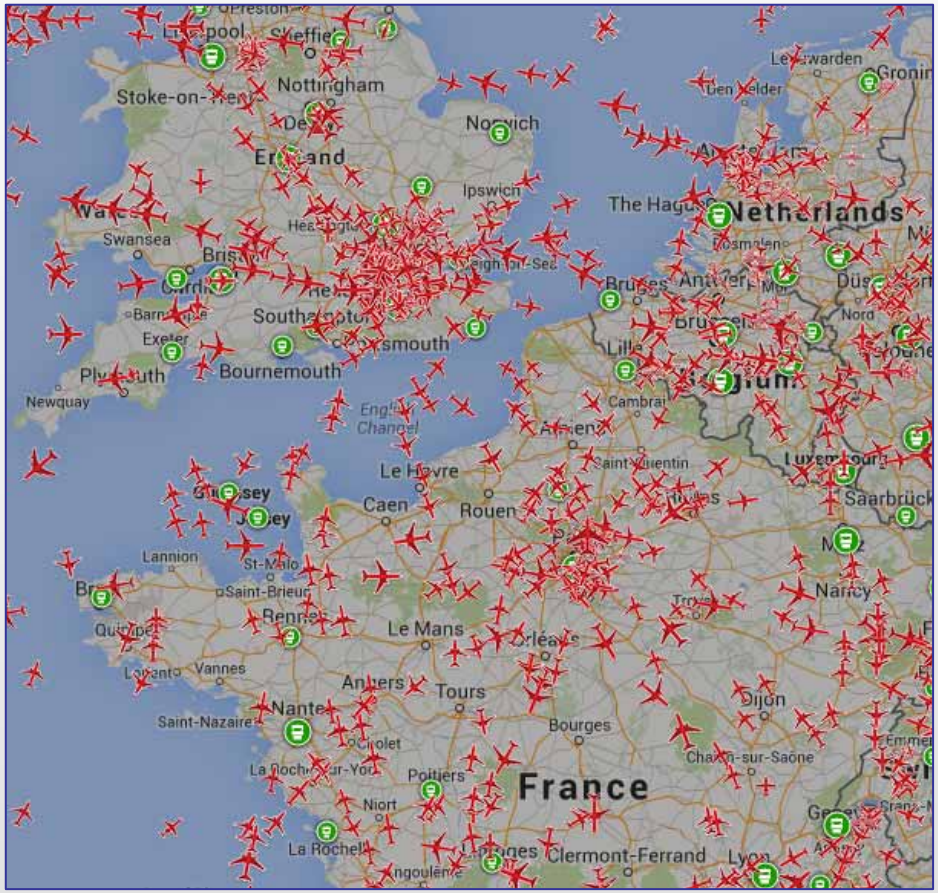
Join our mailing list

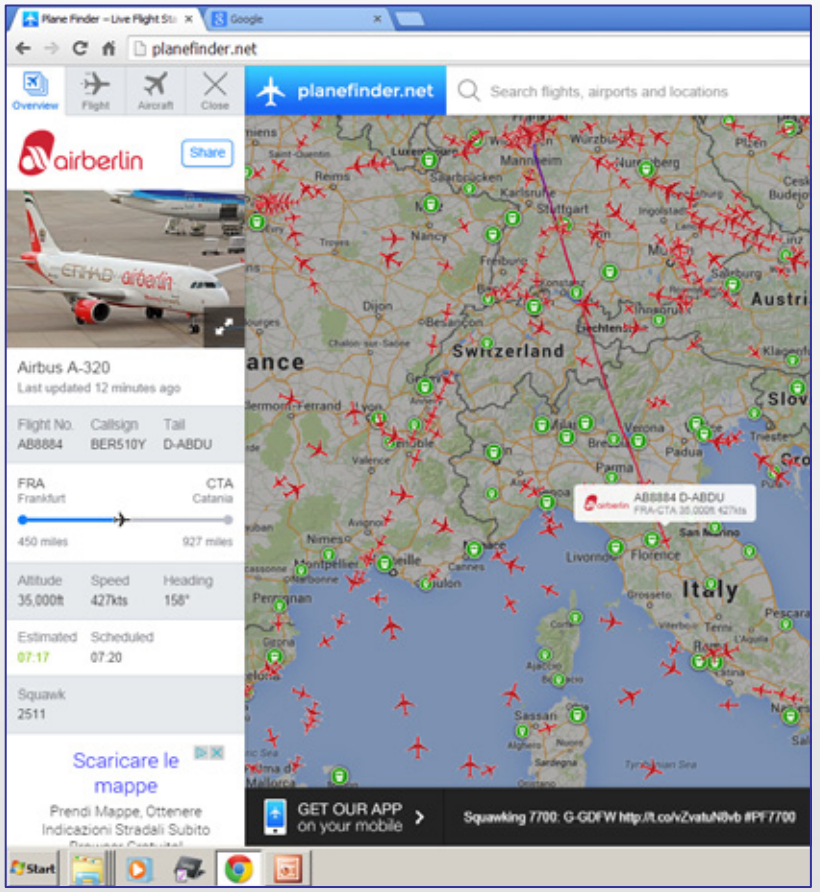


And how can we make sense of this

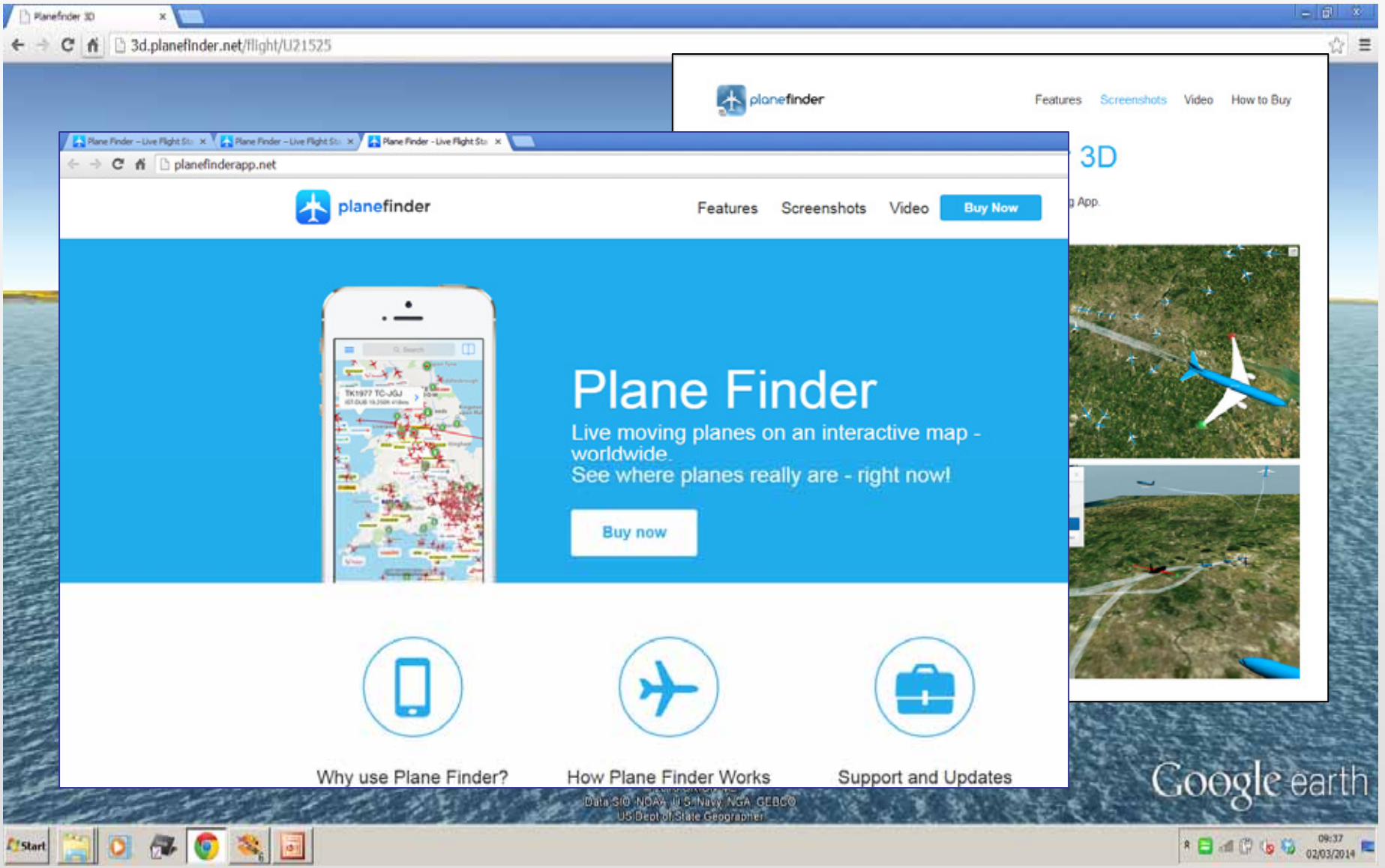
http://www.simulacra.info/

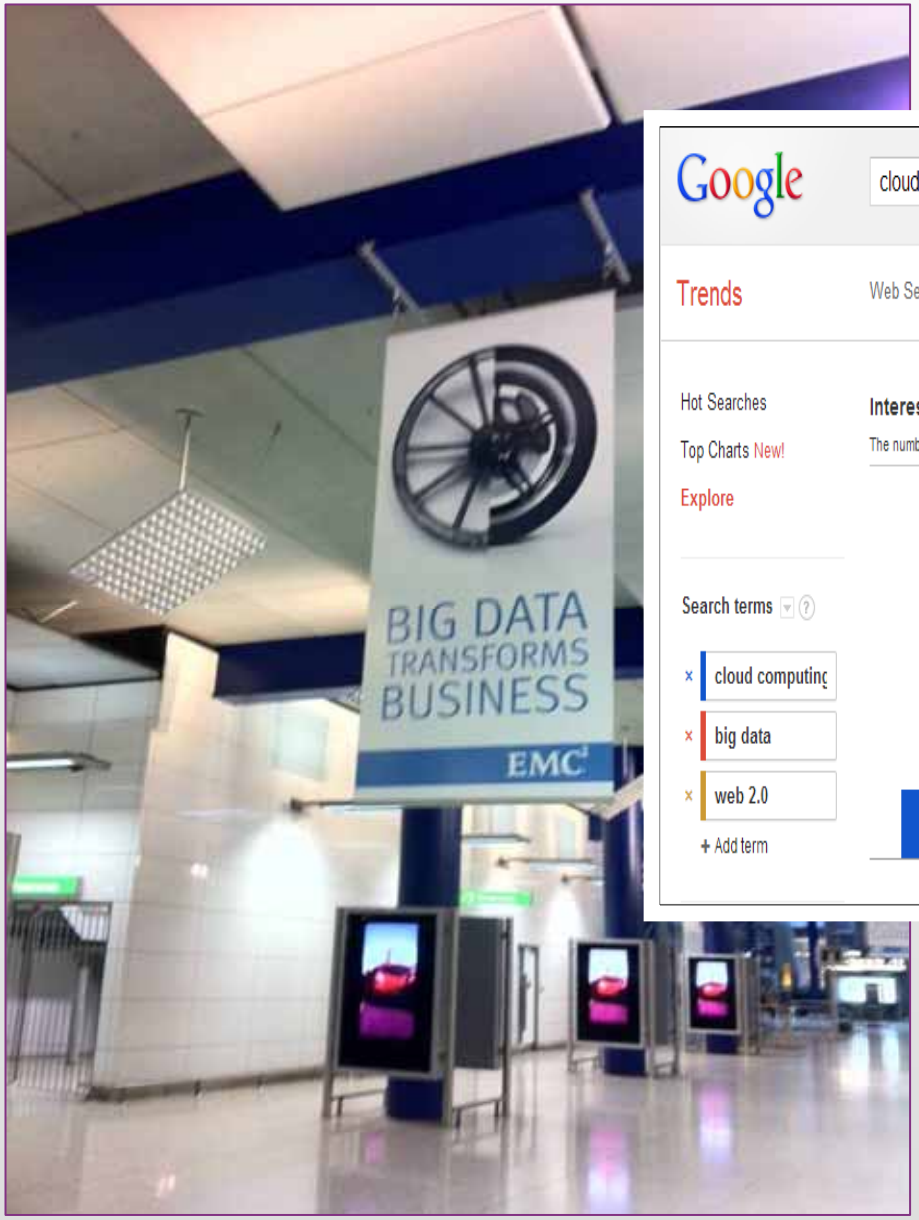


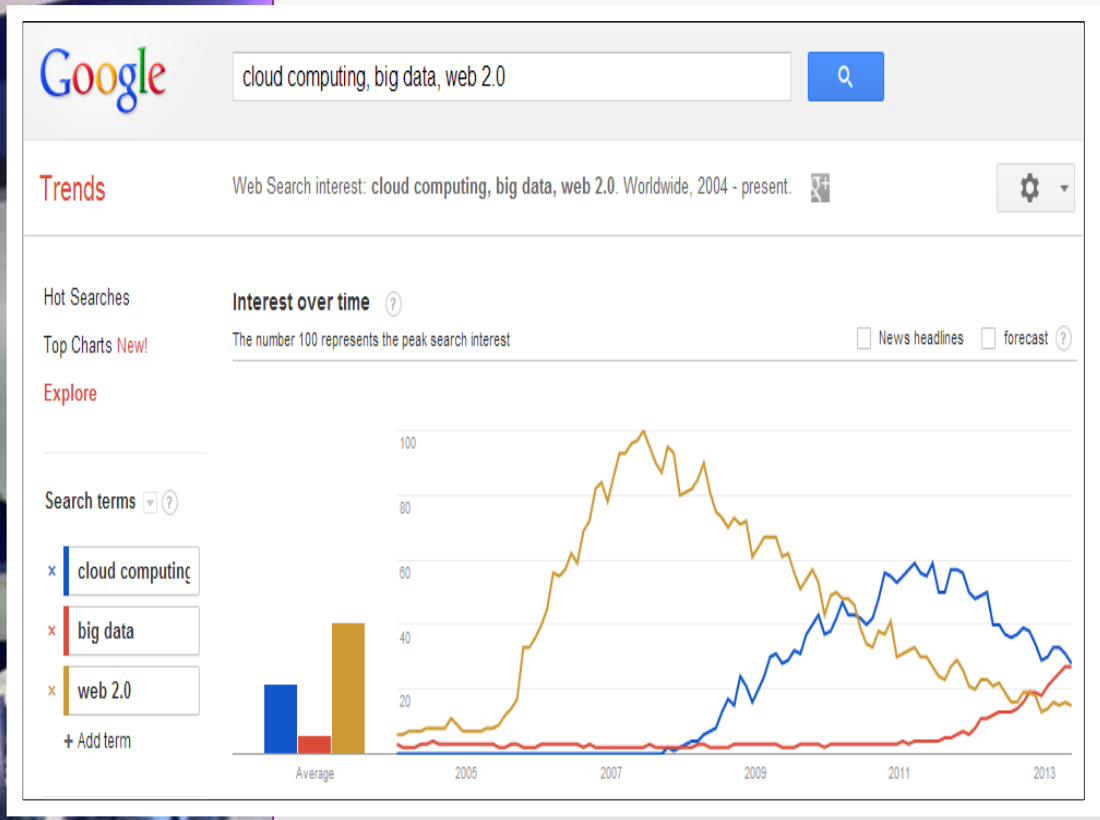




http://planefinder.net/


3d.planefinder.net/flight/U21525
planefinder
Features
Screenshots
Video
How to Buy
3D
planefinderapp.net
planefinder
Features
Screenshots
Video
Buy Now
Plane Finder
Live moving planes on an interactive map - worldwide.
See where planes really are - right now!
Buy now
Why use Plane Finder?
How Plane Finder Works
Support and Updates
Google earth


BIG DATA
TRANSFORMS
BUSINESS
EMC²

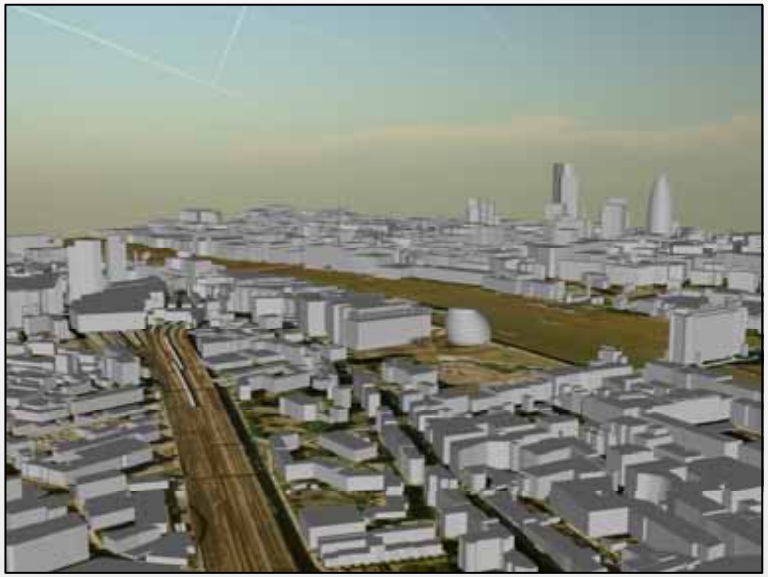

Google
cloud computing, big data, web 2.0
Trends
Web Search interest: cloud computing, big data, web 2.0. Worldwide, 2004 - present.
Hot Searches
Top Charts New!
Explore
Search terms
cloud computing
big data
web 2.0
+ Add term
Interest over time
The number 100 represents the peak search interest
News headlines
forecast
100
80
60
40
20
Average
2005
2007
2009
2011
2013

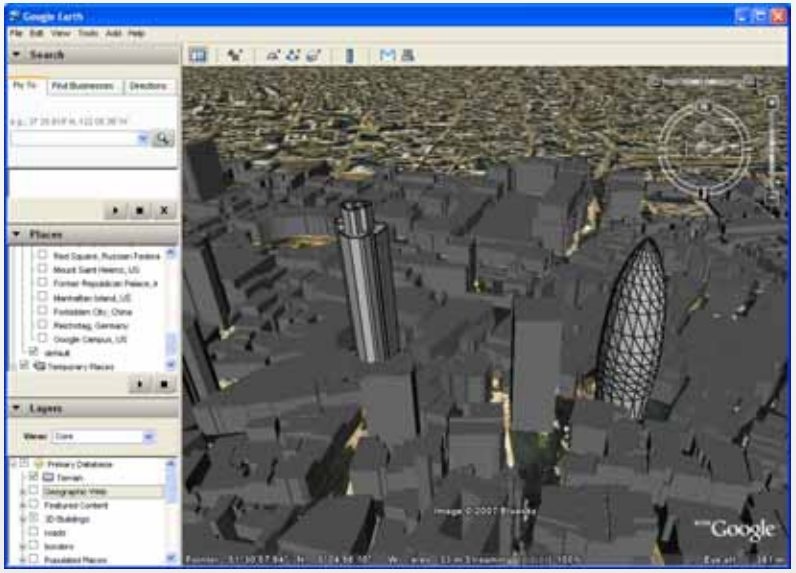
Visualisation is all important in making sense of big data

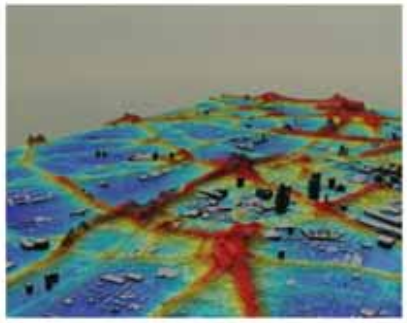
Real time, streamed data is usually unstructured it does not come in a form that is already ordered

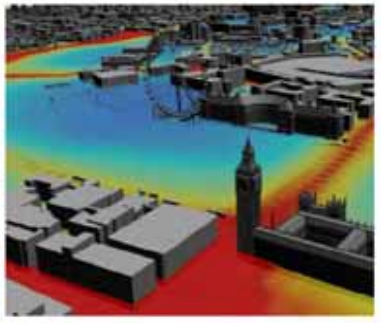
To find patterns in it, we need to visualise it making it a little more abstract

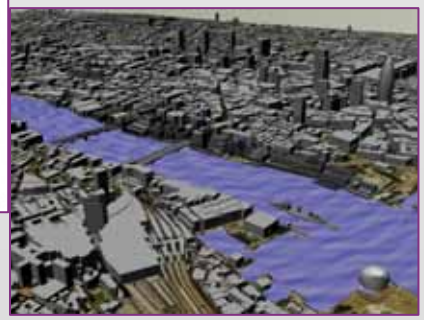
Let me show you some patterns that are clear when we visualise in 3D

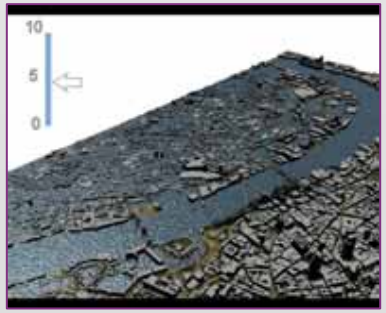






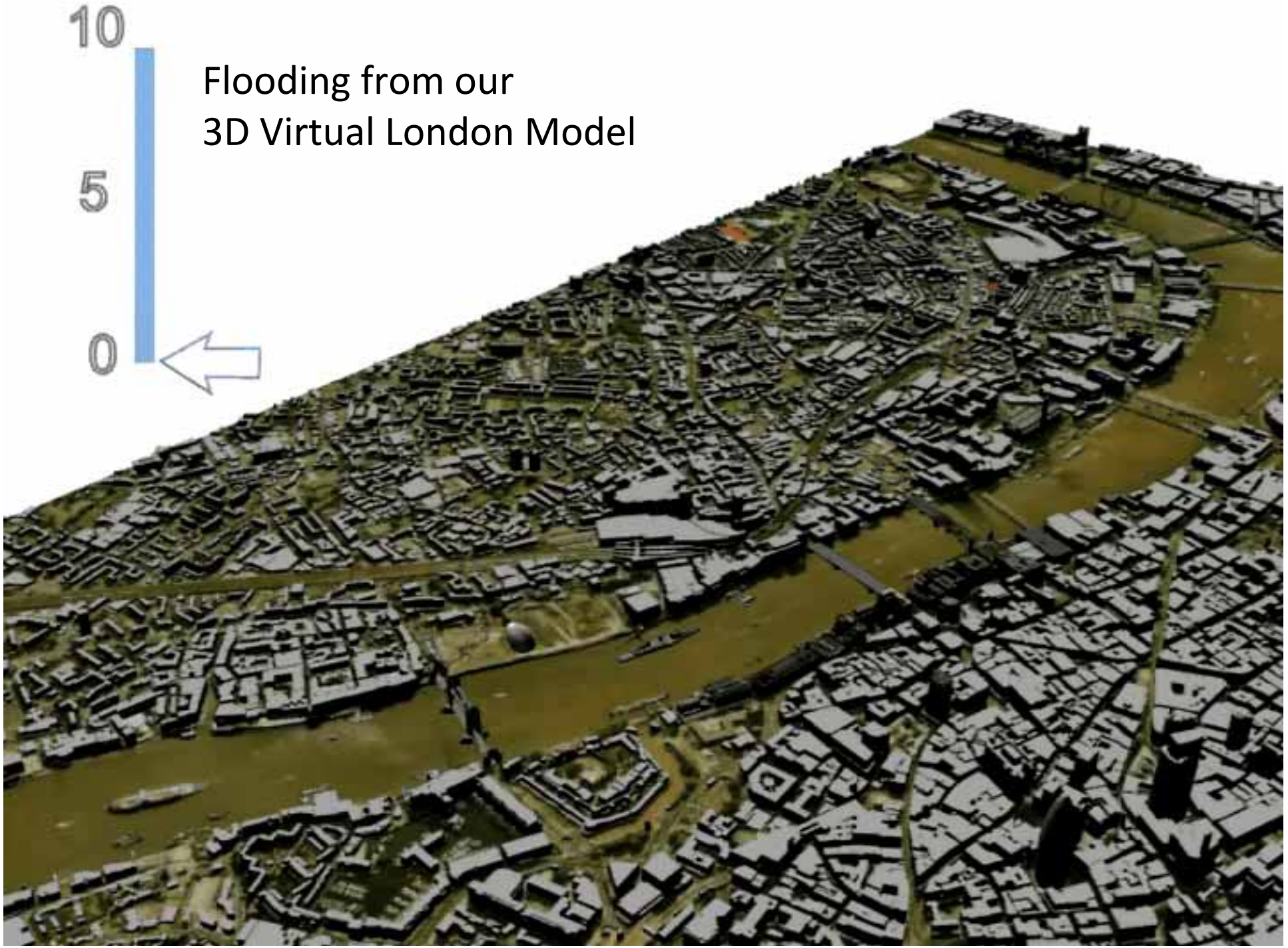


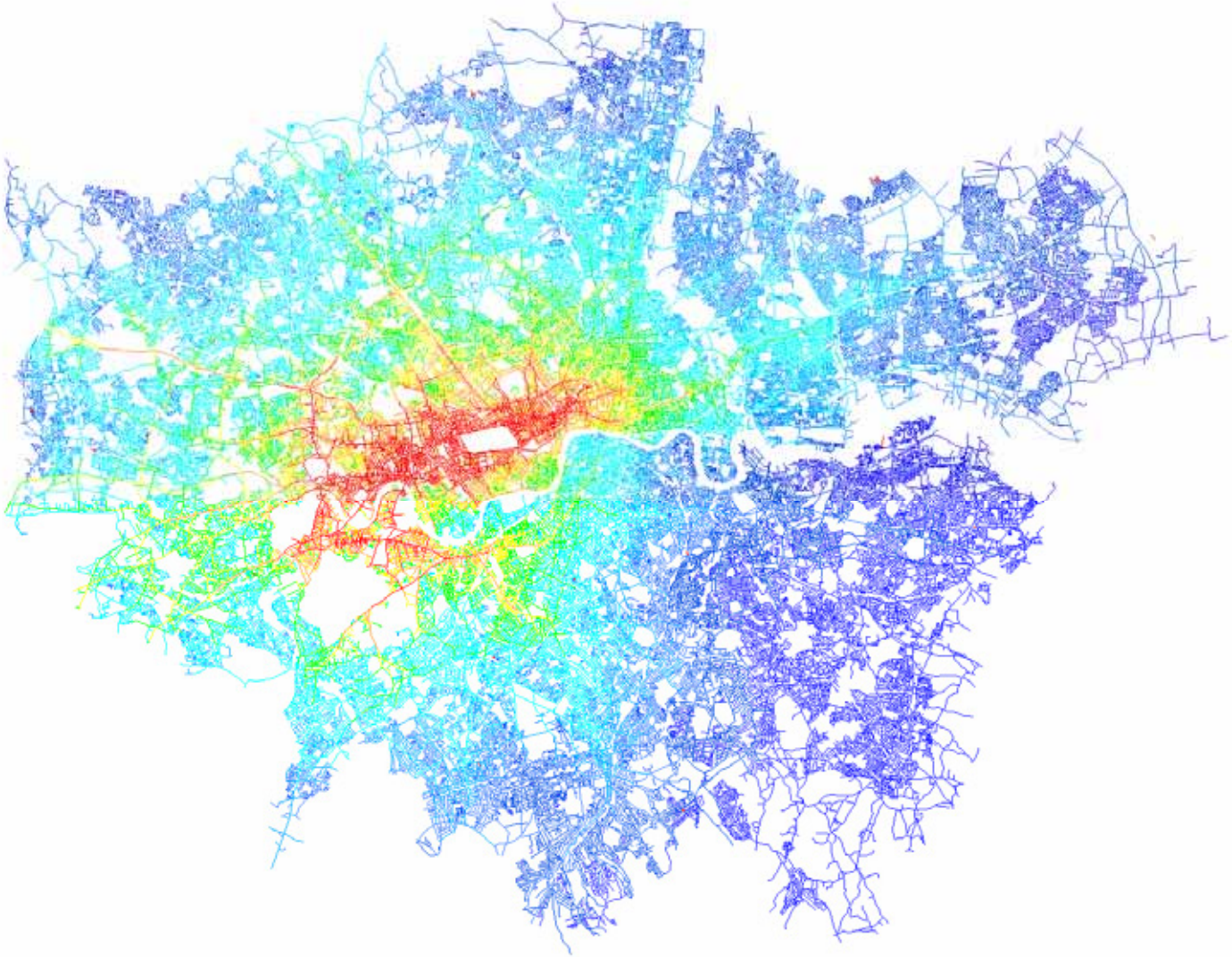




http://www.londonair.org.uk/

Flooding from our
3D Virtual London Model



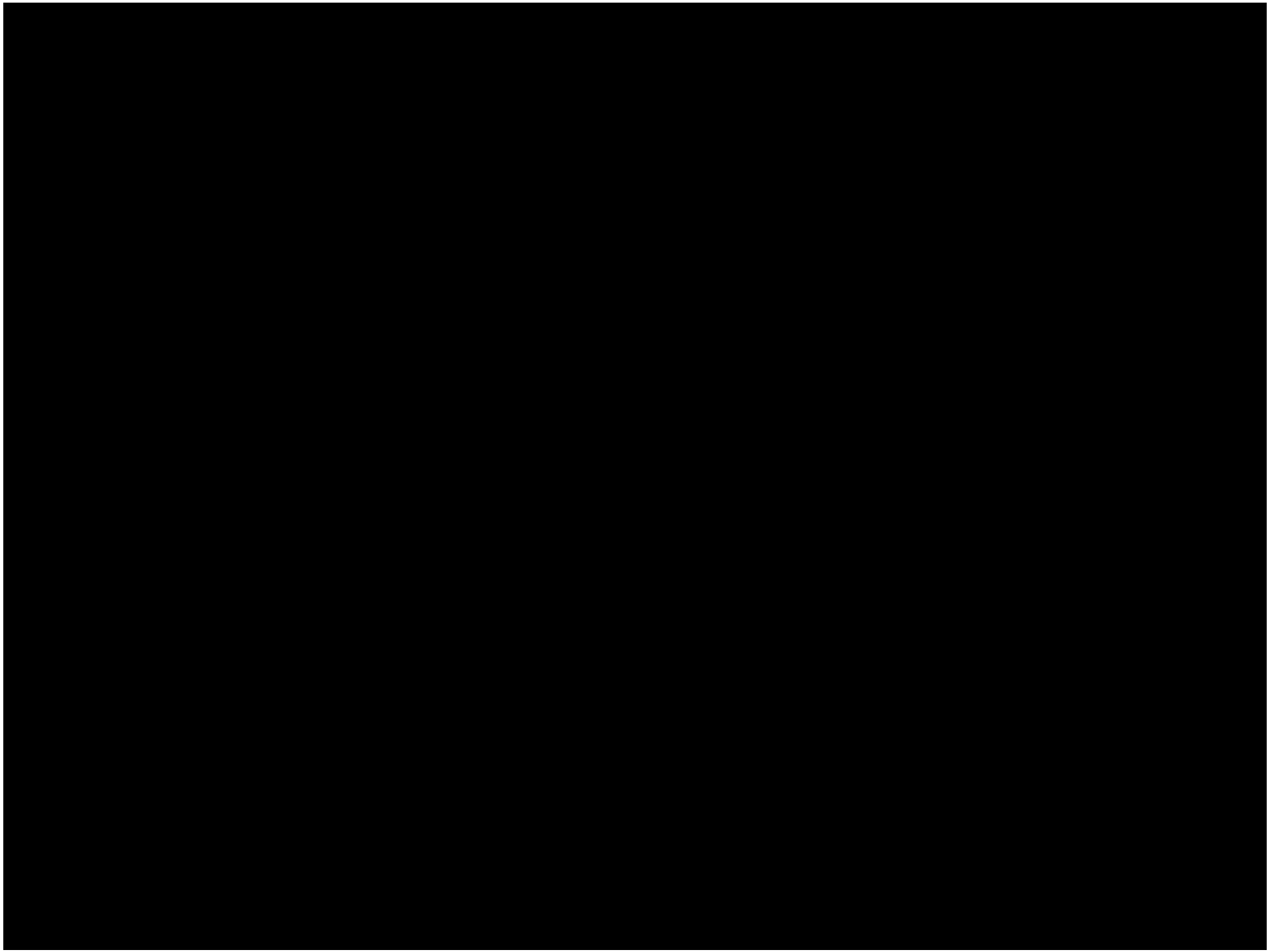


Shifts in Traffic Accessibility if all Bridges across the Thames are Inoperable as far West as Hammersmith

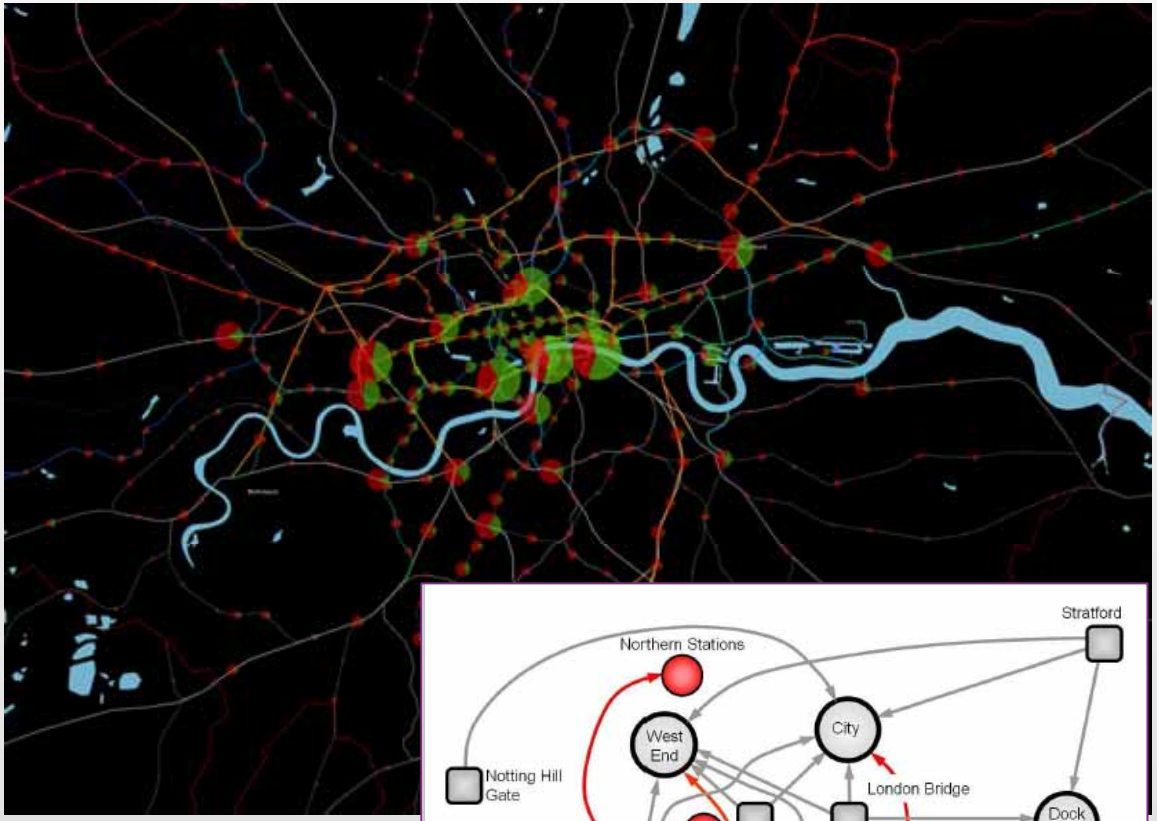
I will return to my subway example using the Oyster card data

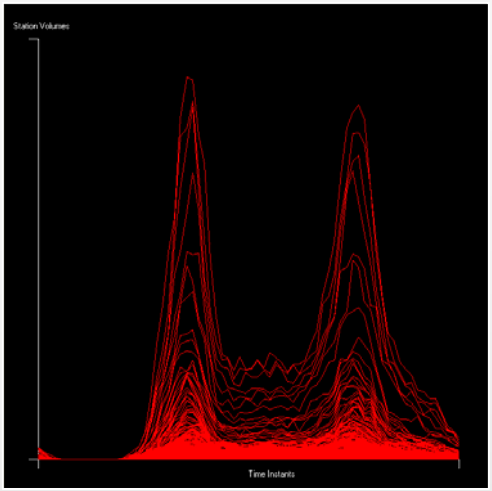
We can do many things with this and one of the key things is to understand how different kinds of passengers travel

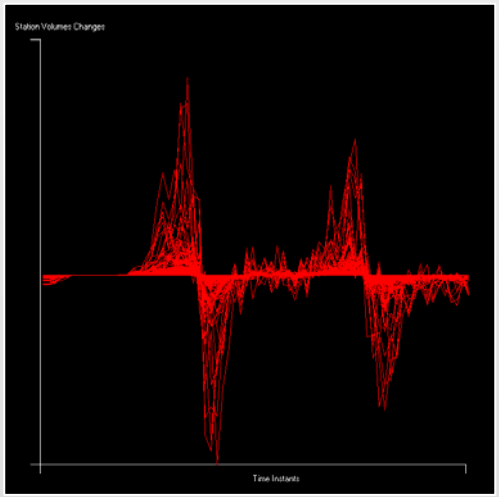
We have just visualised the movement patterns over one day for disabled free pass travellers which can be identified in the data

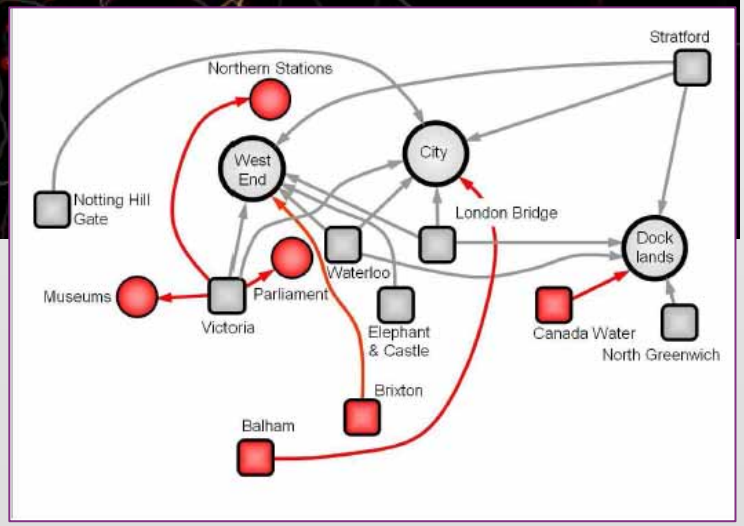


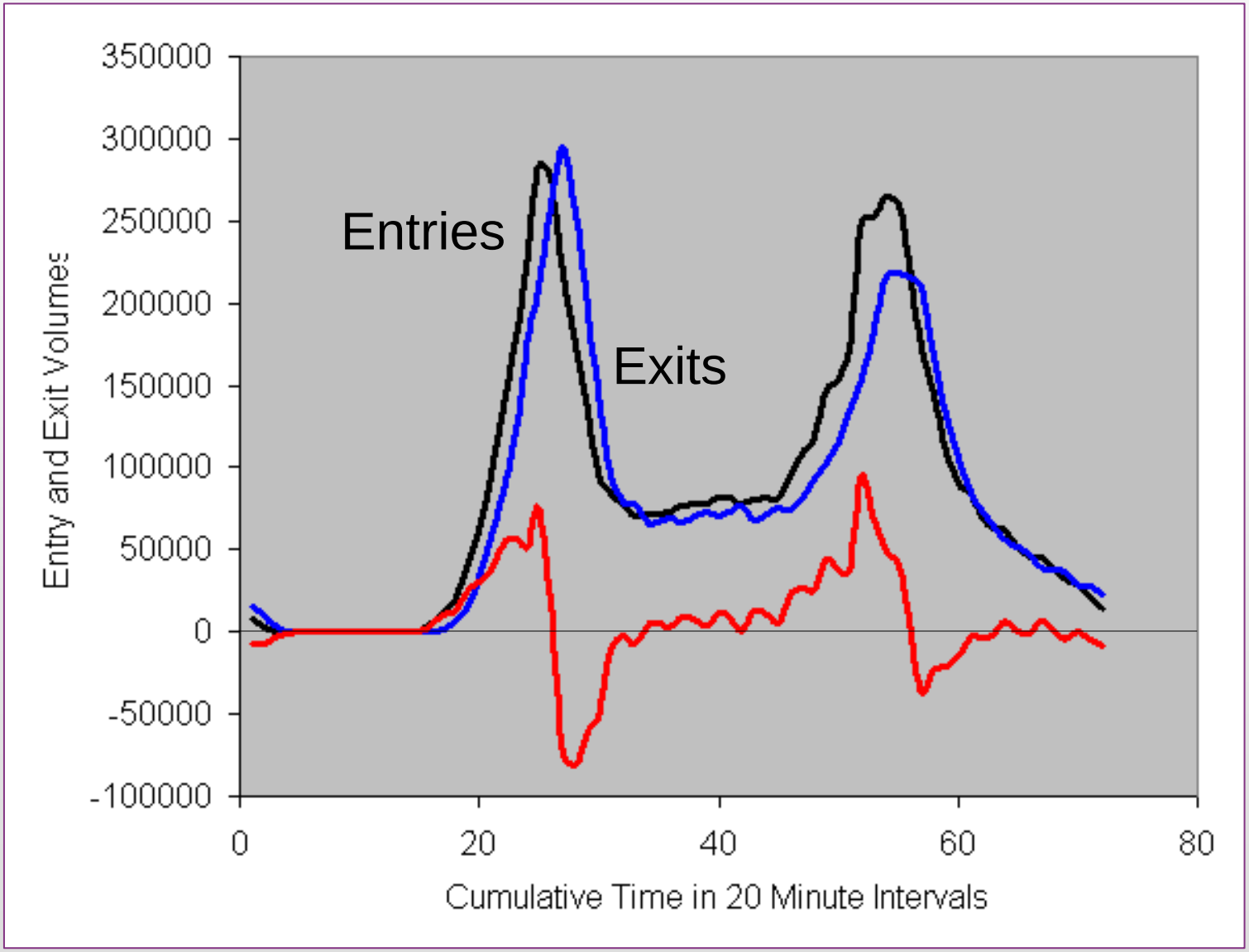
Oyster Card Data – interpreting urban structure, multitrips, etc.



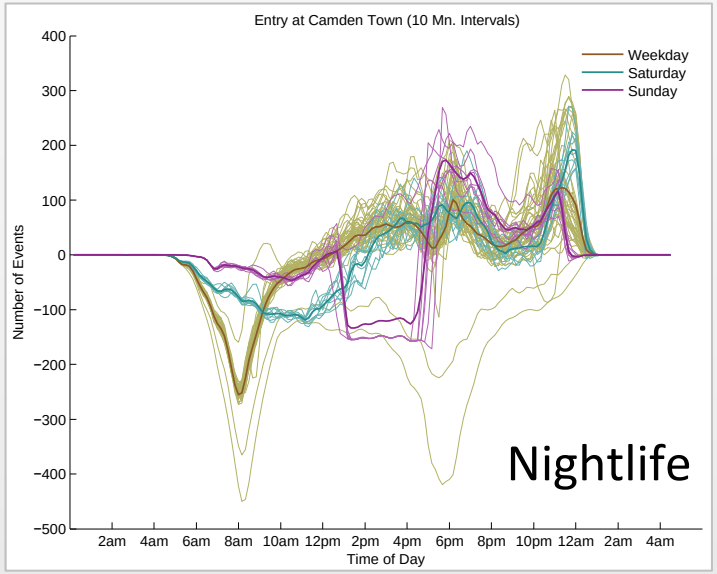


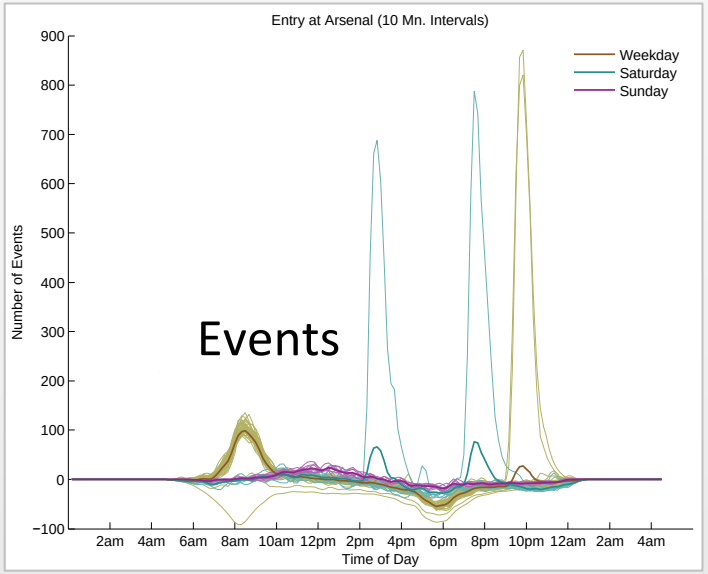


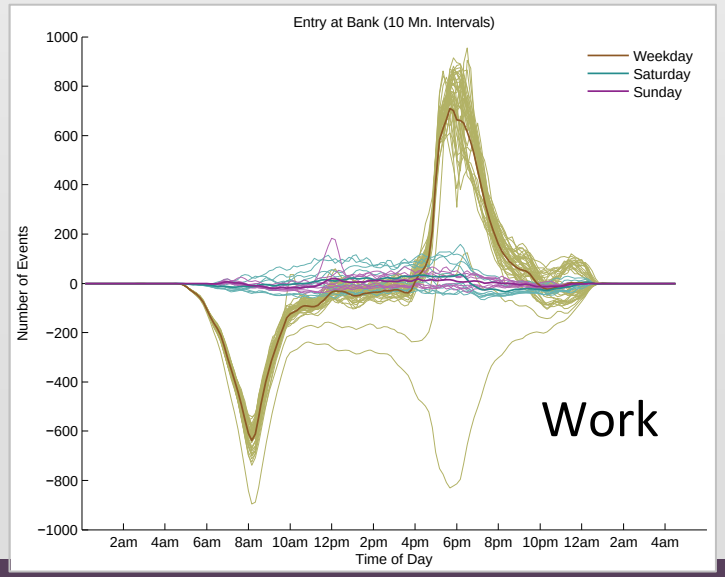


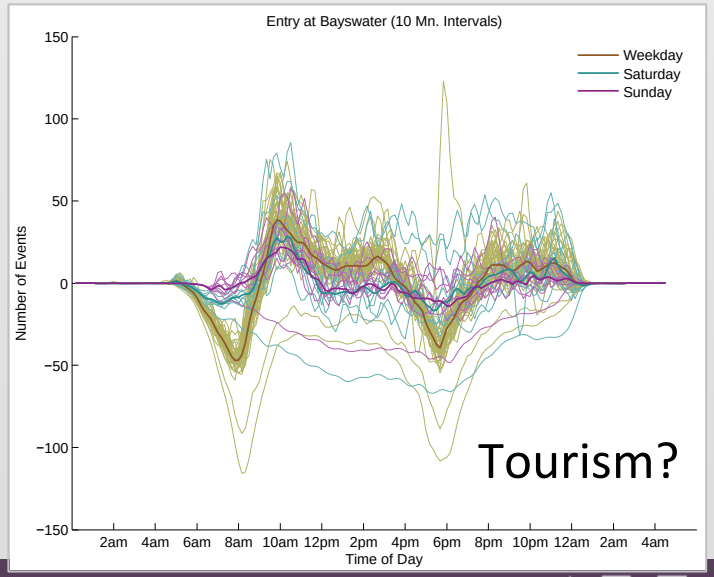

350000
300000
250000
200000
150000
100000
50000
0
-50000
-100000
Entry and Exit Volumes
Entries
Exits
0
20
40
60
80
Cumulative Time in 20 Minute Intervals

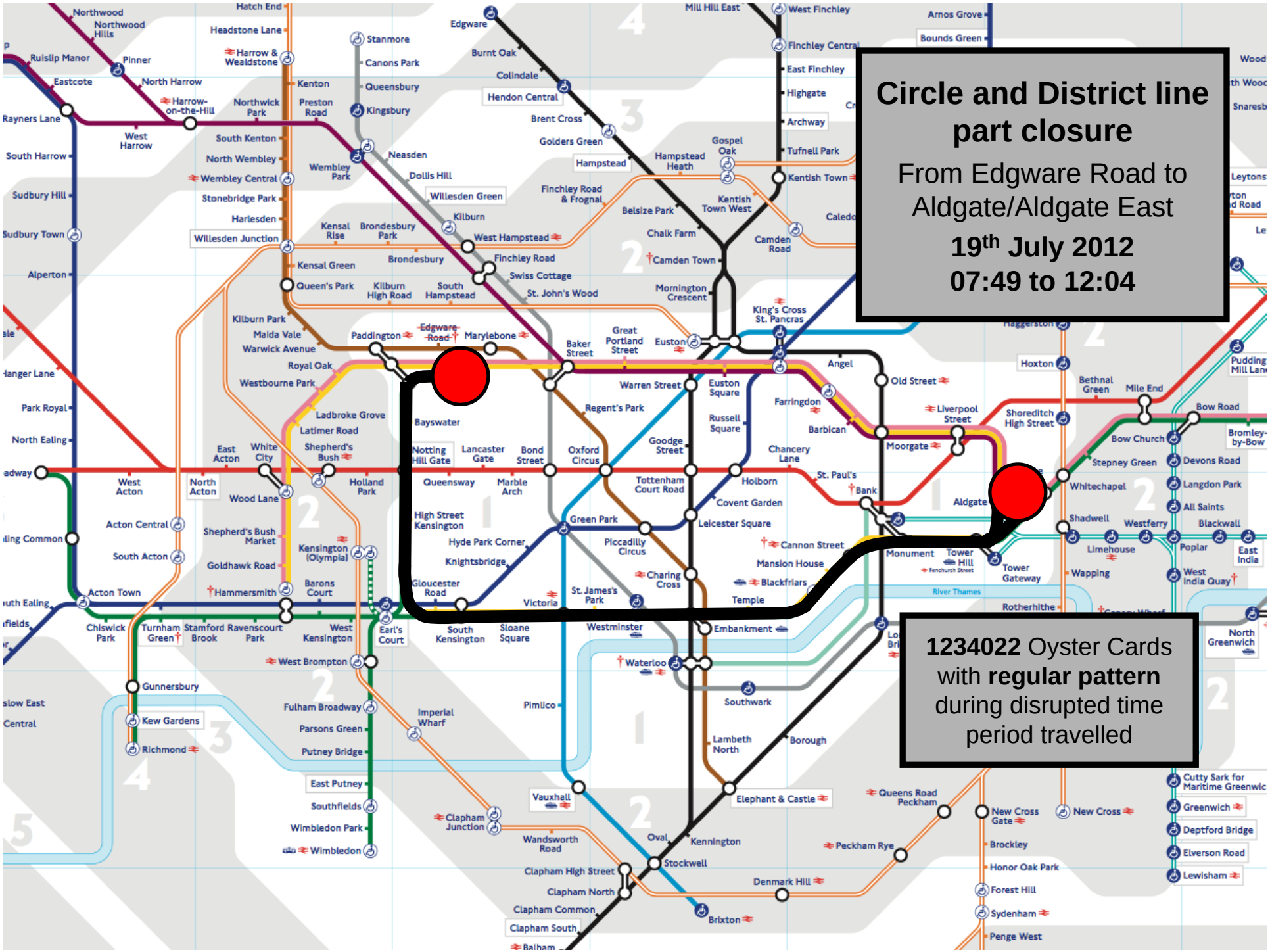
Particular Events: Weekdays, Saturdays and Sundays










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
Edgware
Burnt Oak
Colindale
Hendon Central
Brent Cross
Golders Green
Hampstead
Hampstead Heath
Gospel Oak
Kentish Town
Kentish Town West
Belsize Park
Chalk Farm
Camden Road
Camden Town
Finchley Road & Frognal
Finchley Road
Swiss Cottage
St. John's Wood
Mornington Crescent
King's Cross St. Pancras
Euston
Great Portland Street
Baker Street
Marylebone
Edgware Road
Paddington
Warwick Avenue
Maida Vale
Kilburn Park
Queen's Park
Kilburn High Road
South Hampstead
Brondesbury
Kensal Green
Willesden Junction
Kensal Rise
Brondesbury Park
Kilburn
West Hampstead
Willesden Green
Dollis Hill
Neasden
Wembley Park
Wembley Central
Stonebridge Park
Harlesden
South Kenton
North Wembley
Kenton
Preston Road
Northwick Park
Harrow & Wealdstone
Harrow-on-the-Hill
North Harrow
Pinner
Ruislip Manor
Eastcote
Rayners Lane
West Harrow
South Harrow
Sudbury Hill
Sudbury Town
Alperton
Hatch End
Headstone Lane
Stanmore
Canons Park
Queensbury
Kingsbury
Northwood
Northwood Hills
Mill Hill East
West Finchley
Finchley Central
East Finchley
Highgate
Archway
Tufnell Park
Arnos Grove
Bounds Green
Warren Street
Euston Square
Regent's Park
Bayswater
Ladbroke Grove
Latimer Road
Westbourne Park
Royal Oak
Notting Hill Gate
Lancaster Gate
Bond Street
Oxford Circus
Goodge Street
Tottenham Court Road
Queensway
Marble Arch
Holborn
Chancery Lane
St. Paul's
Bank
Russell Square
Farringdon
Barbican
Moorgate
Liverpool Street
Old Street
Angel
Aldgate
Aldgate East
Shepherd's Bush
White City
East Acton
North Acton
West Acton
Wood Lane
Holland Park
Shepherd's Bush Market
Goldhawk Road
Hammersmith
Barons Court
Kensington (Olympia)
Acton Central
South Acton
Acton Town
Chiswick Park
Turnham Green
Stamford Brook
Ravenscourt Park
West Kensington
Earl's Court
High Street Kensington
Gloucester Road
South Kensington
Sloane Square
Victoria
Hyde Park Corner
Knightsbridge
Green Park
Piccadilly Circus
Leicester Square
Covent Garden
Charing Cross
Cannon Street
Mansion House
Blackfriars
Temple
St. James's Park
Westminster
Embankment
Waterloo
Southwark
Lambeth North
Borough
Elephant & Castle
Vauxhall
Pimlico
Oval
Kennington
Stockwell
Brixton
Clapham Junction
Wandsworth Road
Clapham High Street
Clapham North
Clapham Common
Clapham South
Balham
Denmark Hill
Peckham Rye
Queens Road Peckham
New Cross Gate
New Cross
Brockley
Honor Oak Park
Forest Hill
Sydenham
Penge West
Hoxton
Shoreditch High Street
Bethnal Green
Mile End
Bow Road
Bow Church
Stepney Green
Whitechapel
Devons Road
Langdon Park
All Saints
Poplar
Blackwall
East India
Limehouse
Westferry
Shadwell
Wapping
Rotherhithe
Tower Gateway
Tower Hill
Monument
Fenchurch Street
River Thames
West India Quay
North Greenwich
Cutty Sark for Maritime Greenwich
Greenwich
Deptford Bridge
Elverson Road
Lewisham
Bromley-by-Bow
Pudding Mill Lane
Leytonstone
Wood Green
Tottenham Hale
Seven Sisters
Finsbury Park
Arsenal
Caledonian Road
Barnsbury
Highbury & Islington
Canonbury
Essex Road
Dalston Junction
Haggerston
Hackney Central
Hackney Wick
Stratford
Gunnersbury
Kew Gardens
Richmond
Fulham Broadway
Parsons Green
Putney Bridge
East Putney
Southfields
Wimbledon Park
Wimbledon
West Brompton
Imperial Wharf
Ealing Common
Ealing Broadway
Ealing Common
North Ealing
Park Royal
Hanger Lane
Alperton
Sudbury Hill
Sudbury Town
Harrow & Wealdstone
Kenton
Queensbury
Kingsbury
Wembley Park
Neasden
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Maida Vale
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South Harrow
Sudbury Hill
Sudbury Town
Alperton
Hatch End
Headstone Lane
Stanmore
Canons Park
Queensbury
Kingsbury
Northwood
Northwood Hills
Mill Hill East
West Finchley
Finchley Central
East Finchley
Highgate
Archway
Tufnell Park
Arnos Grove
Bounds Green
Warren Street
Euston Square
Regent's Park
Bayswater
Ladbroke Grove
Latimer Road
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Royal Oak
Notting Hill Gate
Lancaster Gate
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Liverpool Street
Old Street
Angel
Aldgate
Aldgate East
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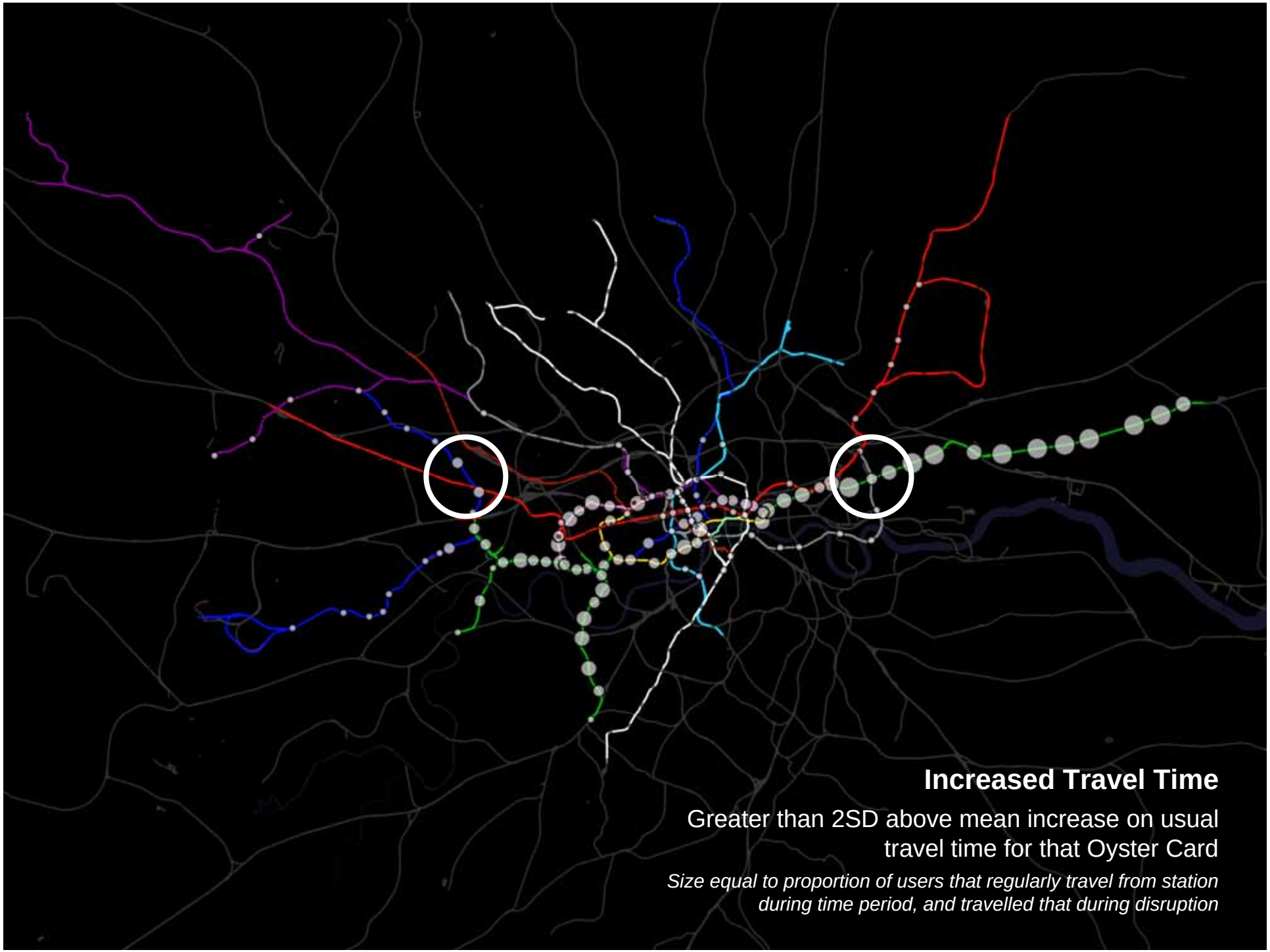
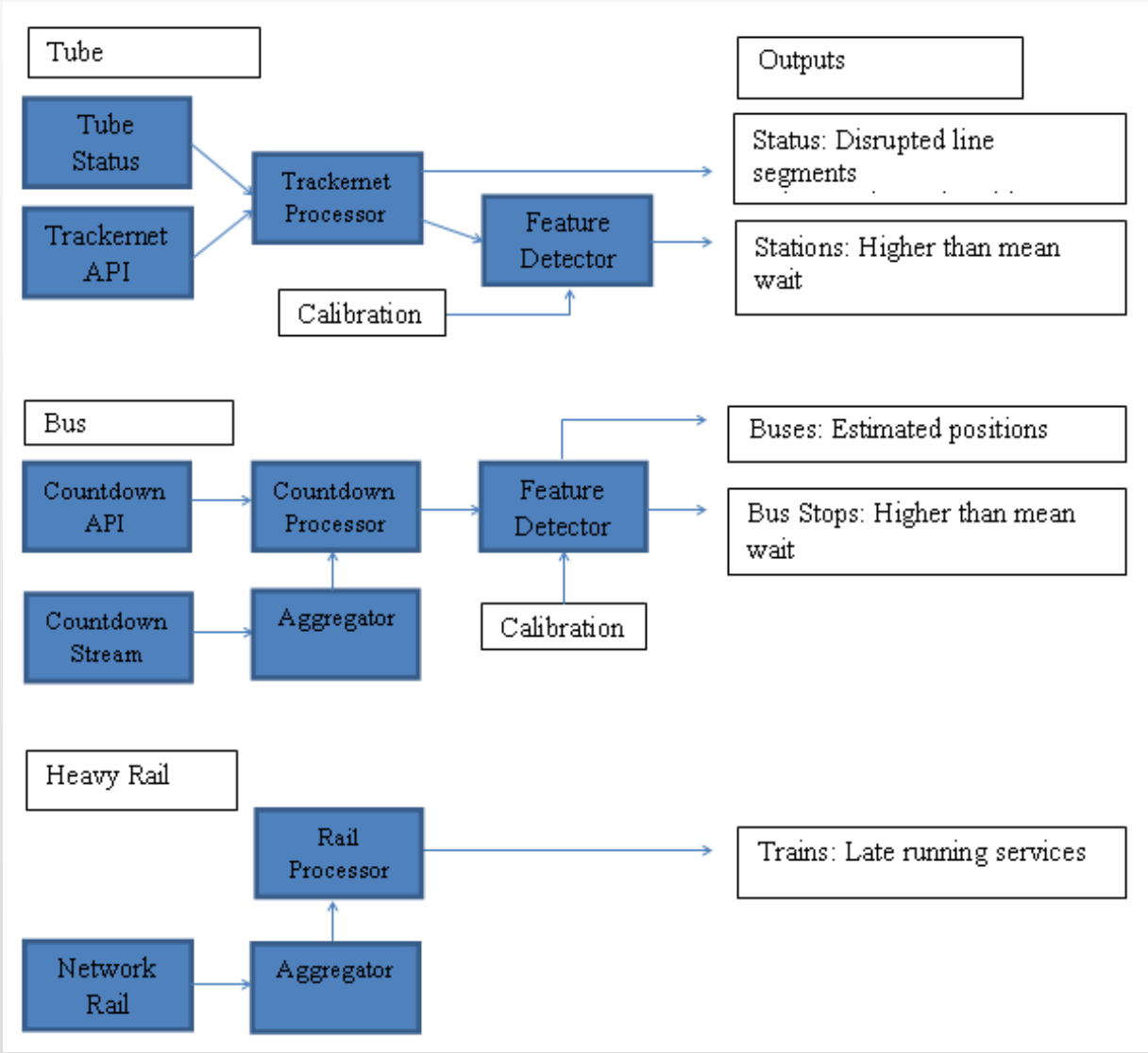
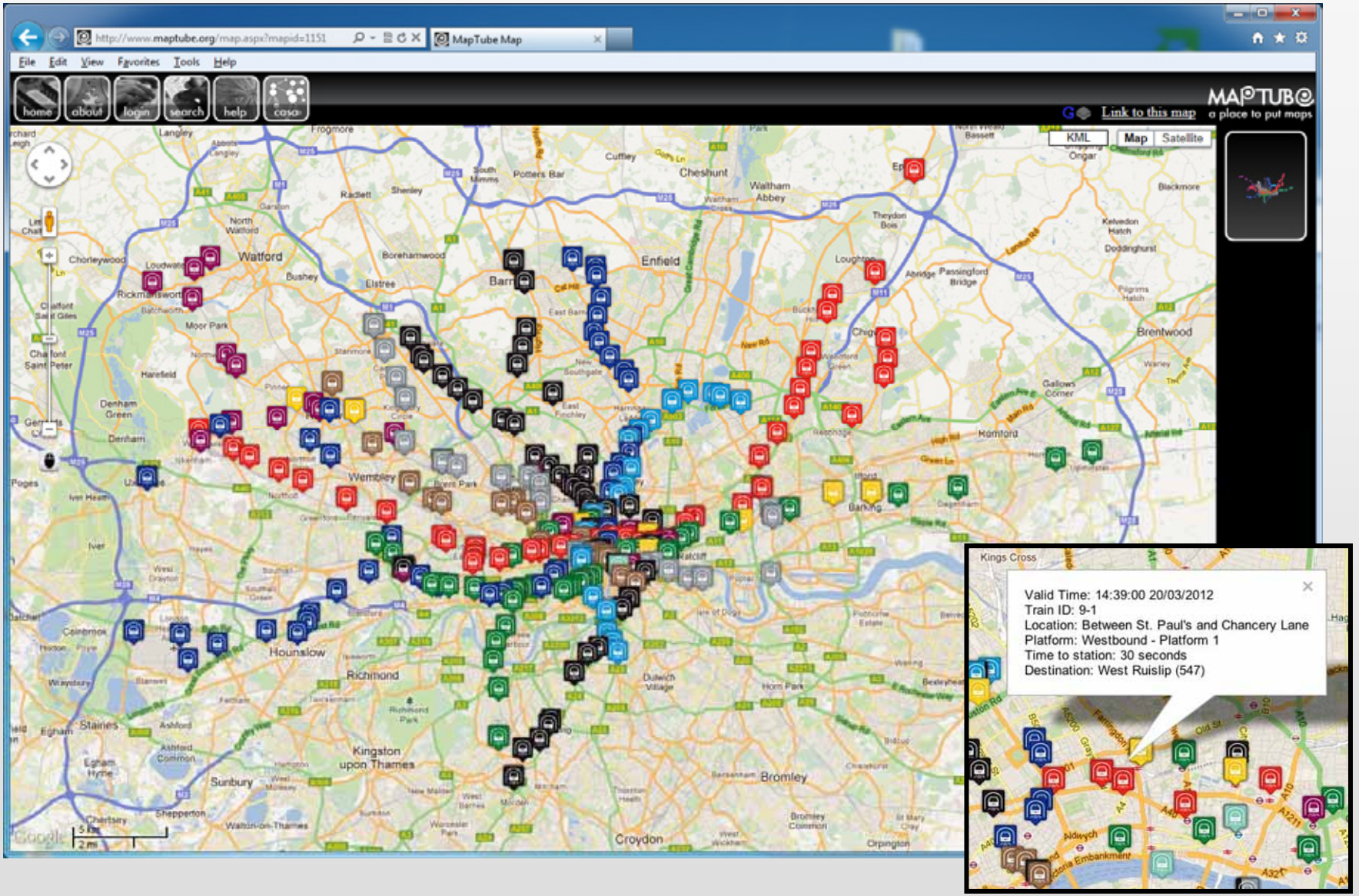
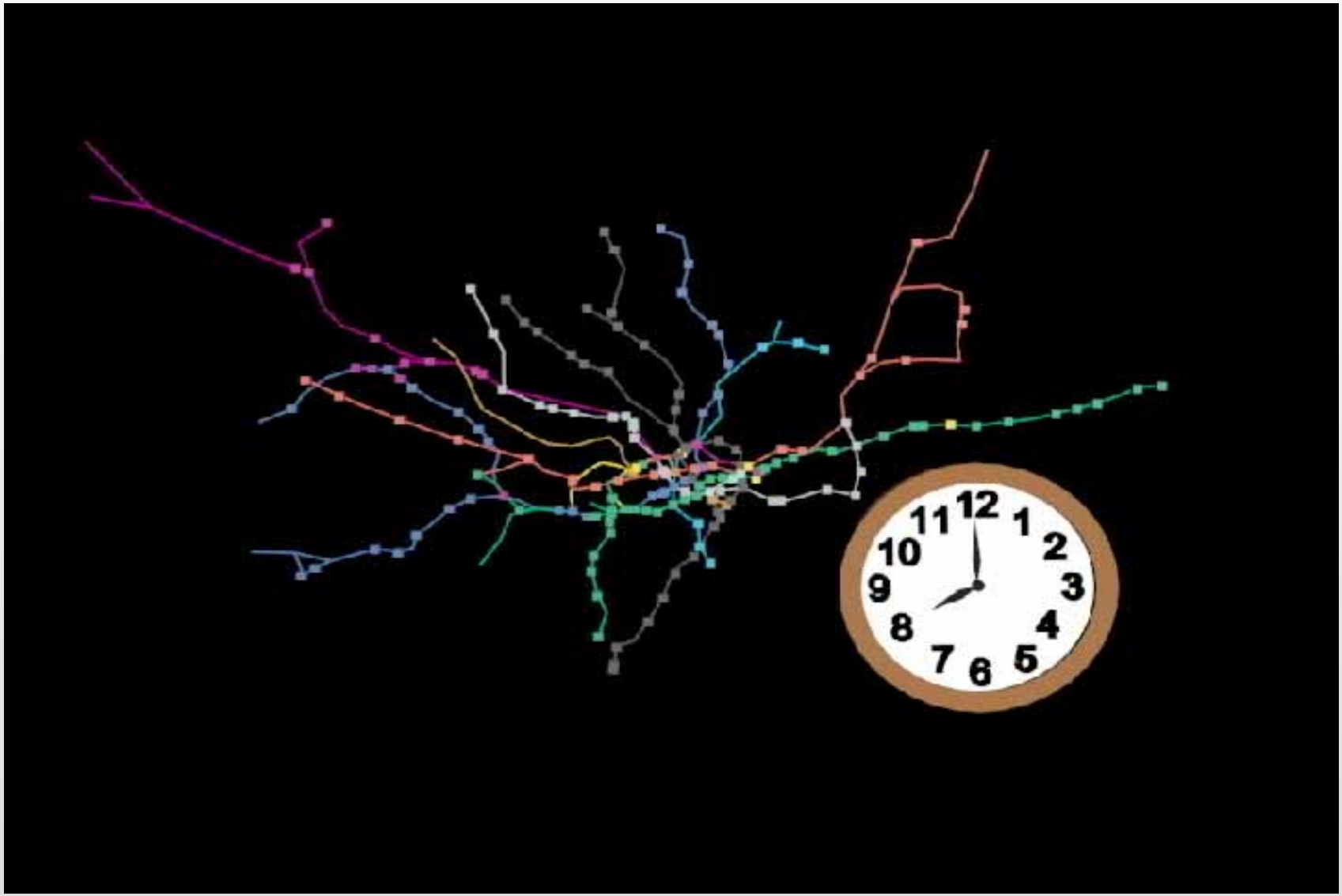
High Street Kensington
Gloucester Road
South Kensington
Sloane Square
Victoria
Hyde Park Corner
Knightsbridge
Green Park
Piccadilly Circus
Leicester Square
Covent Garden
Charing Cross
Cannon Street
Mansion House
Blackfriars
Temple
St. James's Park
Westminster
Embankment
Waterloo
Southwark
Lambeth North
Borough
Elephant & Castle
Vauxhall
Pimlico
Oval
Kennington
Stockwell
Brixton
Clapham Junction
Wandsworth Road
Clapham High Street
Clapham North
Clapham Common
Clapham South
Balham
Denmark Hill
Peckham Rye
Queens Road Peckham
New Cross Gate
New Cross
Brockley
Honor Oak Park
Forest Hill
Sydenham
Penge West
Hoxton
Shoreditch High Street
Bethnal Green
Mile End
Bow Road
Bow Church
Stepney Green
Whitechapel
Devons Road
Langdon Park
All Saints
Poplar
Blackwall
East India
Limehouse
Westferry
Shadwell
Wapping
Rotherhithe
Tower Gateway
Tower Hill
Monument
Fenchurch Street
River Thames
West India Quay
North Greenwich
Cutty Sark for Maritime Greenwich
Greenwich
Deptford Bridge
Elverson Road
Lewisham
Bromley-by-Bow
Pudding Mill Lane
Leytonstone
Wood Green
Tottenham Hale
Seven Sisters
Finsbury Park
Arsenal
Caledonian Road
Barnsbury
Highbury & Islington
Canonbury
Essex Road
Dalston Junction
Haggerston
Hackney Central
Hackney Wick
Stratford
Gunnersbury
Kew Gardens
Richmond
Fulham Broadway
Parsons Green
Putney Bridge
East Putney
Southfields
Wimbledon Park
Wimbledon
West Brompton
Imperial Wharf
Ealing Common
Ealing Broadway
Ealing Common
North Ealing
Park Royal
Hanger Lane
Alperton
Sudbury Hill
Sudbury Town


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




MapTube Map
File Edit View Favorites Tools Help
home about login search help casa
MAPTUBE
a place to put maps
Link to this map
KML Map Satellite
Kings Cross
Valid Time: 14:39:00 20/03/2012
Train ID: 9-1
Location: Between St. Paul's and Chancery Lane
Platform: Westbound - Platform 1
Time to station: 30 seconds
Destination: West Ruislip (547)


12
1
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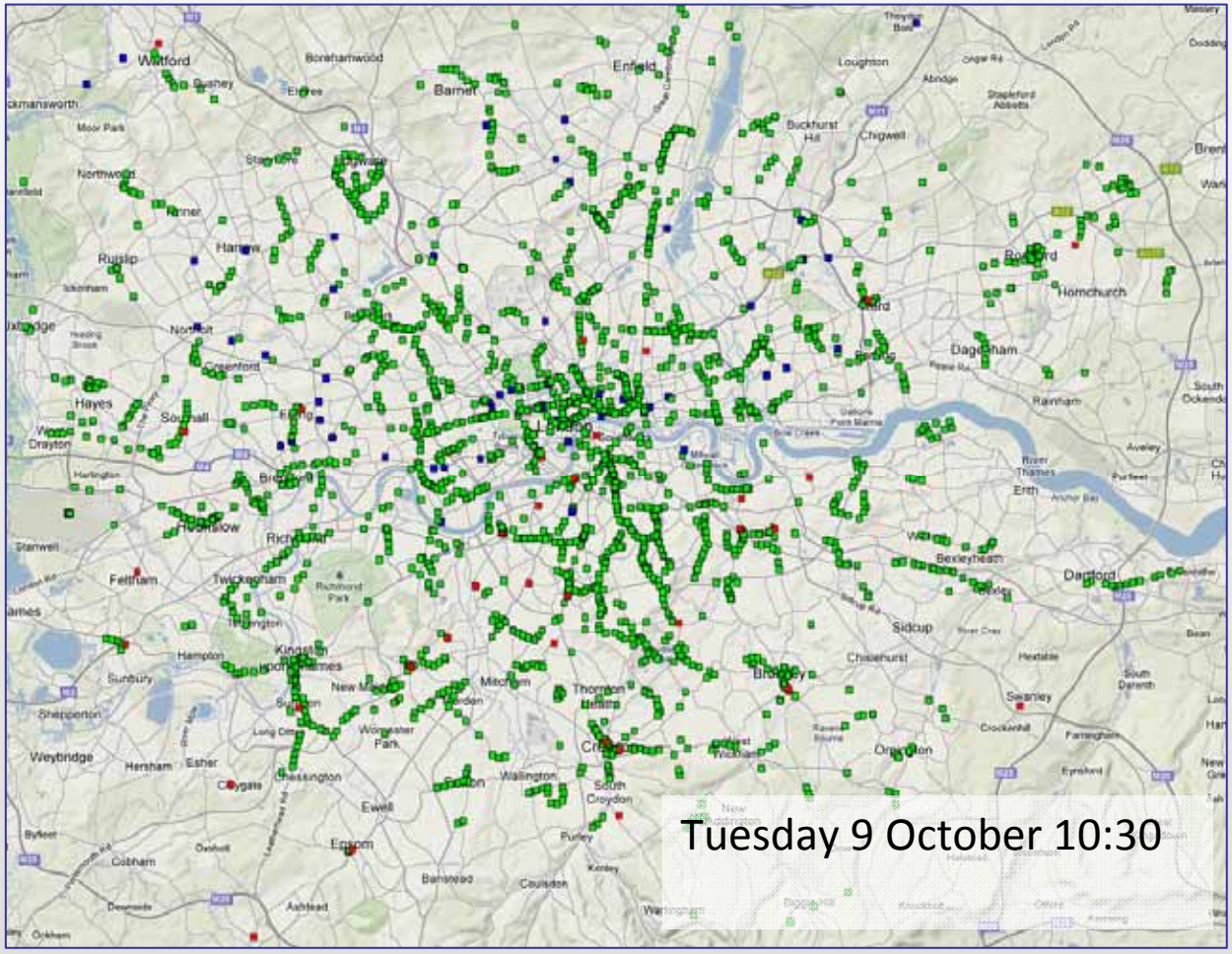
11

Delays from Tube, National Rail and Bus Fused



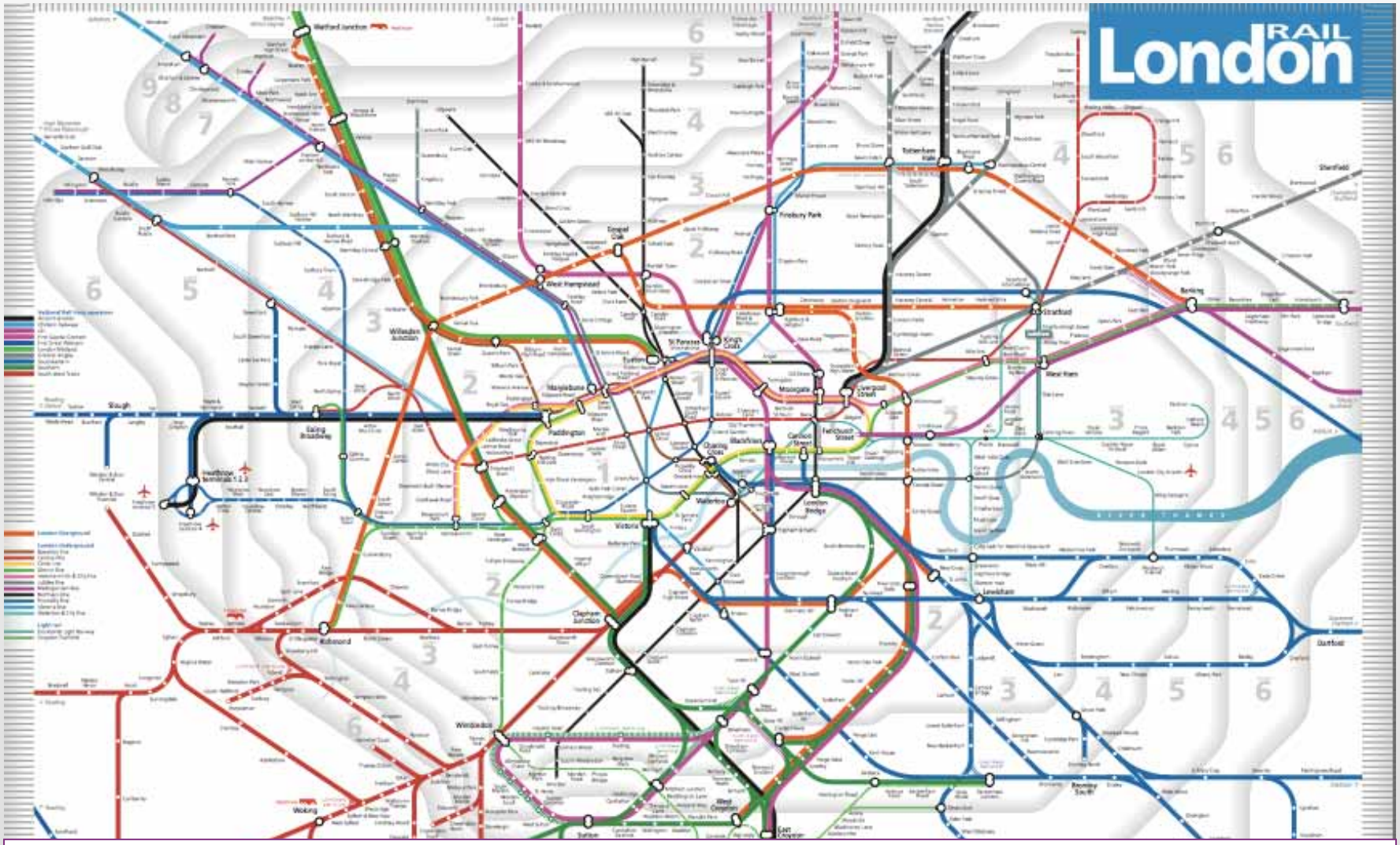
Key

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

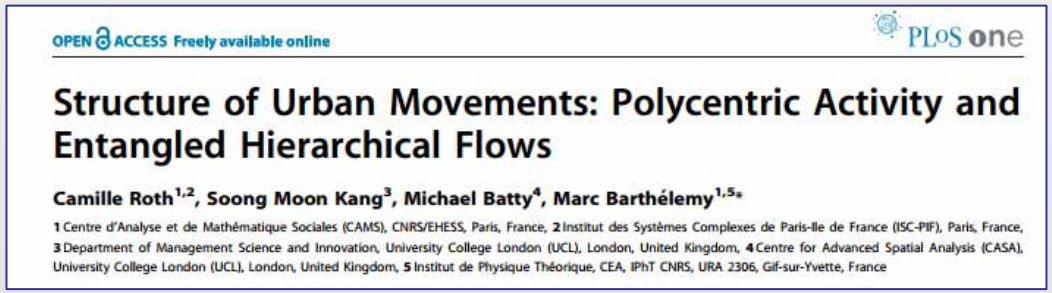


Tube, Overground and National Rail Networks in London
where Oyster cards can be used

Just to bring us academics back to earth we need to write our papers on all this stuff in learned journals so here are some examples

Here is a digression into our alchemy

We did a paper in 2011 with Marc Barthelemy in PLOS One



OPEN ACCESS Freely available online

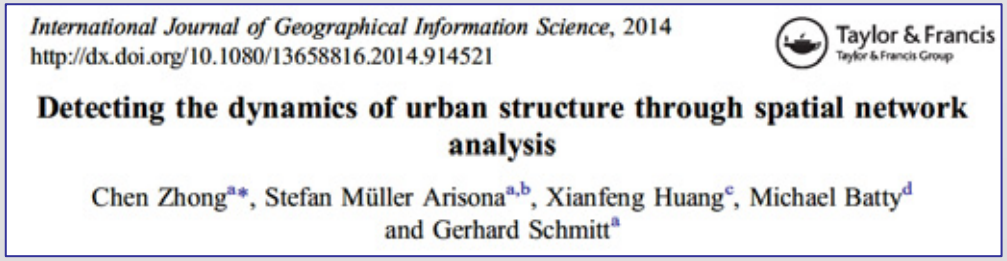
PLoS one

Structure of Urban Movements: Polycentric Activity and Entangled Hierarchical Flows

Camille Roth[1,2], Soong Moon Kang[3], Michael Batty[4], Marc Barthélemy[1,5]*

1 Centre d'Analyse et de Mathématique Sociales (CAMS), CNRS/EHESS, Paris, France, 2 Institut des Systèmes Complexes de Paris-Ile de France (ISC-PIF), Paris, France, 3 Department of Management Science and Innovation, University College London (UCL), London, United Kingdom, 4 Centre for Advanced Spatial Analysis (CASA), University College London (UCL), London, United Kingdom, 5 Institut de Physique Théorique, CEA, IPhT CNRS, URA 2306, Gif-sur-Yvette, France

We have done a paper recently with Chen Zhong for the Easy-Link data in Singapore



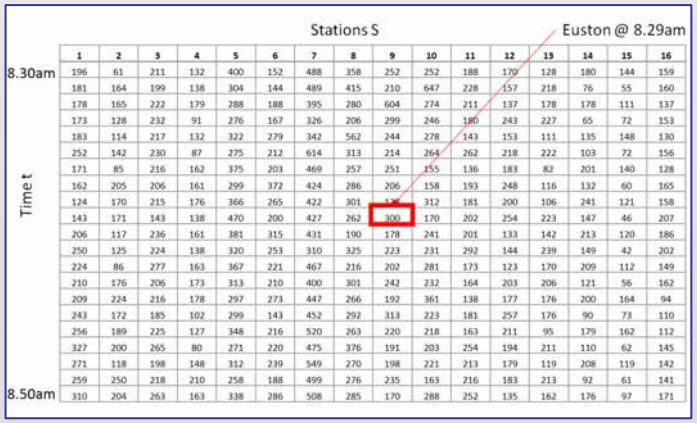
International Journal of Geographical Information Science, 2014
http://dx.doi.org/10.1080/13658816.2014.914521

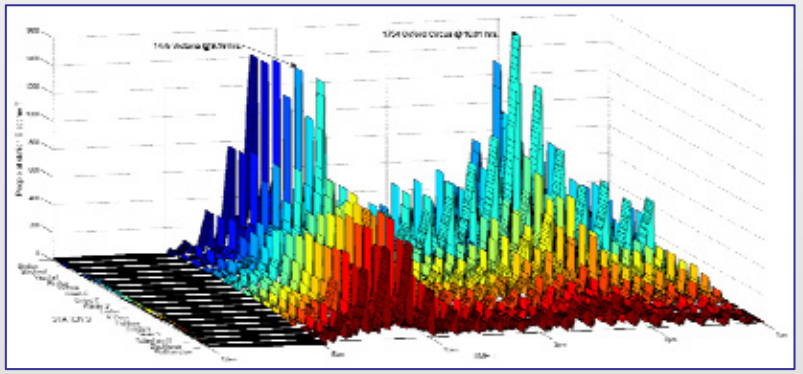
Taylor & Francis
Taylor & Francis Group

Detecting the dynamics of urban structure through spatial network analysis

Chen Zhong[a]*, Stefan Müller Arisona[a,b], Xianfeng Huang[c], Michael Batty[d] and Gerhard Schmitt[a]

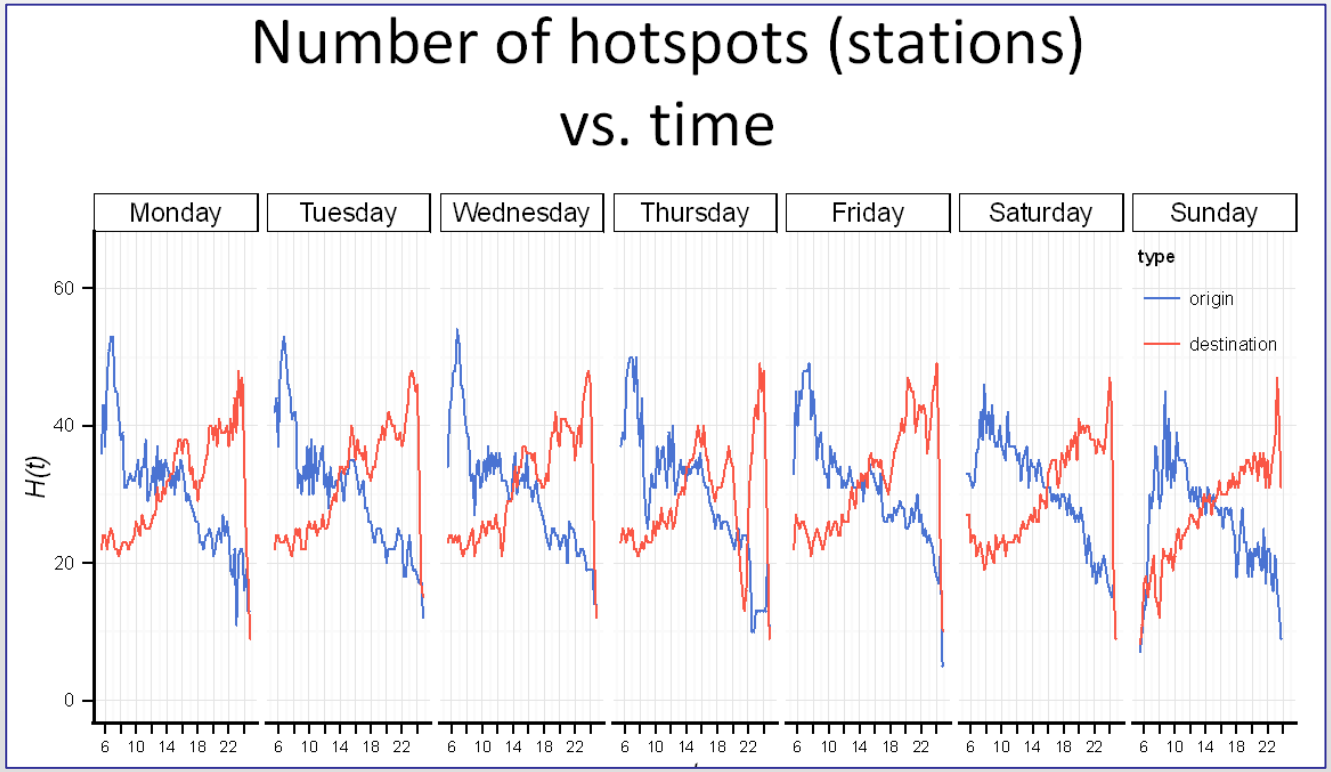
We are currently using information theory to figure out how much information from trips is transmitted from station to station through time by working out how many passengers are in stations or on trains in stations over time. We are using the concept of **transfer entropy** to do this. I don't have time to say much about this but here is a picture about this for one line in London

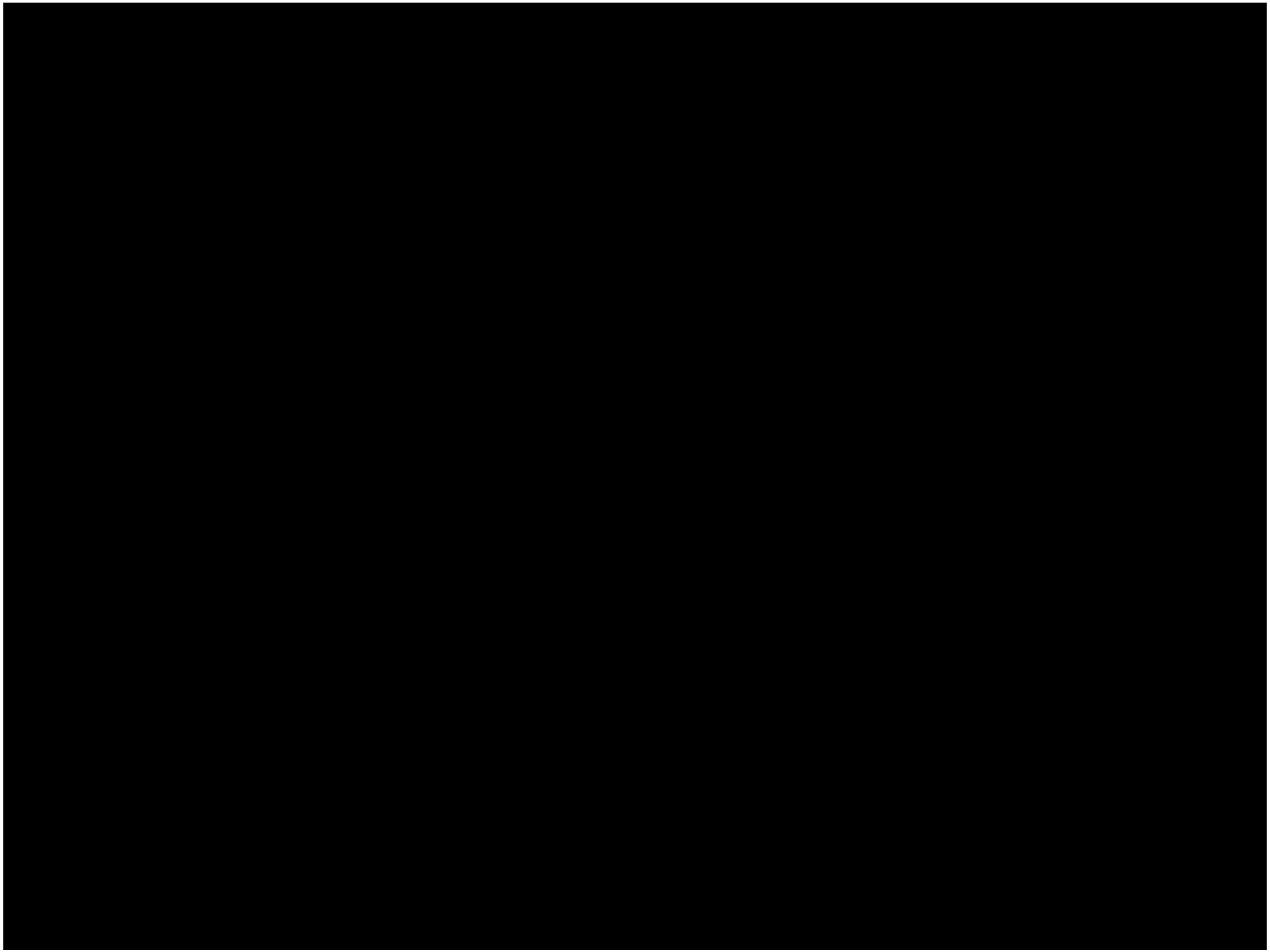




$$T_{YX} = \sum_{t=1} p(y_{t+1}, y_t, x_t) \log \frac{p(y_{t+1}|y_t, x_t)}{p(y_{t+1}|y_t)}$$

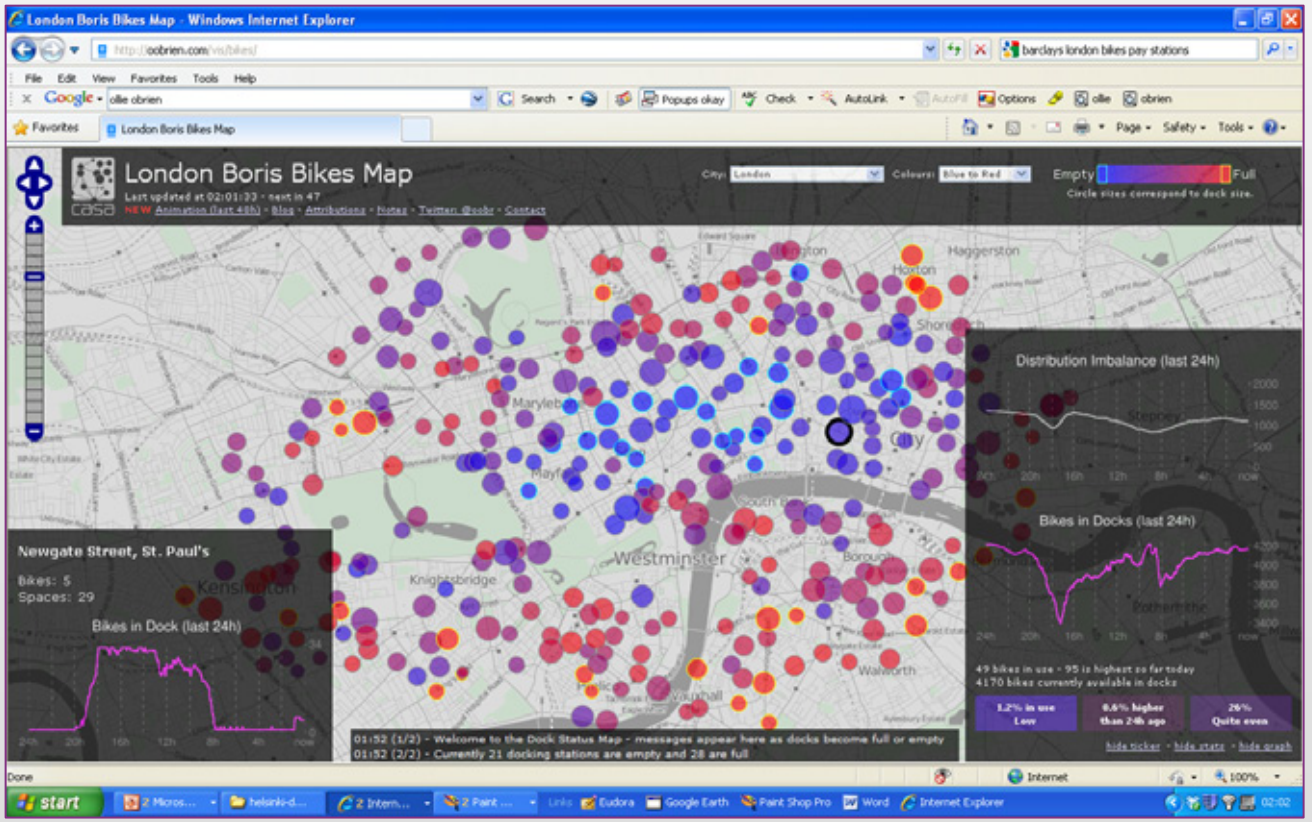
Second we are working with the Oyster data again with Melanie Bosredon in out group and Marc Barthelemy in Paris on extracting clusters from the travel data using a new method of defining intensity. I will show this as a simple movie of origin and destination intensities as they change over time of day.

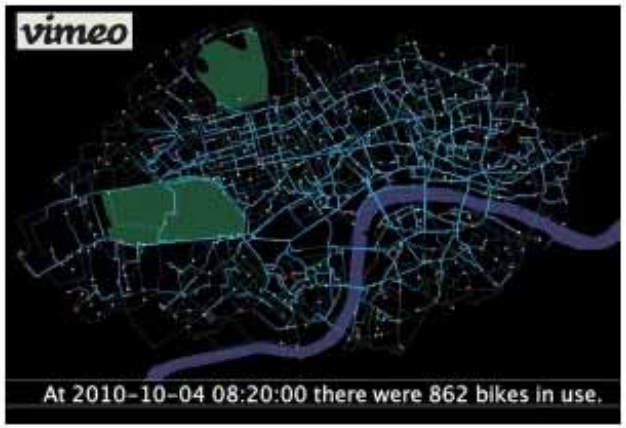




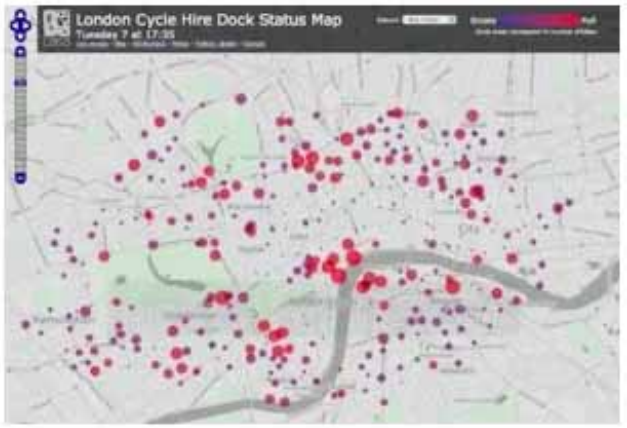
A lot of data is now coming online for travel and one of our group Oliver O'Brien has some 97 bike schemes world wide for which he has online data in real time

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





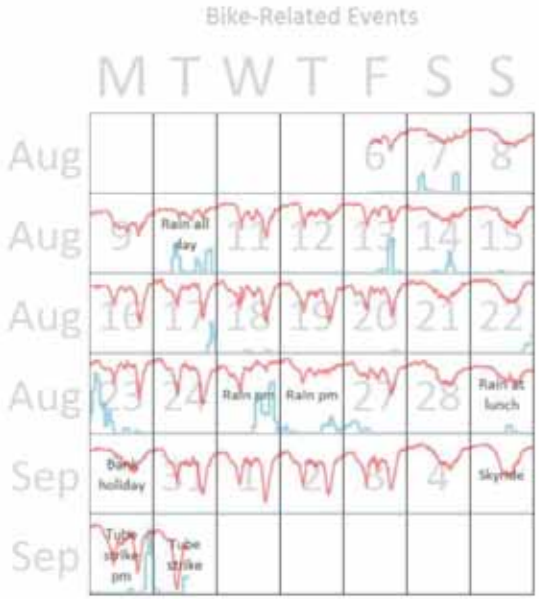
Animations of Public Bike Movements



Animations of Changes in the Bike Nodes: Docking

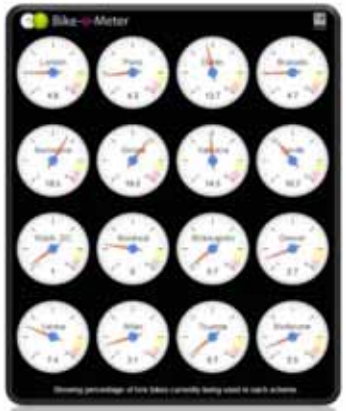
More Analysis

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

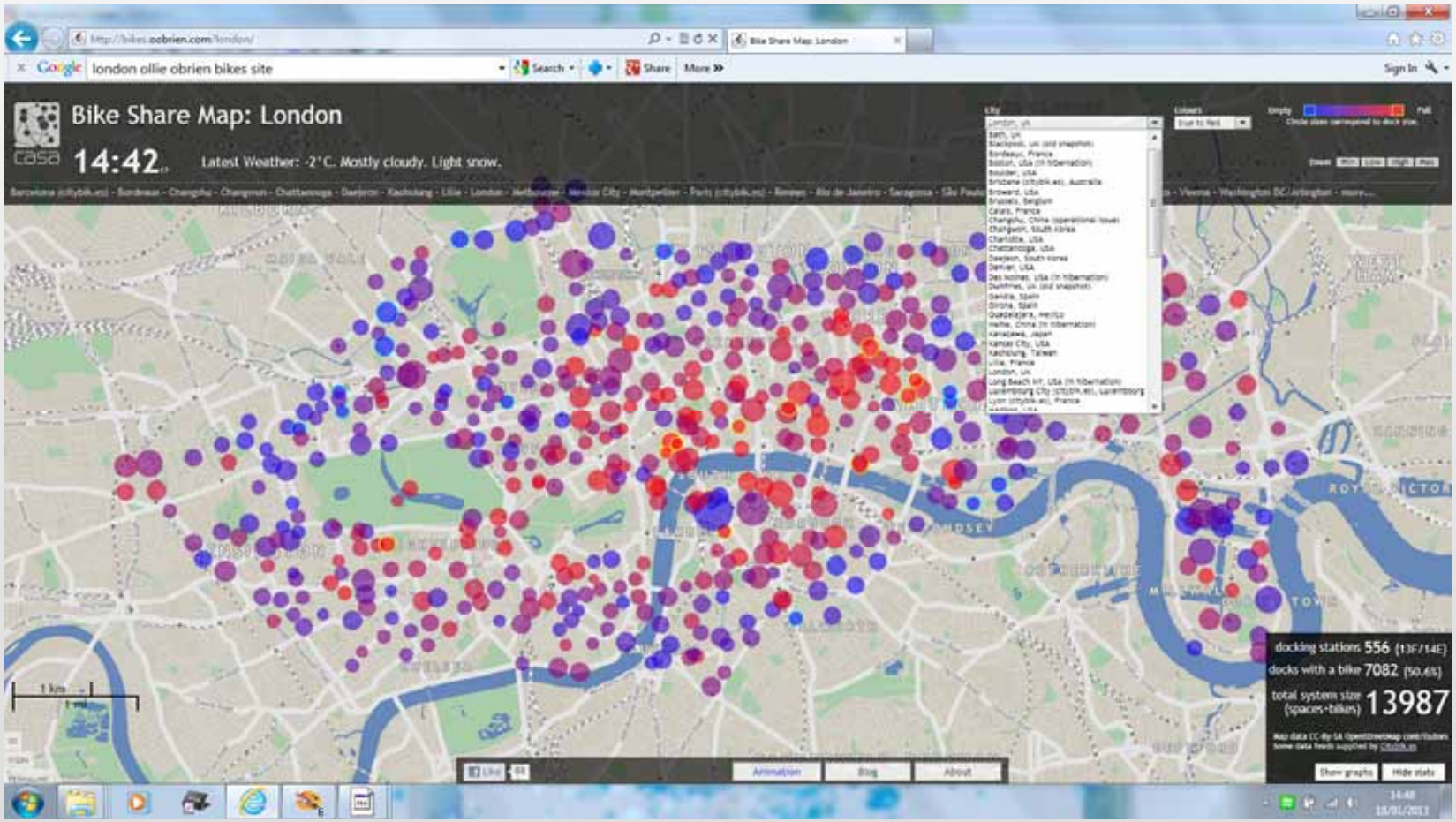


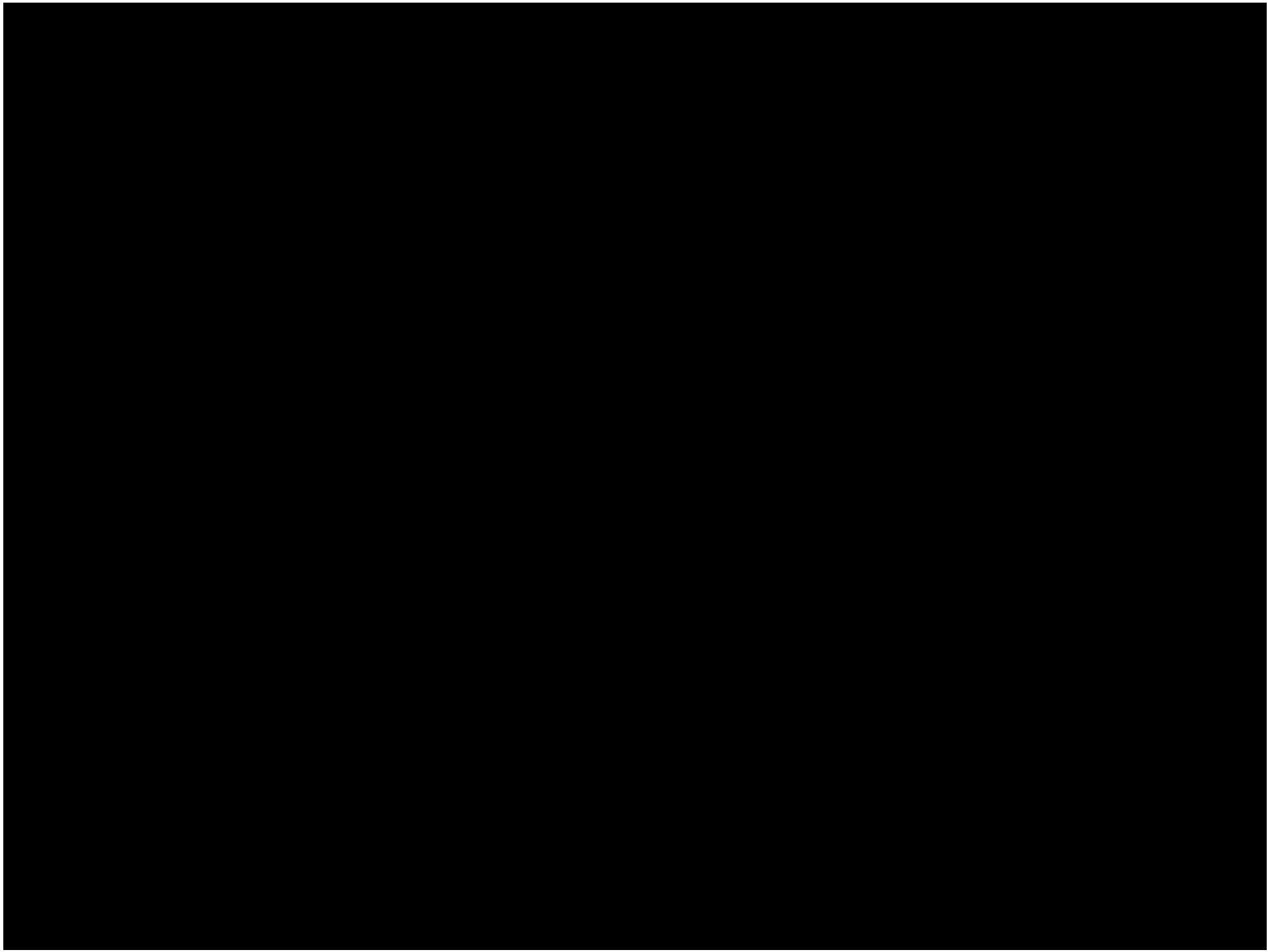
Bike-o-Meter
casa.ucl.ac.uk/bom

- 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/





We are collecting some of this real time data together in one stop portals – City Dashboards

And here is our example for London but we have some other cities too such as Manchester, Bristol and so on

London
51.51 N, 0.13 W
Mon 30 Jun @ 20:47:27
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
Hampstead NW3
1.6 mph
0 mph
W
15.2 °C
80%
0.7 mm
1017.0 mbar
Hard Rain
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
Available Bikes (last 24h)
24h 20h 16h 12h 8h 4h now
Traffic Cameras (Two at Random) (TfL)
A5 Cricklewood Broadway
A23 Streatham H Rd/Mitcham Ln
Camera 00001.04514
In use keeping London moving*
BBC London News (BBC)
Islamic extremism concerns at school
when mother shot
East London bridge design revealed
Armed officers in Harrow stand-off
chased and stabbed to death
Electricity (N.Grid)
Demand (Great Britain)
34988
Mood (LSE Mappiness)
5% unhappier than the long term average for here
3% happier than the whole country right now
Twitter Trends for London
Data unavailable
London News and Events (Twitter)
Data unavailable
London Universities (Twitter)
Data unavailable
Tweet 1,363
About
UCL
NCRM
JISC
Good Service
366
7,104
6409.67
247,000
504,611
UCL ENTERPRISE
UCL

I will change tack to finish and talk about data that we generate ourselves

We can use the power of the web to collect data with a spatial or travel reference using what is called crowdsourcing

We can use data from hand held devices which pertain to movement as Laslo indicated in the previous talk

home about login search help casa

MAPTUBE
a place to put maps

BBC RADIO 4

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

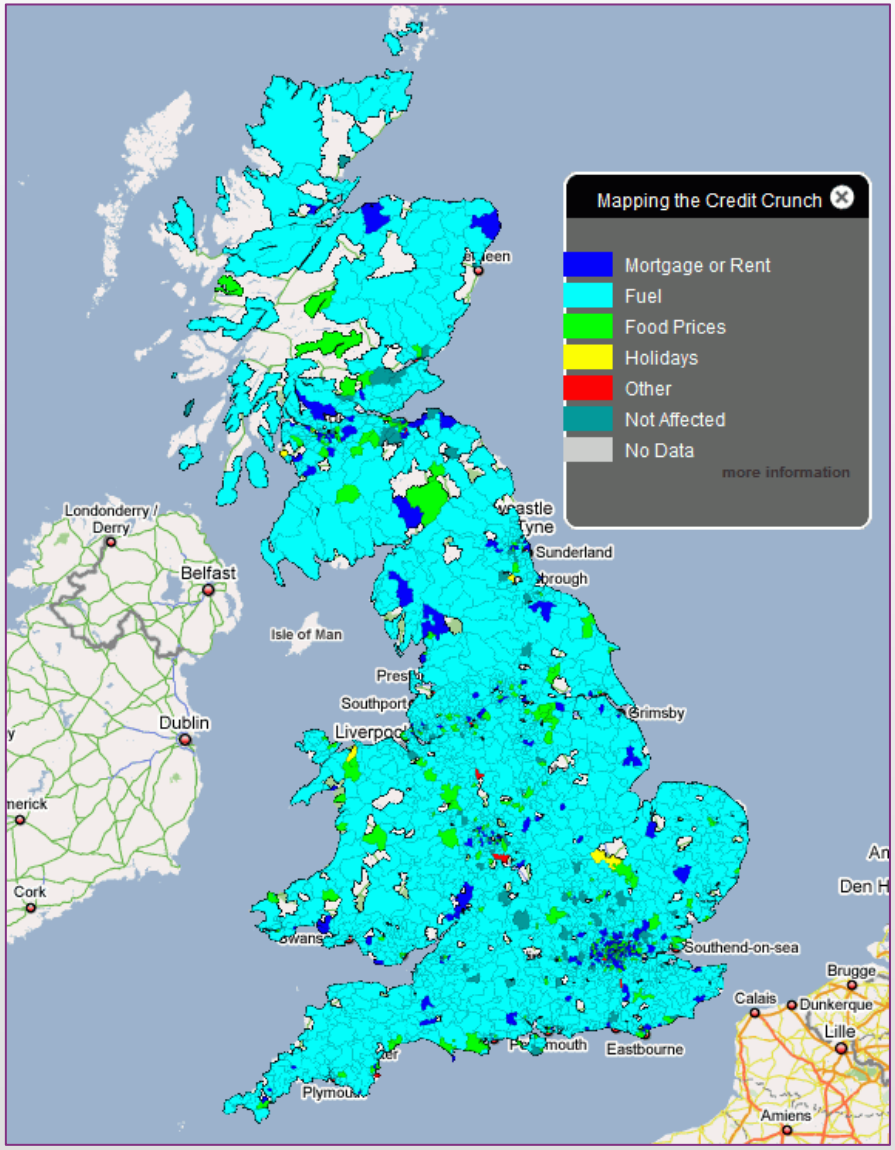
Enter the first part of your postcode:

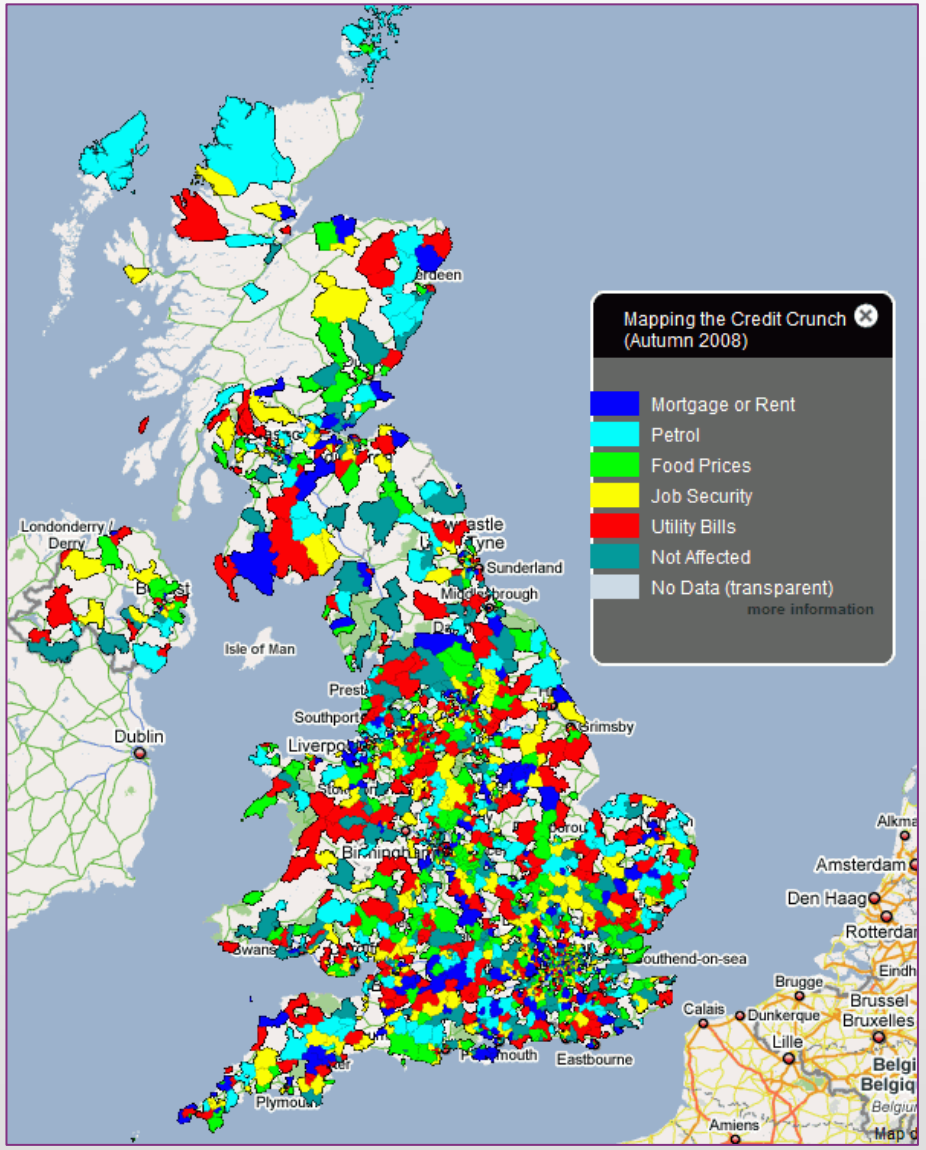
Submit

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

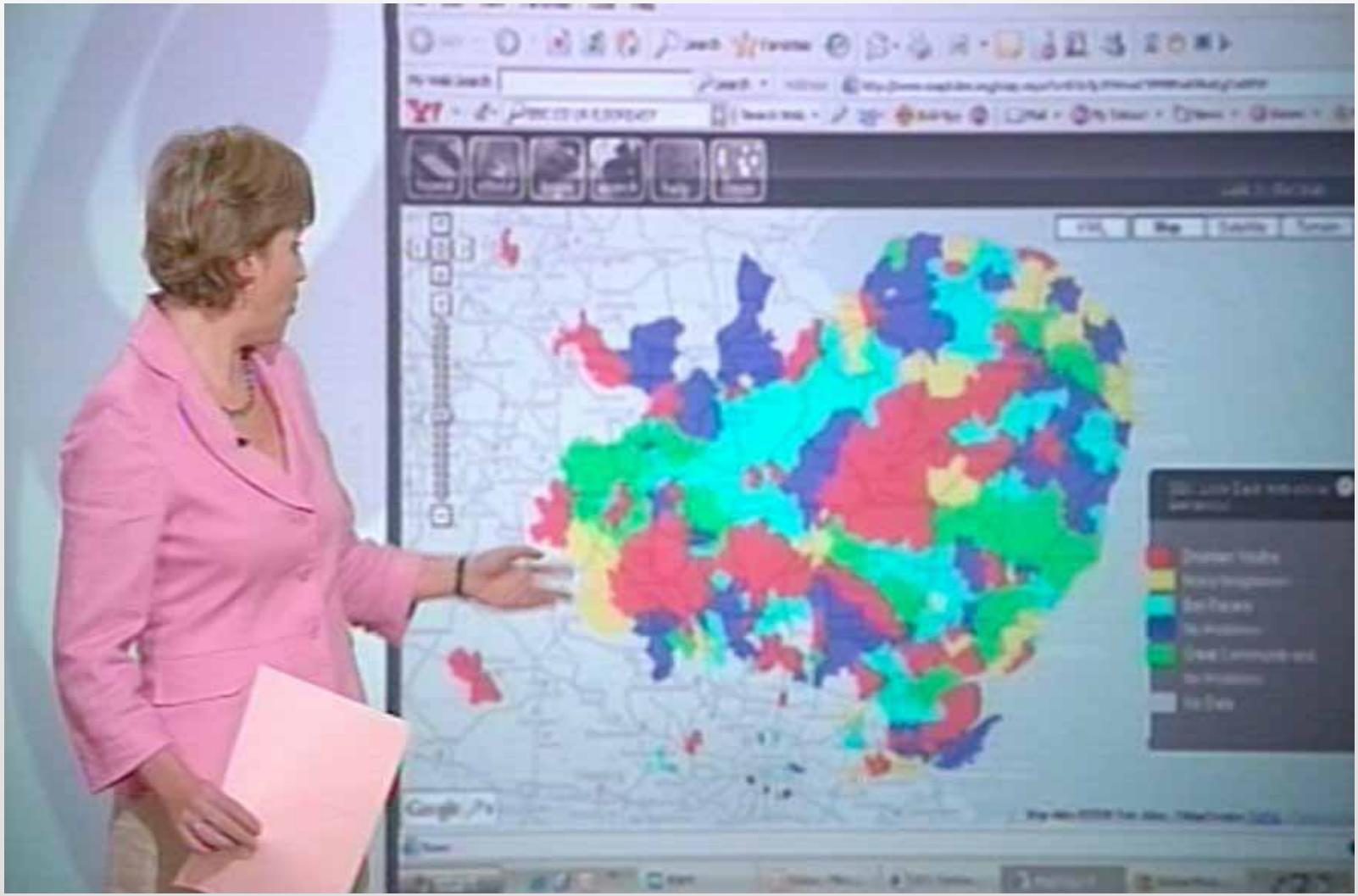
A new credit crunch survey started in October and currently has 3,802 responses.





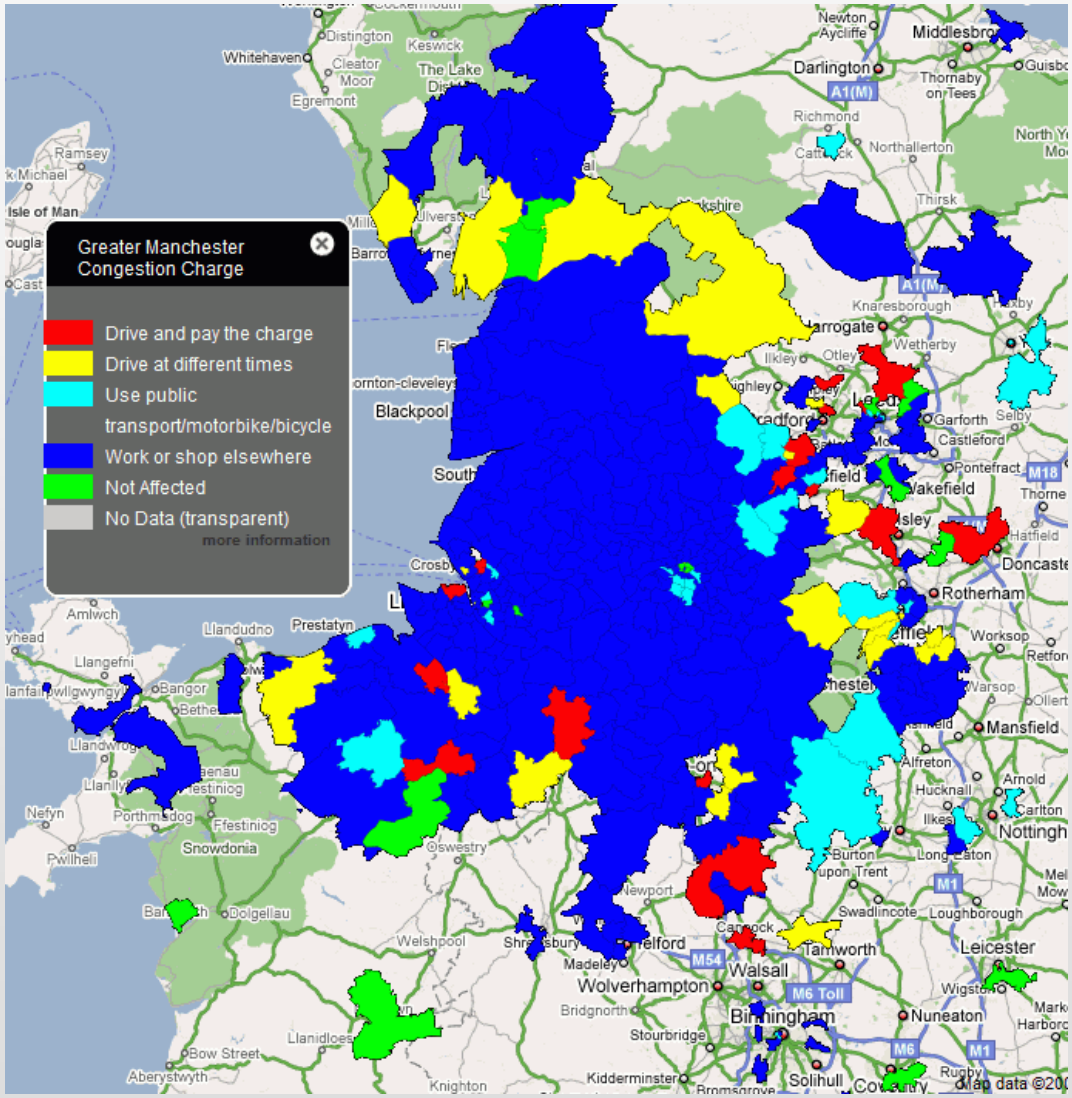
http://www.maptube.org/creditcrunch/

BBC Look East: Anti-Social Behaviour

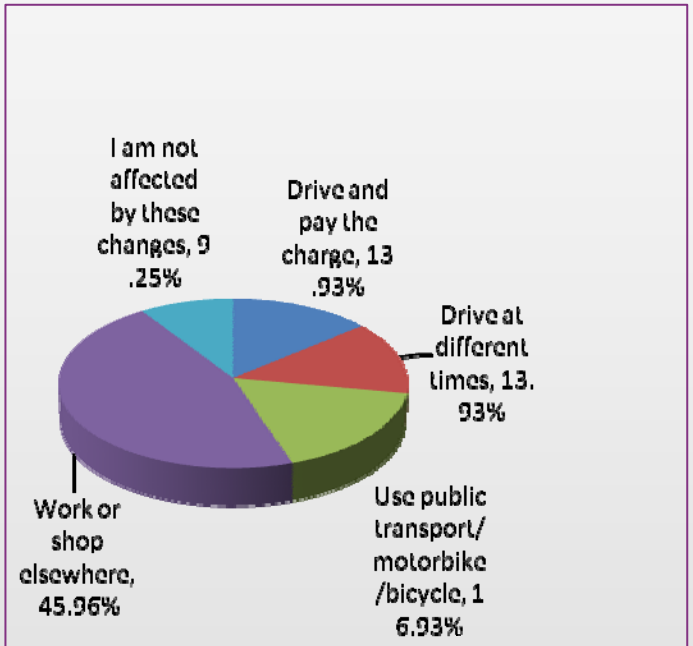


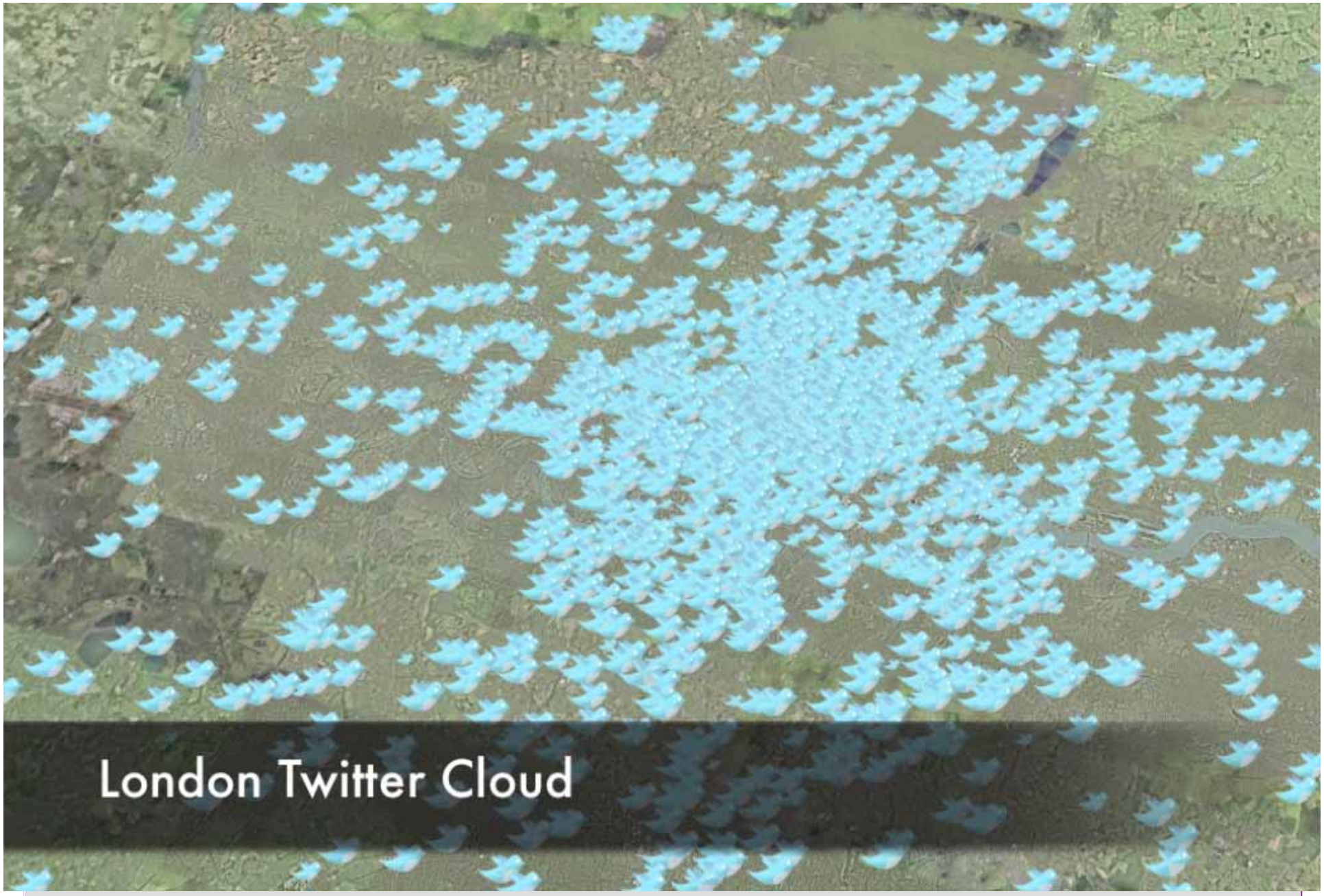
http://www.maptube.org/lookeast

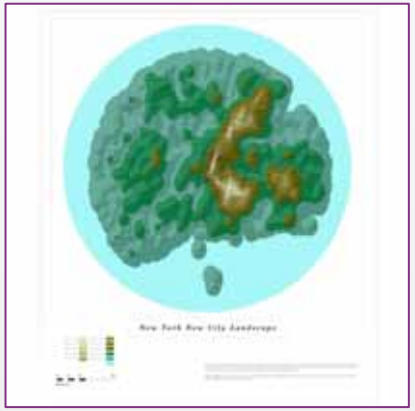
Manchester Congestion Charge



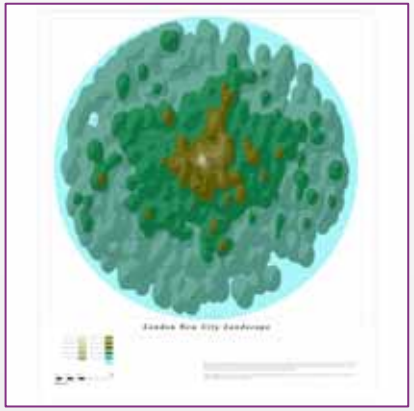
15,902 responses
October to December 2008



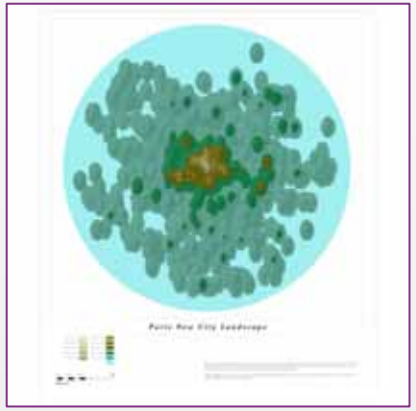

London Twitter Cloud



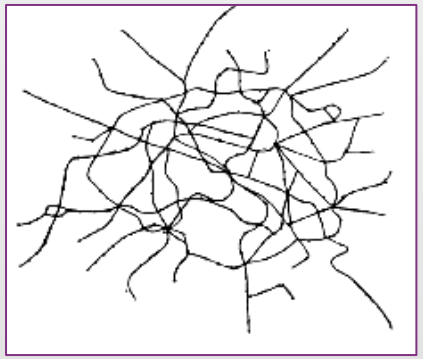
New York

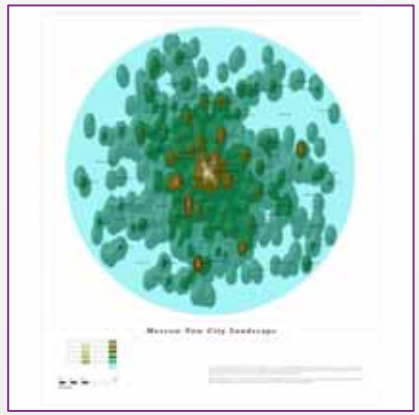


London

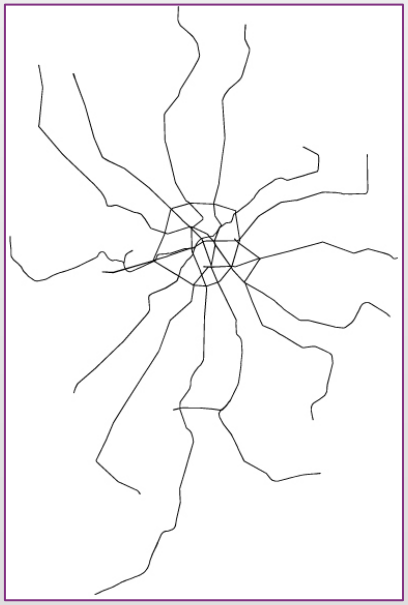


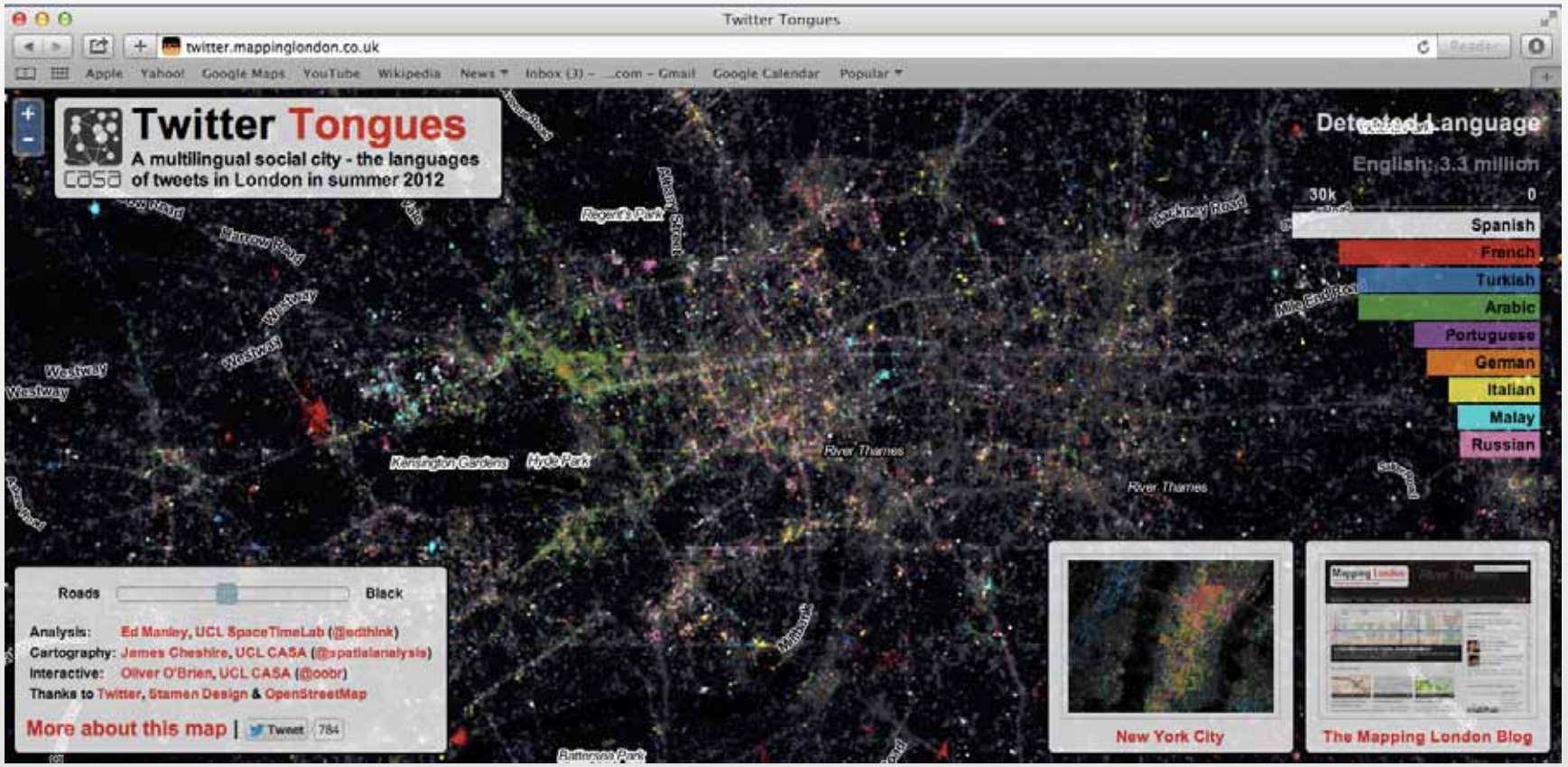
Paris

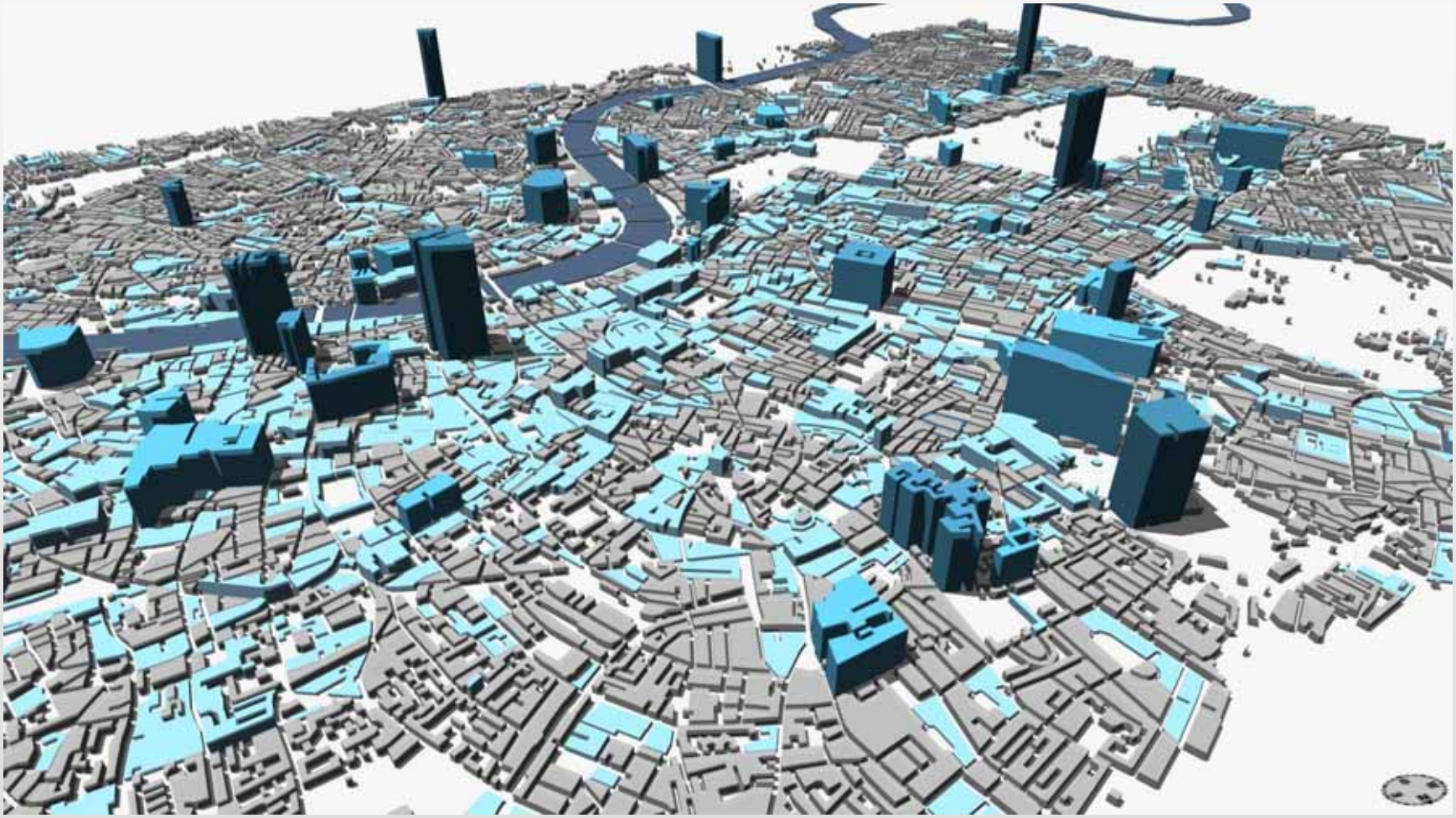


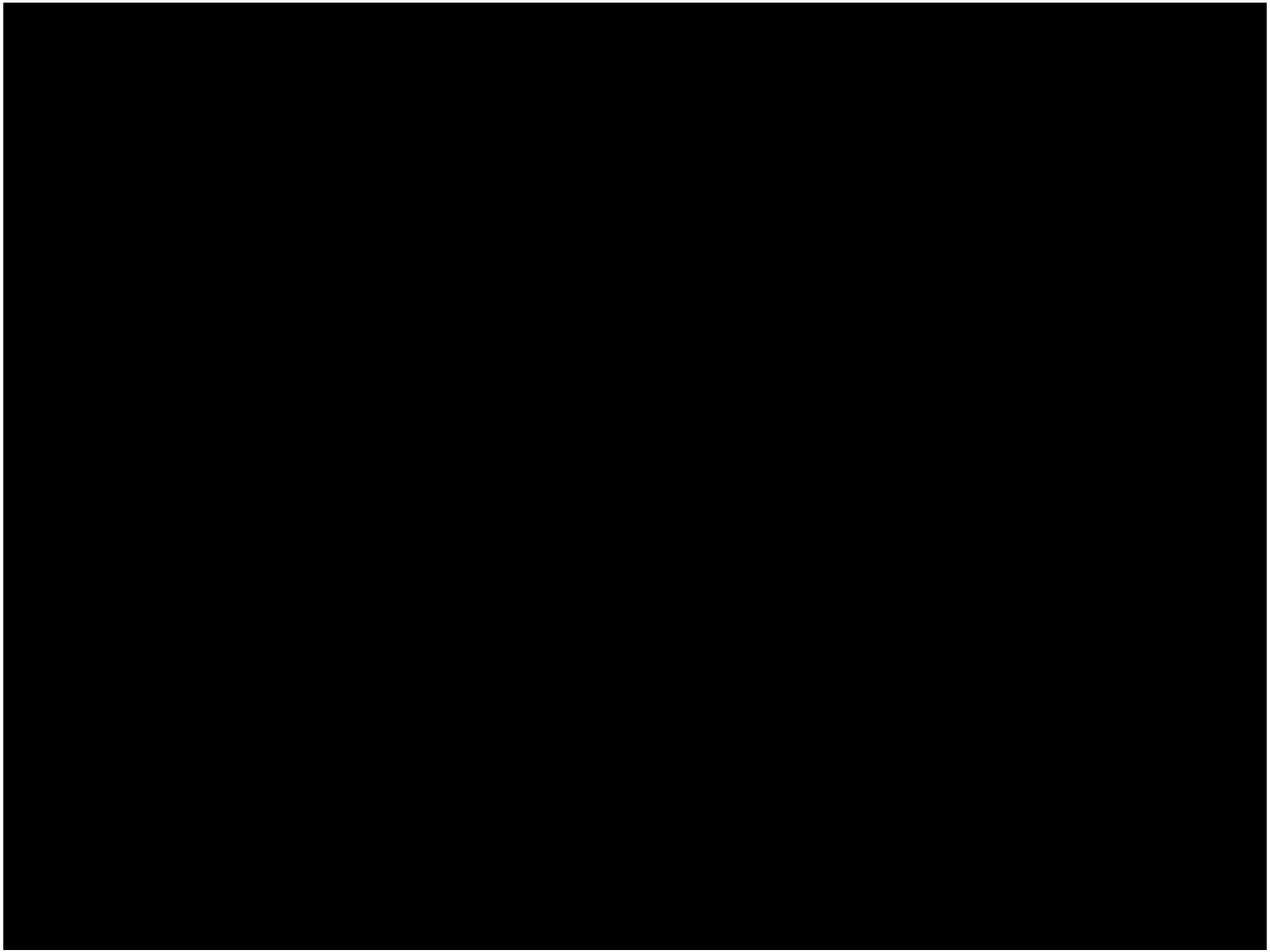


Moscow




Twitter Tongues
twitter.mappinglondon.co.uk
Twitter Tongues
A multilingual social city - the languages of tweets in London in summer 2012
Detected Language
English: 3.3 million
30k
0
Spanish
French
Turkish
Arabic
Portuguese
German
Italian
Malay
Russian
Roads
Black
Analysis: Ed Manley, UCL SpaceTimeLab (@edthink)
Cartography: James Cheshire, UCL CASA (@spatialanalysis)
Interactive: Oliver O'Brien, UCL CASA (@oobr)
Thanks to Twitter, Stamen Design & OpenStreetMap
More about this map
Tweet
784
New York City
The Mapping London Blog





- So Data is very diverse and you need powerful tools to analyze it
- Powerful methods to visualise it
- And of course it is the essence of modelling, simulation and predictions
- Next week networks and communications

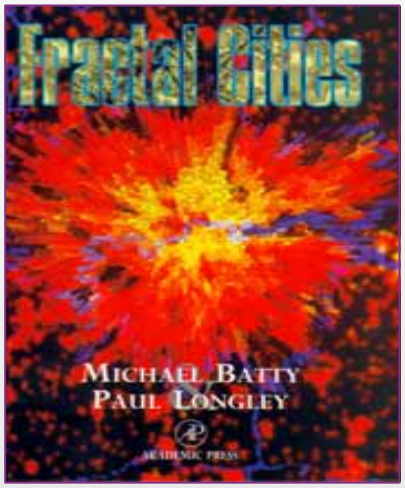
Thanks

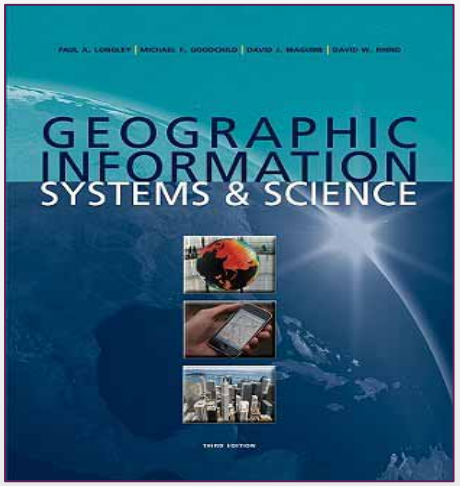
http://www.spatialcomplexity.info/
http://www.complexcity.info/
http://blogs.casa.ucl.ac.uk/
http://www.casa.ucl.ac.uk/

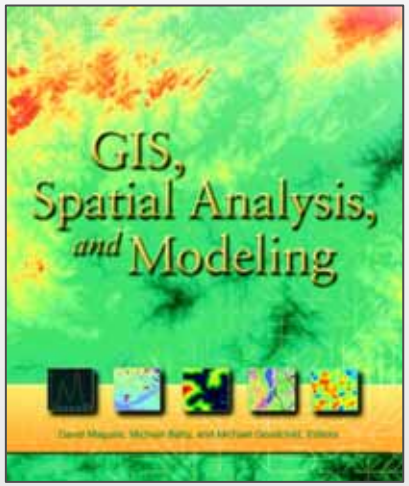
Acknowledgements

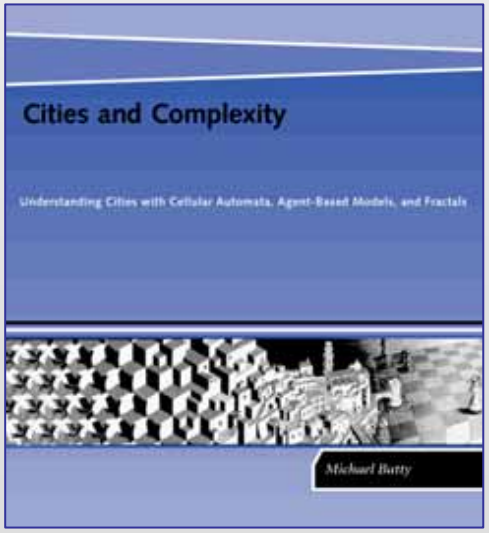
Andy Hudson-Smith, Melanie Bosredon, Gareth Simmonds, Roberto Murcio, Richard Milton, Oliver O'Brien, Stephen Gray, Fabian Neuhaus, Pete Ferguson, Martin Austwick, Joan Serras, Camilo-Vargas-Ruiz, Paul Longley, Jon Reades, Ed Manley, Anders Johansson, Flora Roumpani and Stephan Hugel

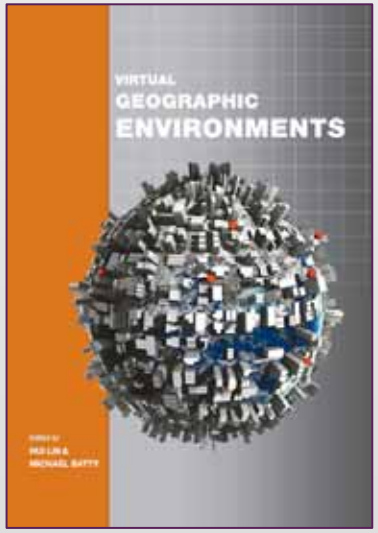
Some of our books which are about some of this

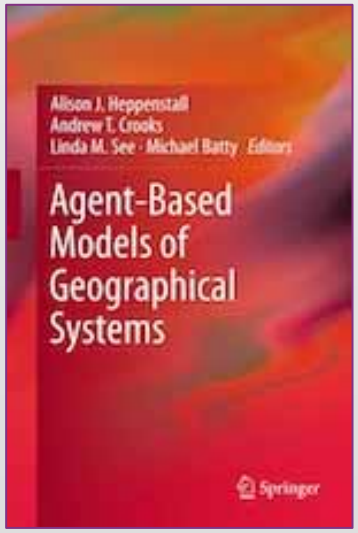


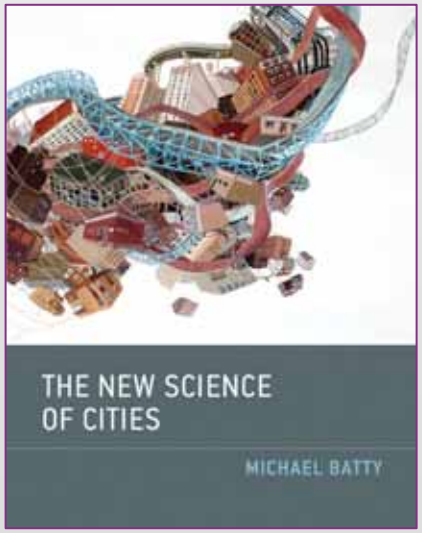












Networks, Communications & Cities

Michael Batty
m.batty@ucl.ac.uk
@jmichaelbatty

http://www.complexcity.info/
http://www.spatialcomplexity.info/

Outline

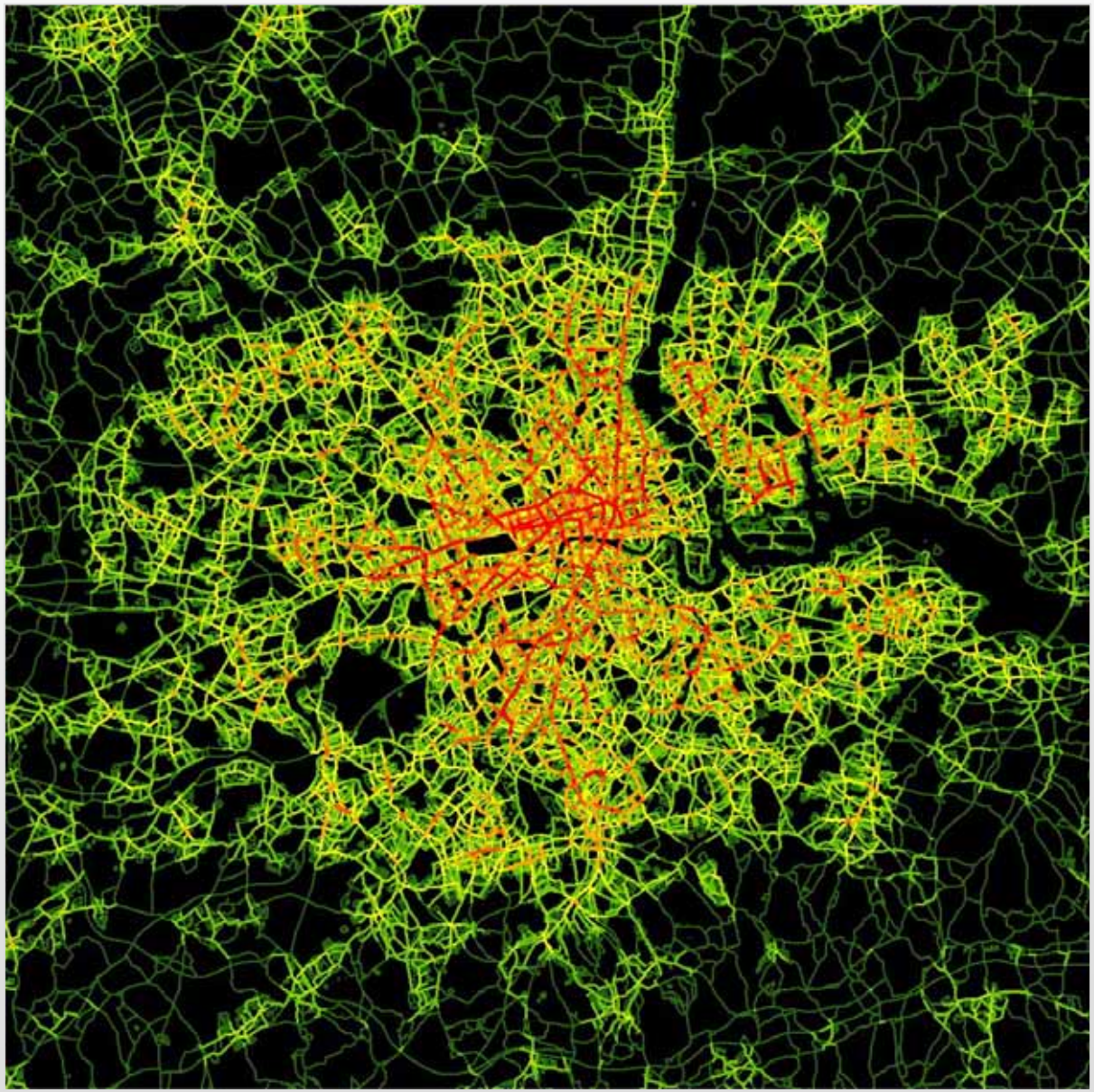
- What are Networks in Cities: A Little Bit of History
- A Question of Spatial Scale: Planarity v Topology
- Down At Street Level: Space Syntax
- Urban Transport Infrastructures
- Throwing Out the Planarity
- Growing Networks
- Flows on Networks: Scale Again – Local to Global
- The Mathematics and Beyond
- An Indulgent and Interesting Example to Finish

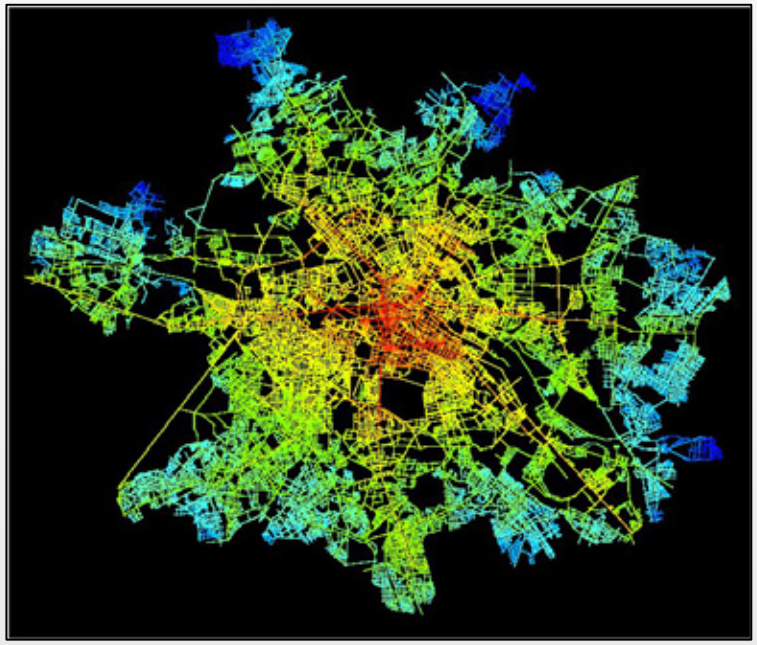
What are Networks in Cities: A Little Bit of History

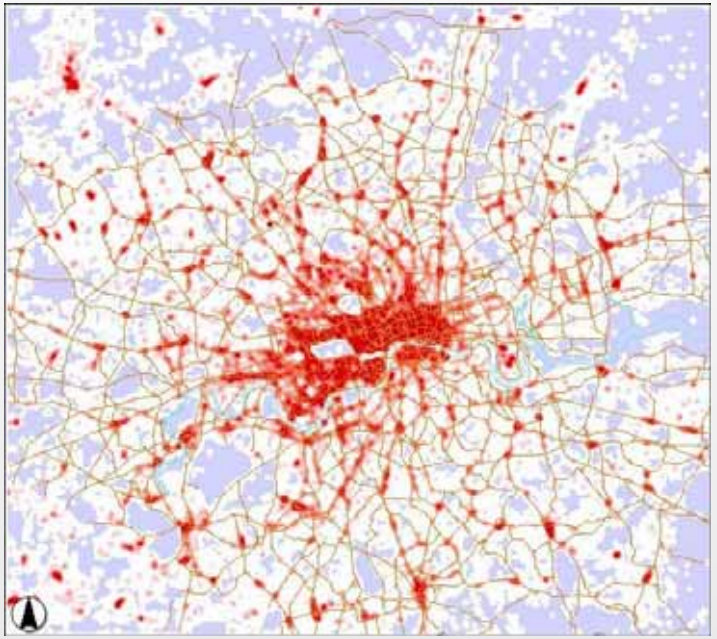
Haggett and Chorley's famous book Network Analysis in Geography 1969 about rivers, transport networks, and flow systems of all kinds that permeated geographical Euclidean space but it was linked very strongly to location as well as interaction.

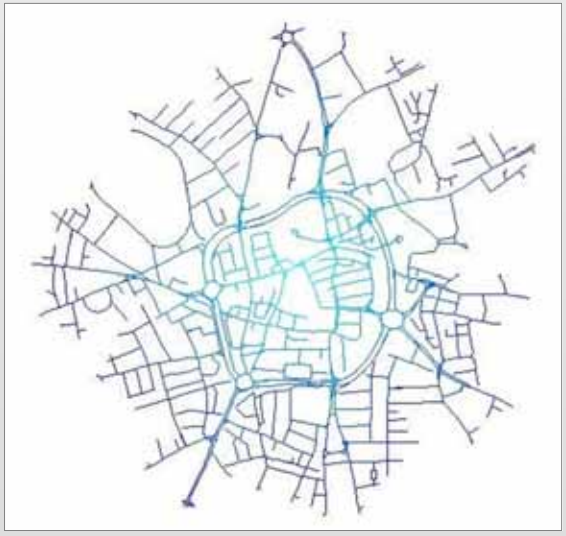
Networks in this sense dealt with flows and their infrastructure as arcs and nodes. Graph theory essentially was discovered in these fields

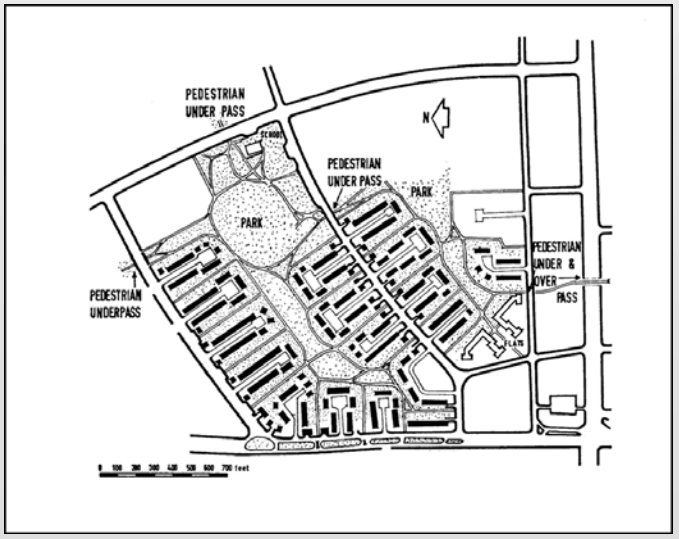
But these two worlds of flows and graphs were separate. Let me show you these contrasts by way of introduction







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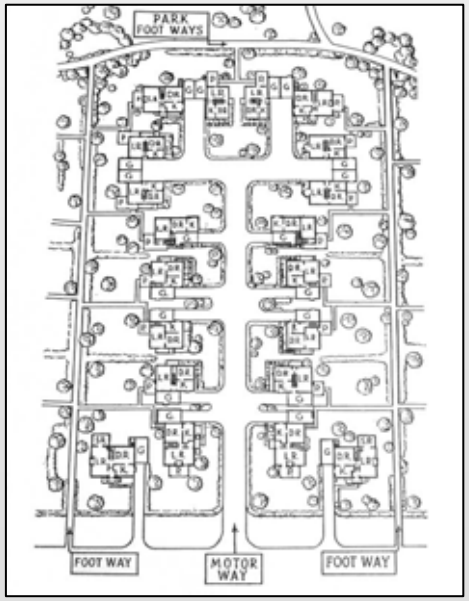
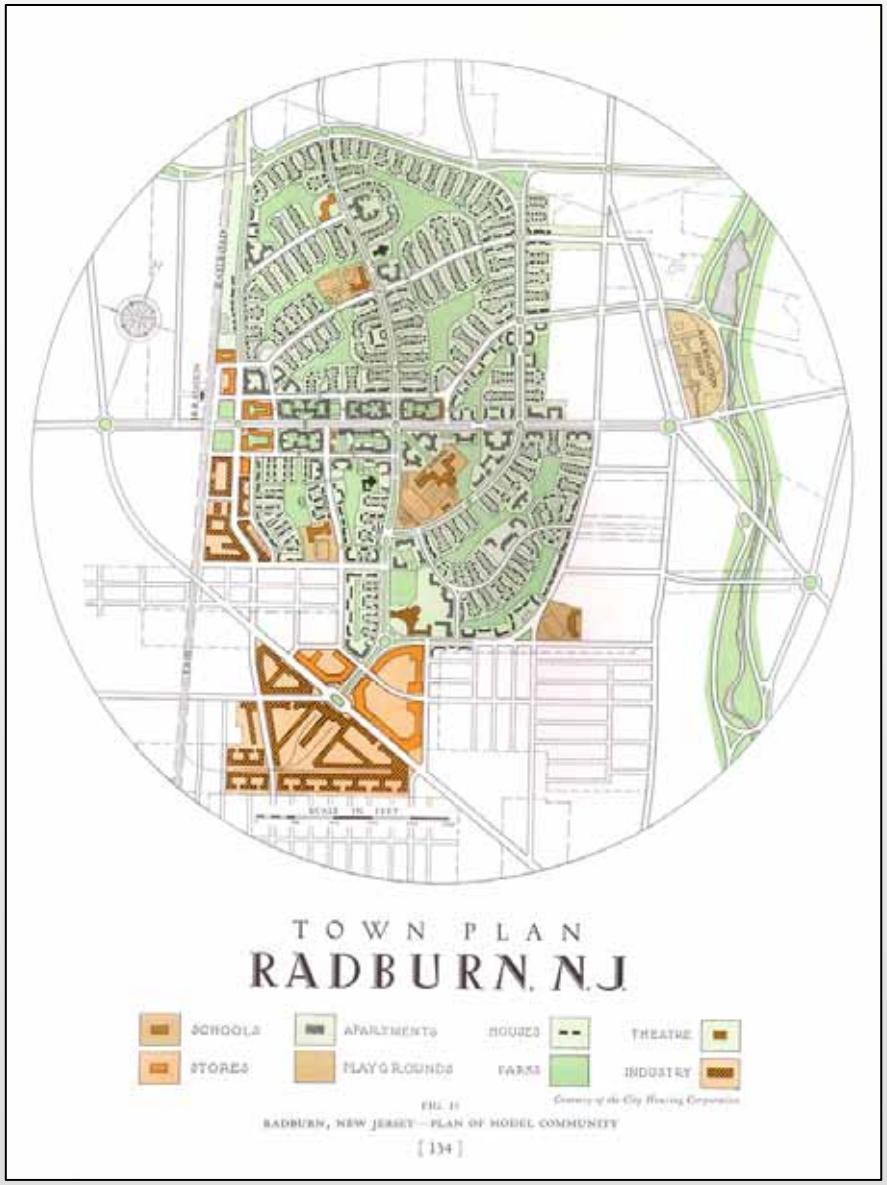

PARK
FOOT WAYS
FOOT WAY
MOTOR WAY
FOOT WAY

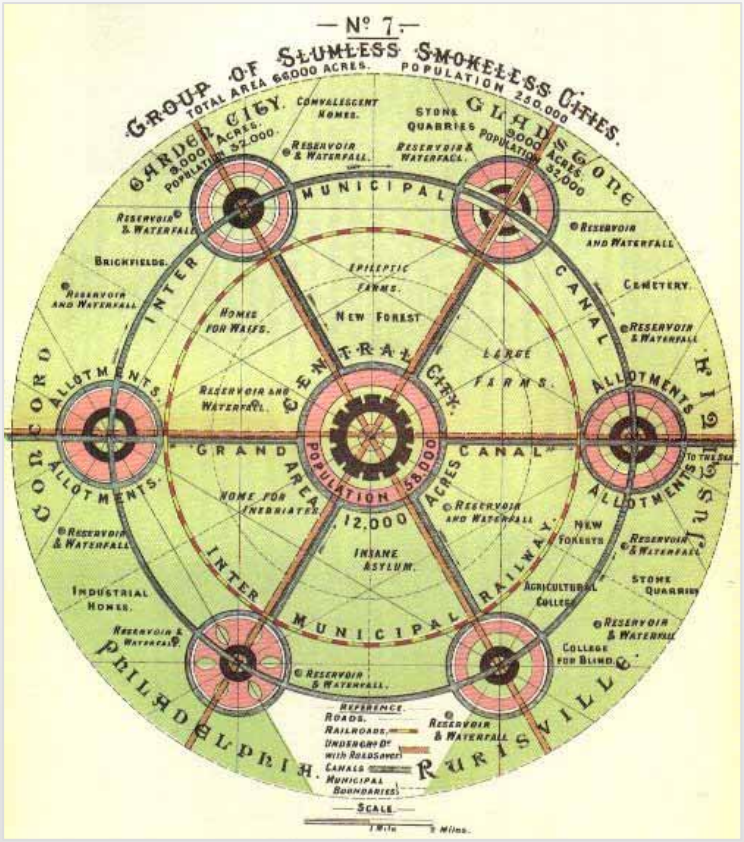

TOWN PLAN
RADBURN, N.J.
SCHOOLS
APARTMENTS
HOUSES
THEATRE
STORES
PLAYGROUNDS
FARMS
INDUSTRY
RADBURN, NEW JERSEY — PLAN OF MODEL COMMUNITY
[134]

A Question of Spatial Scale: Planarity v Topology

Essentially at the fine scale, in cities we deal with Euclidean space but as we aggregate in terms of spatial scale, we abstract and space although rooted in the 2 or 3 dimensional world becomes a world of points and lines.

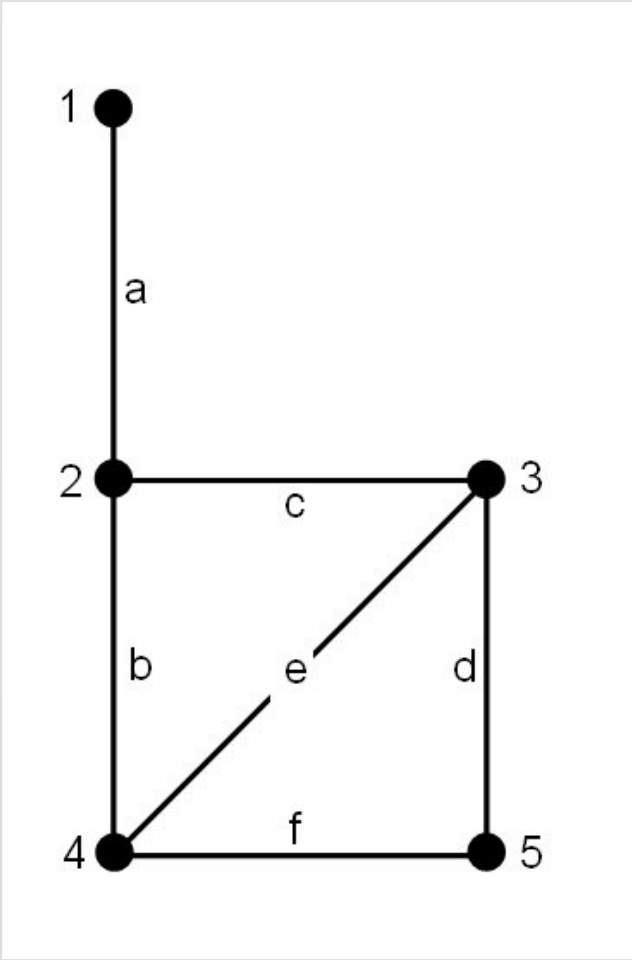
In short we move from planar graphs such as street networks to graphs of flows between cities, which can be treated topologically

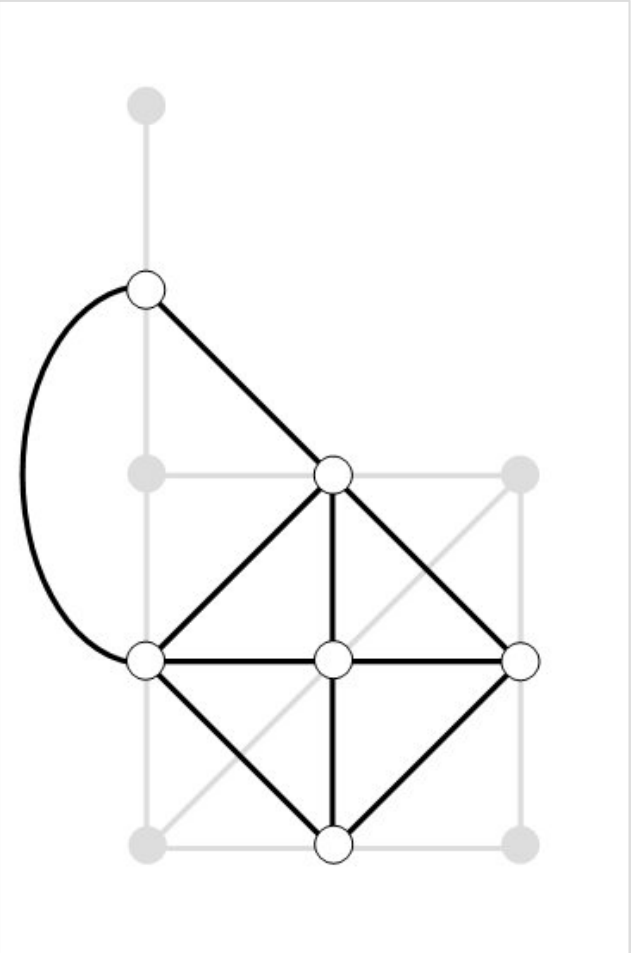
Network science which developed well after this early forays into graph theory in the 1960s such as those by Haggett and Chorley, has largely eschewed planarity but it is coming.

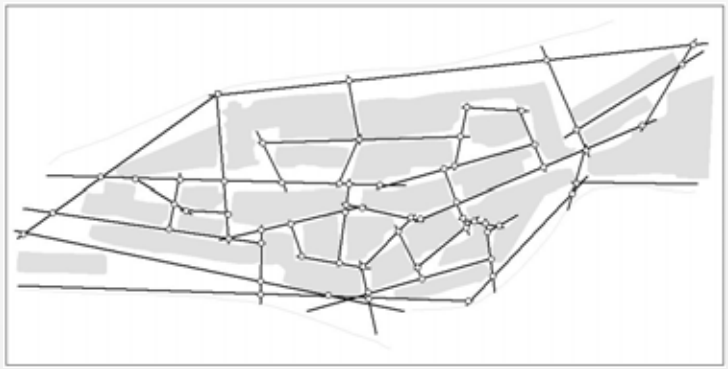


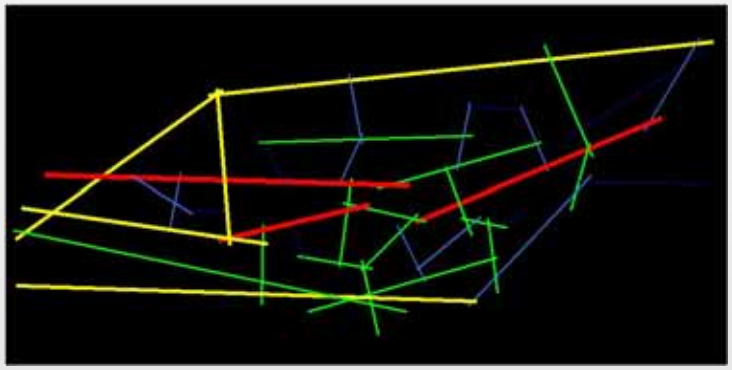
— Nº 7 —
GROUP OF SLUMLESS SMOKELESS CITIES.
TOTAL AREA 66,000 ACRES.
POPULATION 250,000
GARDEN CITY.
9,000 ACRES.
POPULATION 32,000.
GLADSTONE
9,000 ACRES.
POPULATION 32,000
CONCORD
PHILADELPHIA.
RURISVILLE.
JUSTICE
MUNICIPAL
INTER
CANAL
CENTRAL CITY.
GRAND
CANAL
AREA
12,000
ACRES
POPULATION 58,000
RAILWAY.
INTER
MUNICIPAL
ALLOTMENTS.
ALLOTMENTS.
ALLOTMENTS.
ALLOTMENTS.
CONVALESCENT HOMES.
STONE QUARRIES
RESERVOIR & WATERFALL.
RESERVOIR AND WATERFALL
BRICKFIELDS.
CEMETERY.
EPILEPTIC FARMS.
NEW FOREST
HOMES FOR WAIFS.
LARGE FARMS.
HOME FOR INEBRIATES.
INSANE ASYLUM.
NEW FORESTS
AGRICULTURAL COLLEGE
STONE QUARRIES
INDUSTRIAL HOMES.
COLLEGE FOR BLIND.
TO THE SEA
REFERENCE.
ROADS.
RAILROADS.
UNDERGRD Dr
WITH ROADSAVERS
CANALS
MUNICIPAL BOUNDARIES
SCALE

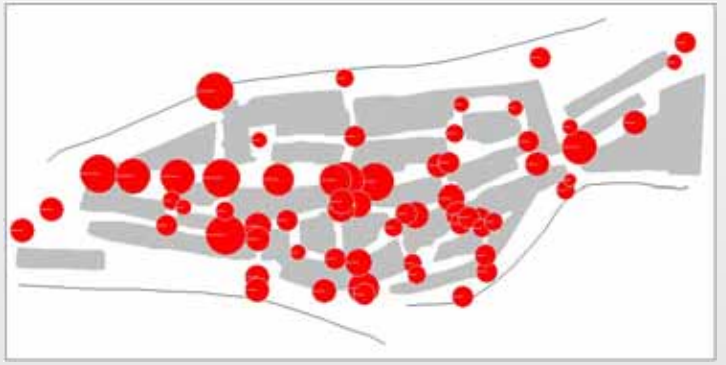
Down At Street Level: Space Syntax

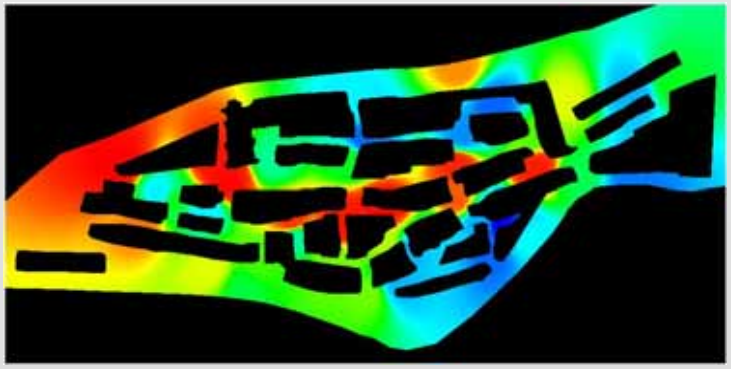


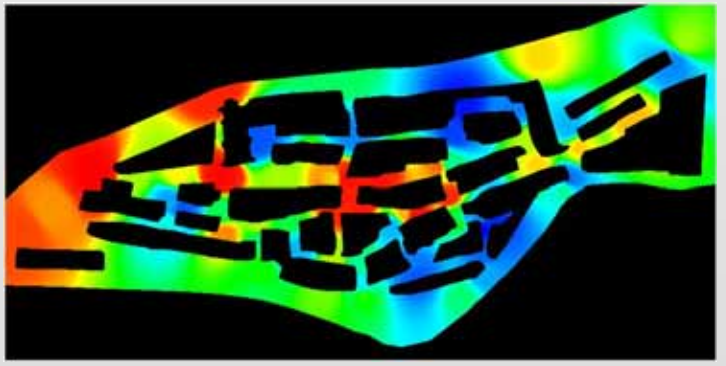




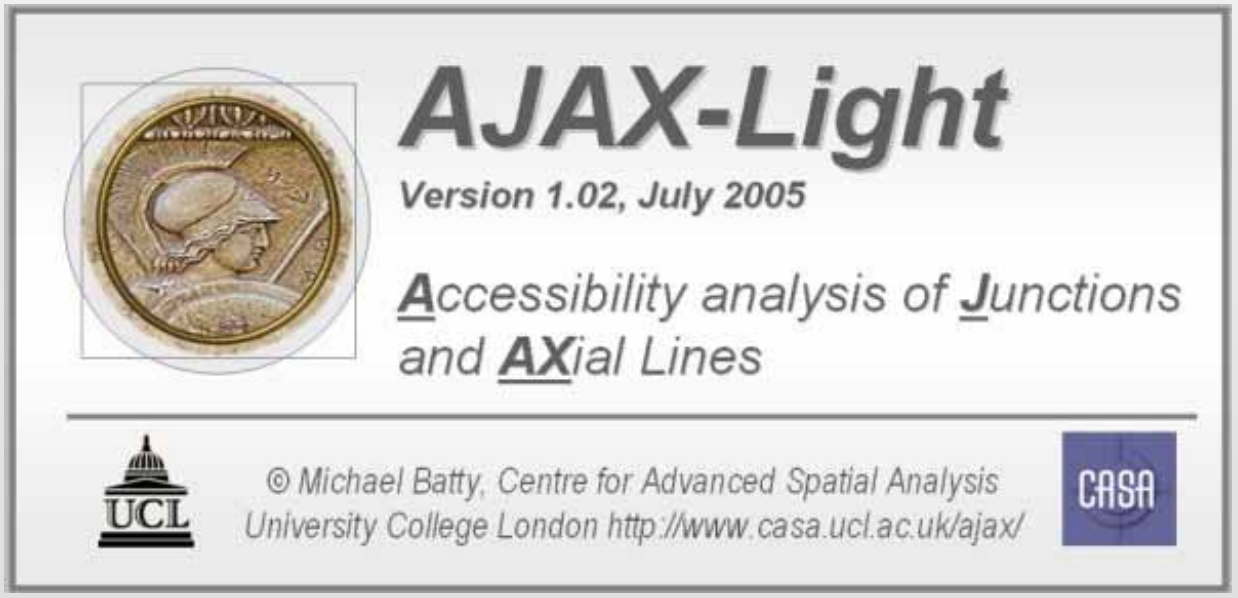






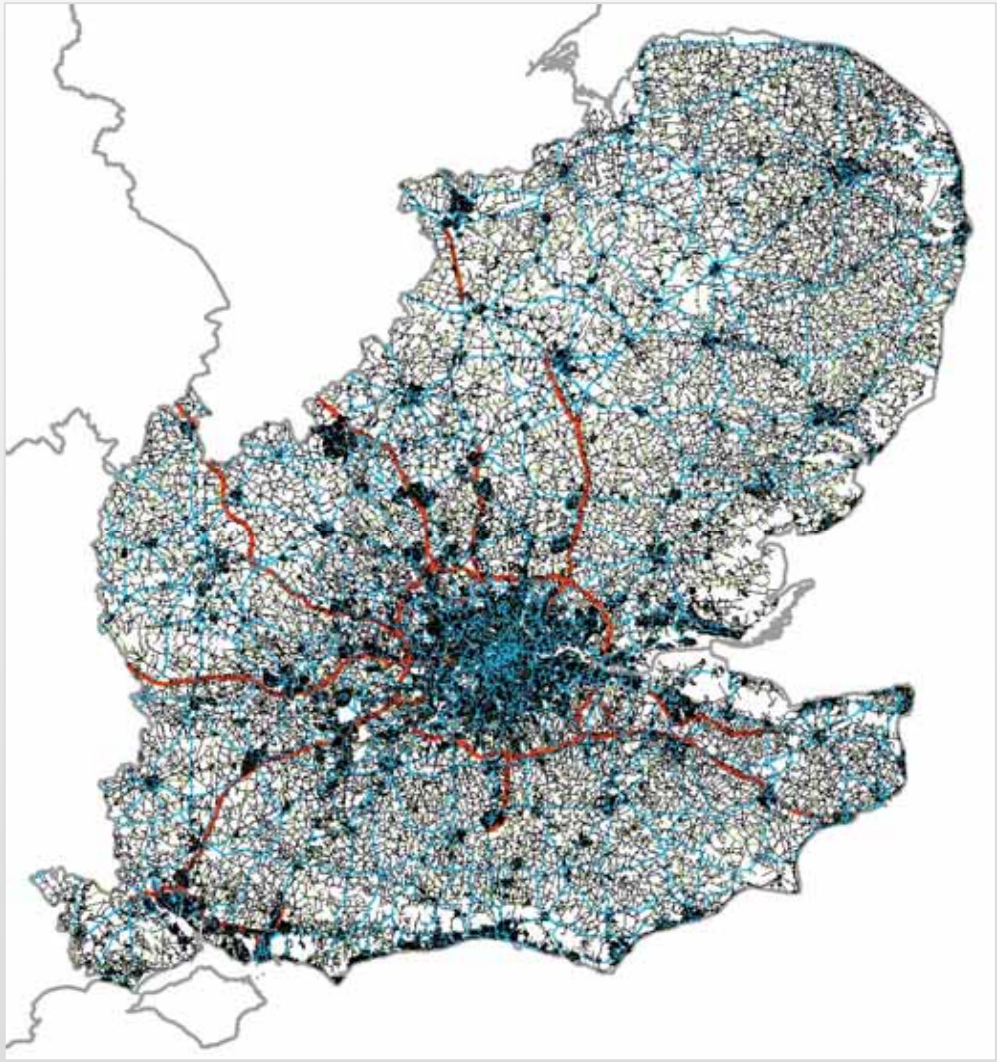


There are a couple of chapters on this in my book **The New Science of Cities** and you can download the software from the CASA website



Urban Transport Infrastructures

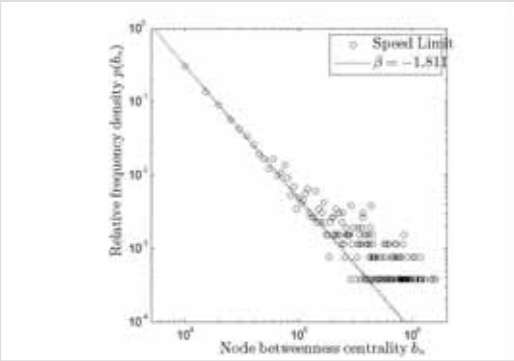
- Network size:
  - ~10^6 road nodes
  - ~$2x10^6$ road links
- Extracted from Ordnance Survey's Integrated Transport Network Layer

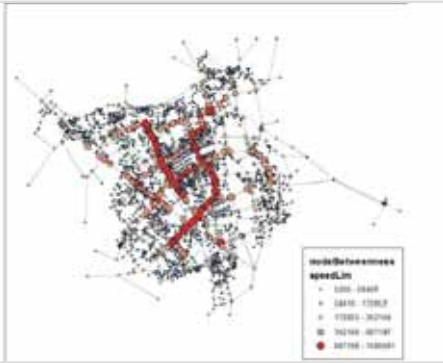


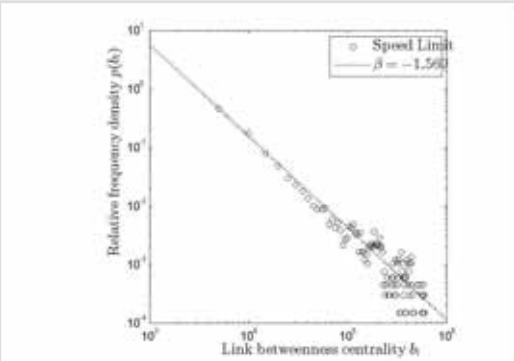
- Road network for Milton Keynes
- Network size:
  - ~$3x10^3$ road nodes
  - ~$7x10^3$ road links

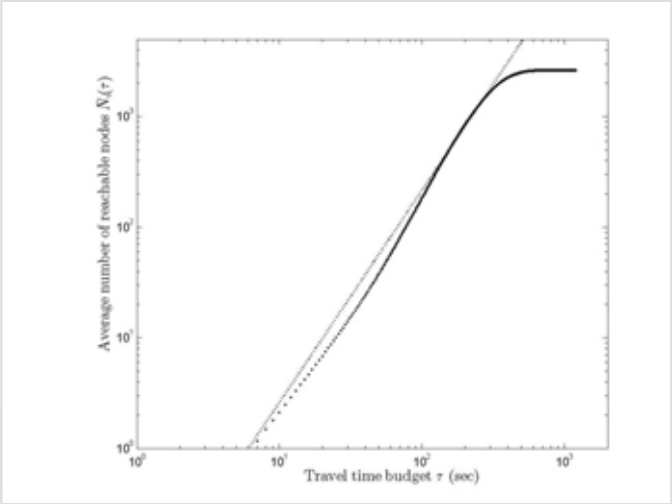
Power laws in road networks topology

- ❑ Effective dimension
- ❑ Node betweenness centrality
- ❑ Link betweenness centrality

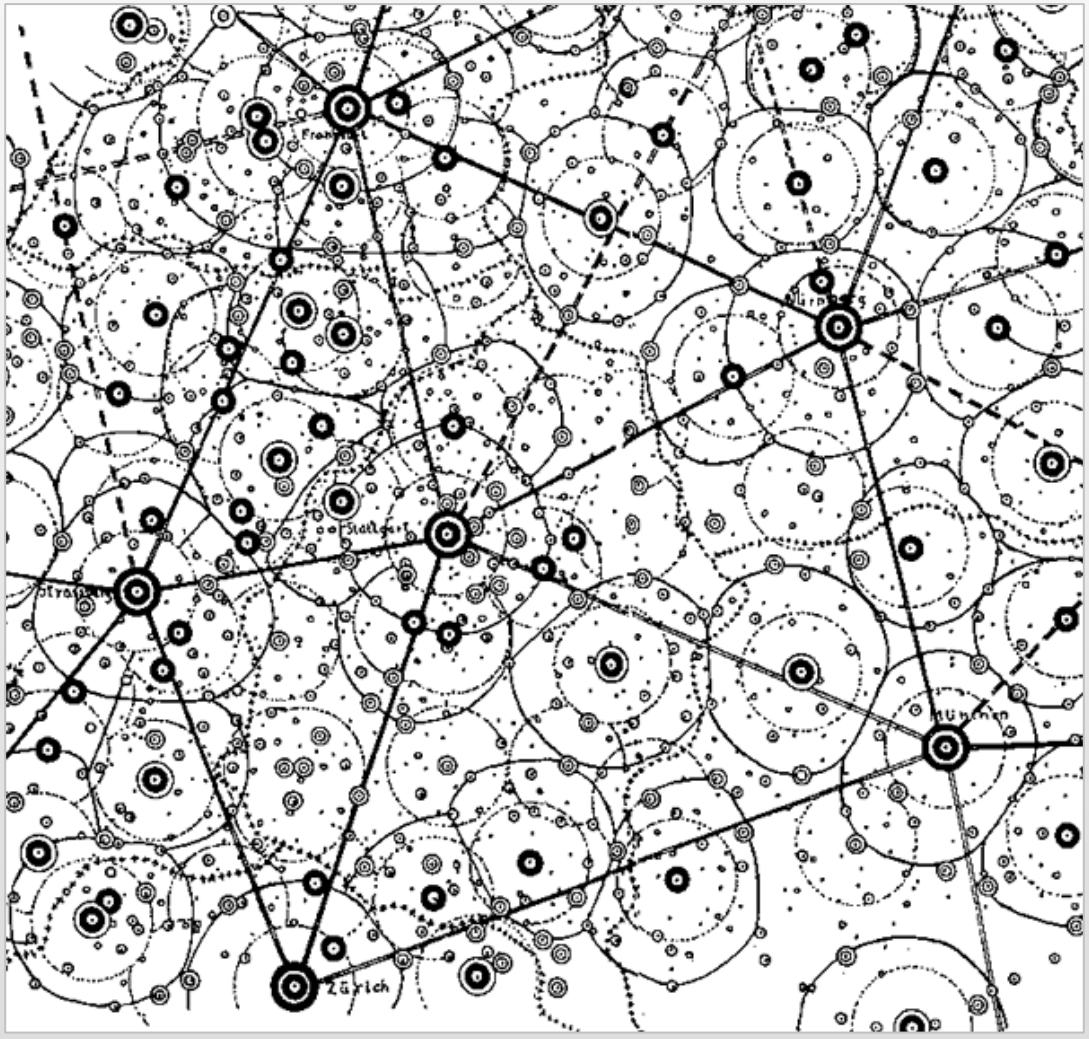


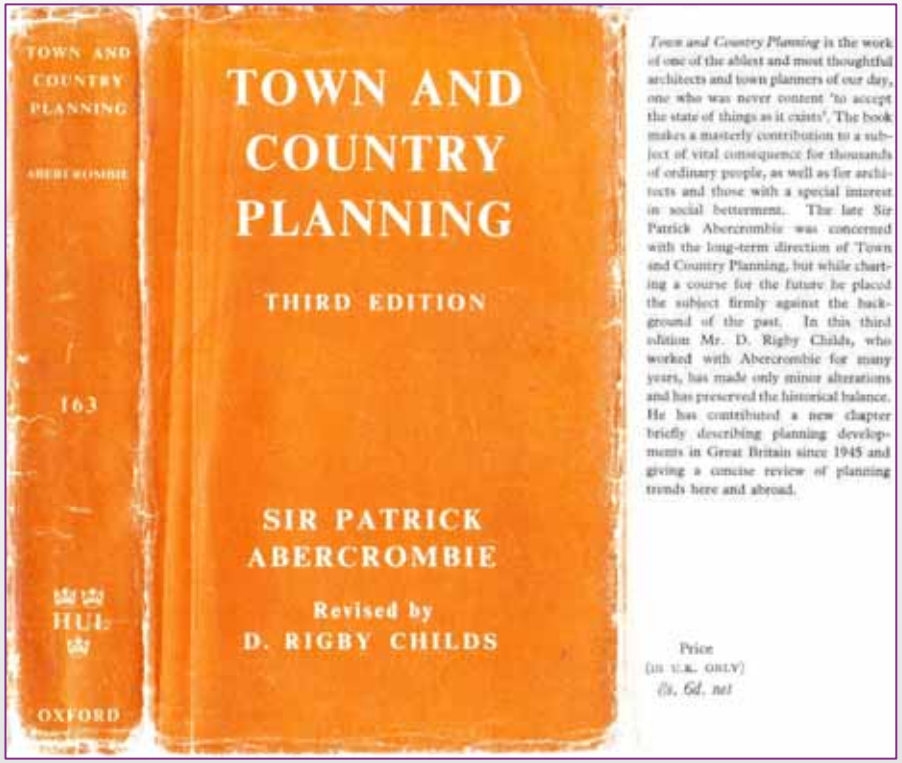






Throwing Out the Planarity

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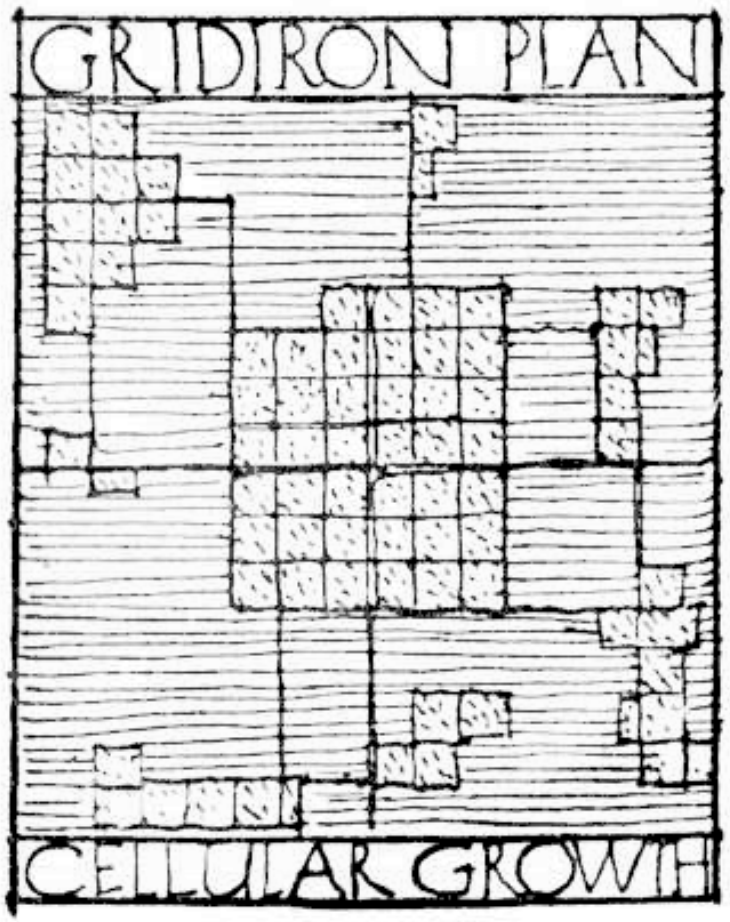

GRIDIRON PLAN
CELLULAR GROWTH

FIG. 1.

Historical Examples – from Abercrombie's book **Town and Country Planning** (1935)

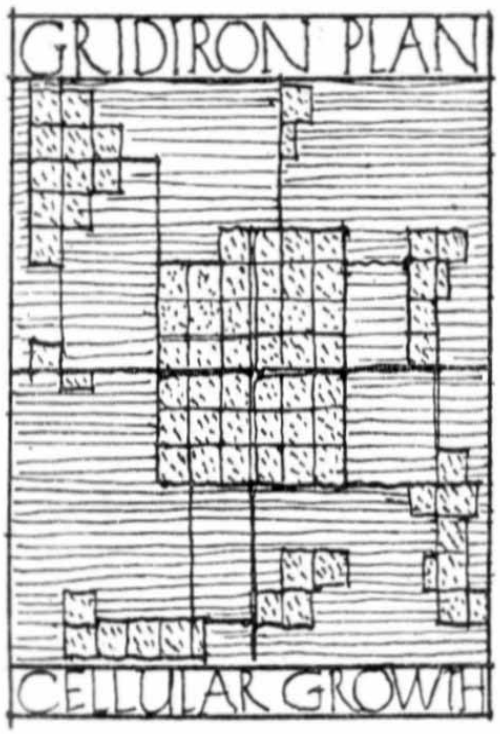


FIG. 1.

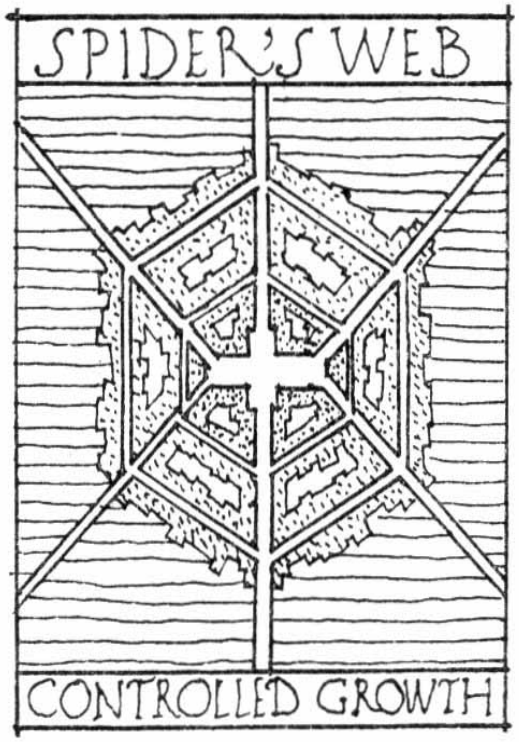


FIG. 3.

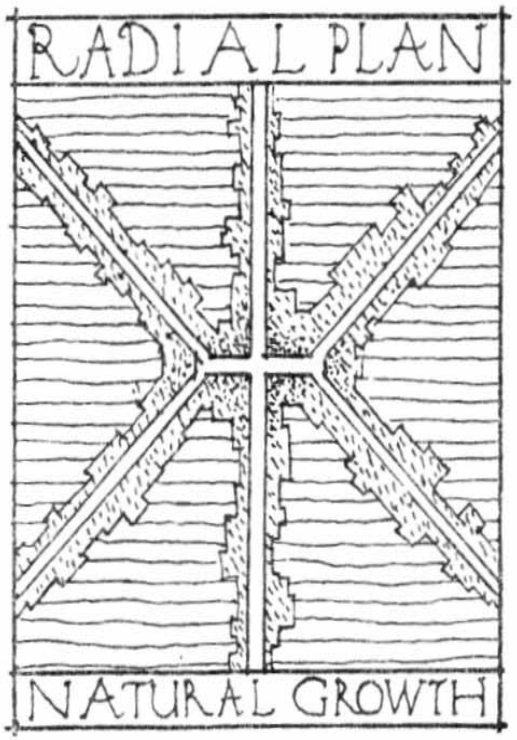
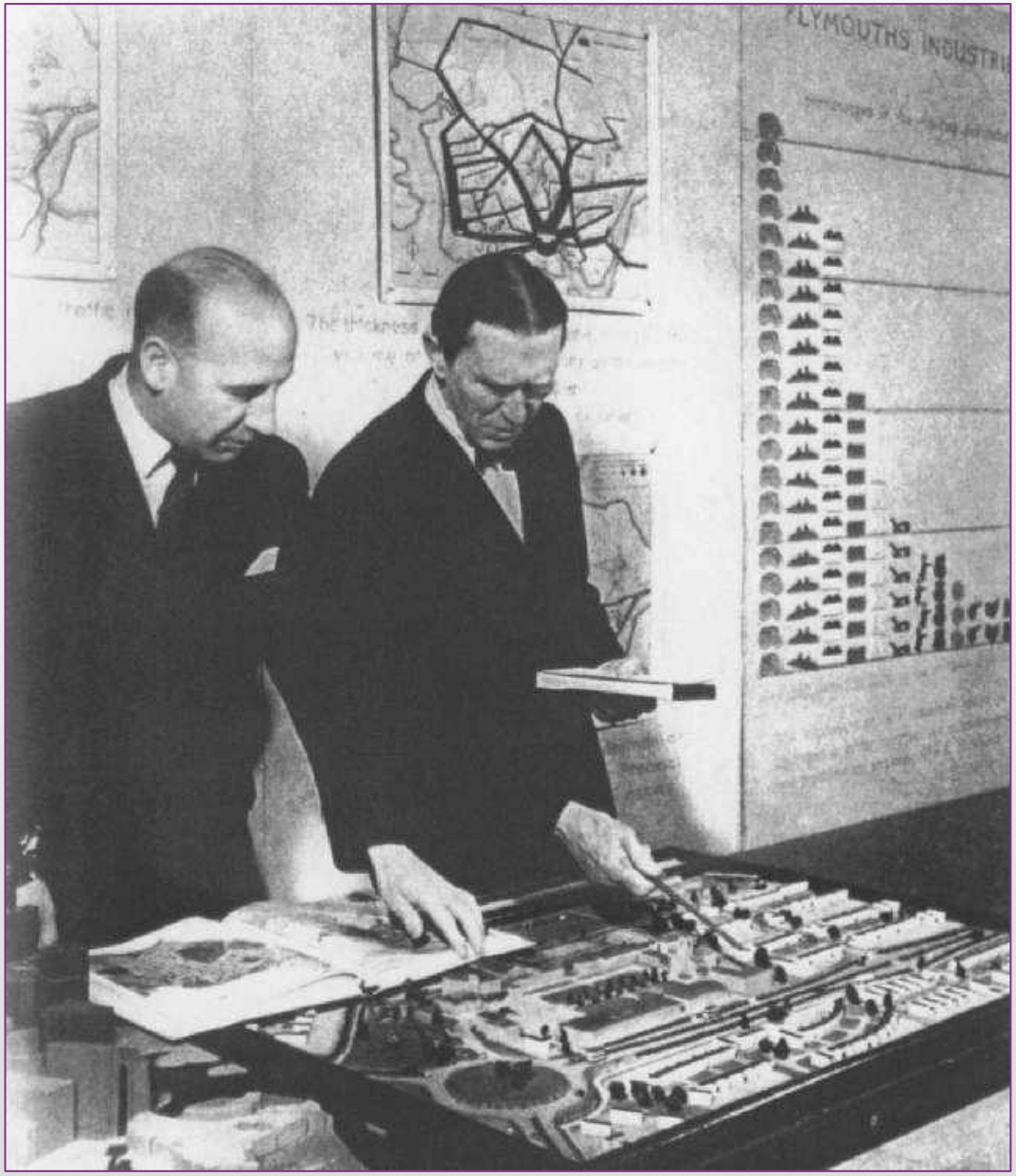
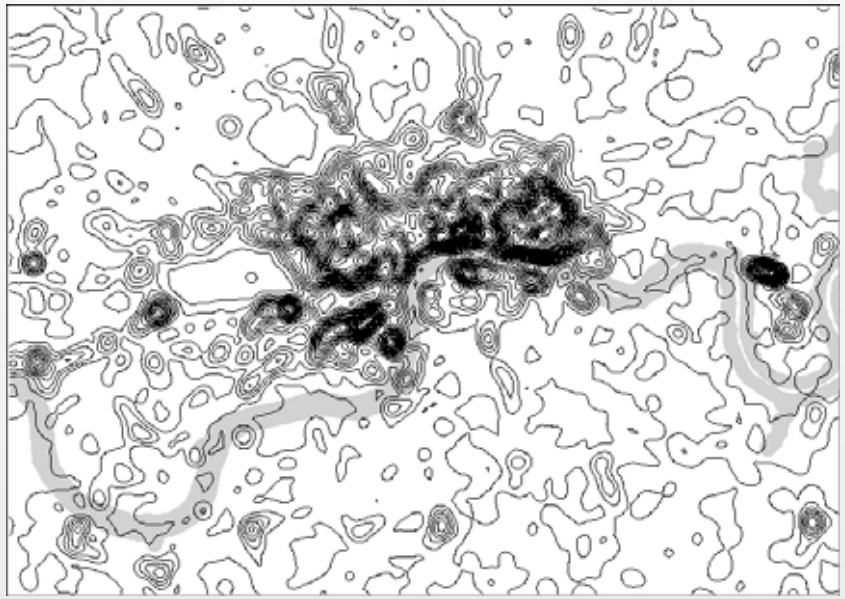


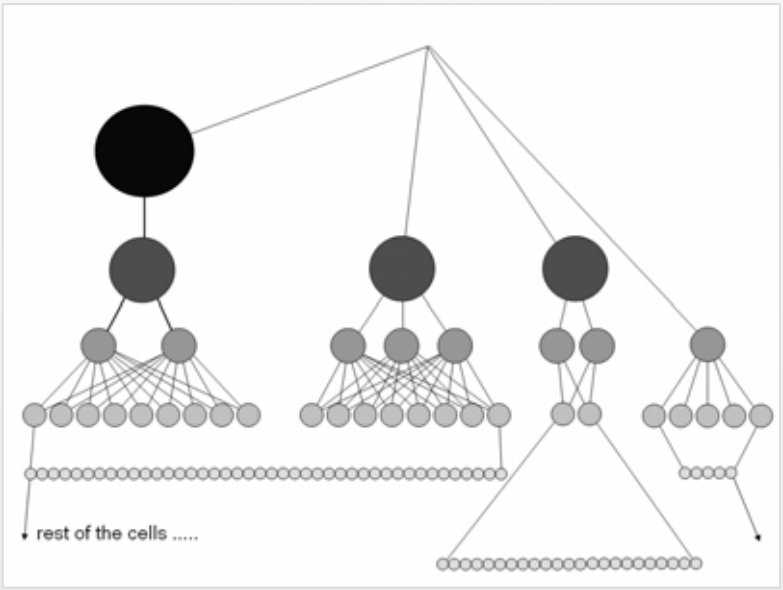
FIG. 2.



Note the flow of traffic and the pictogram – or histogram of employment.

Essential science supporting the physical plan

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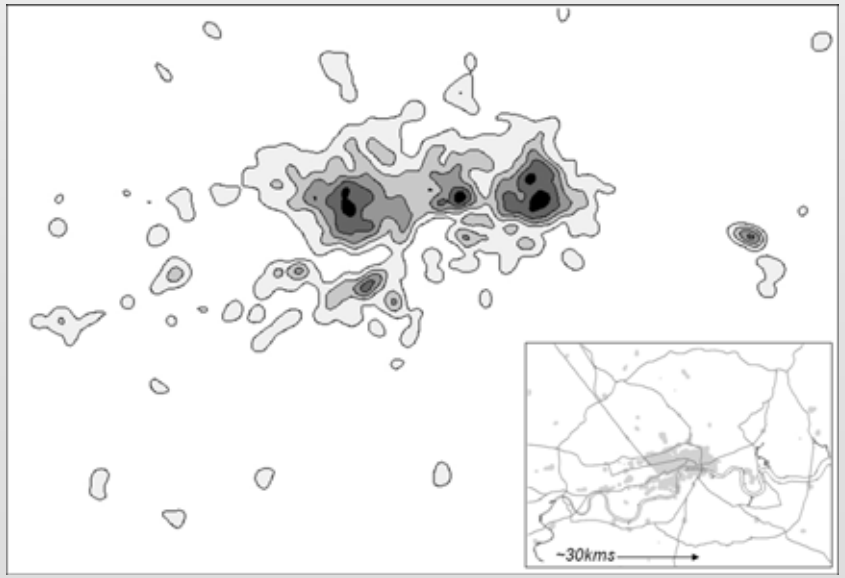
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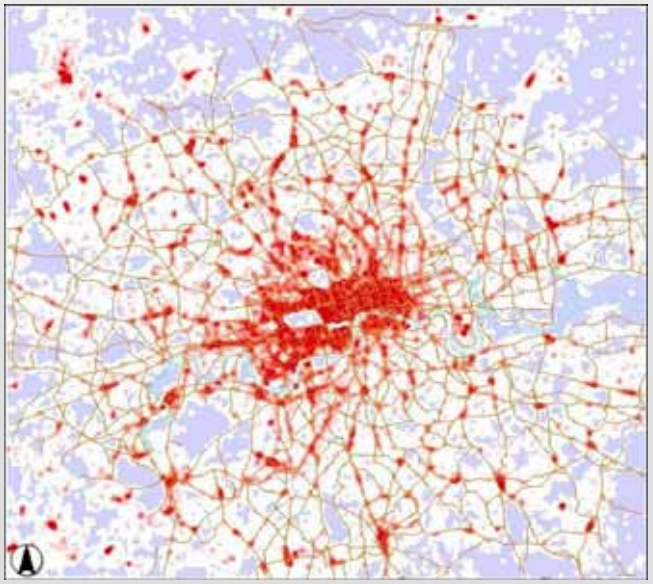
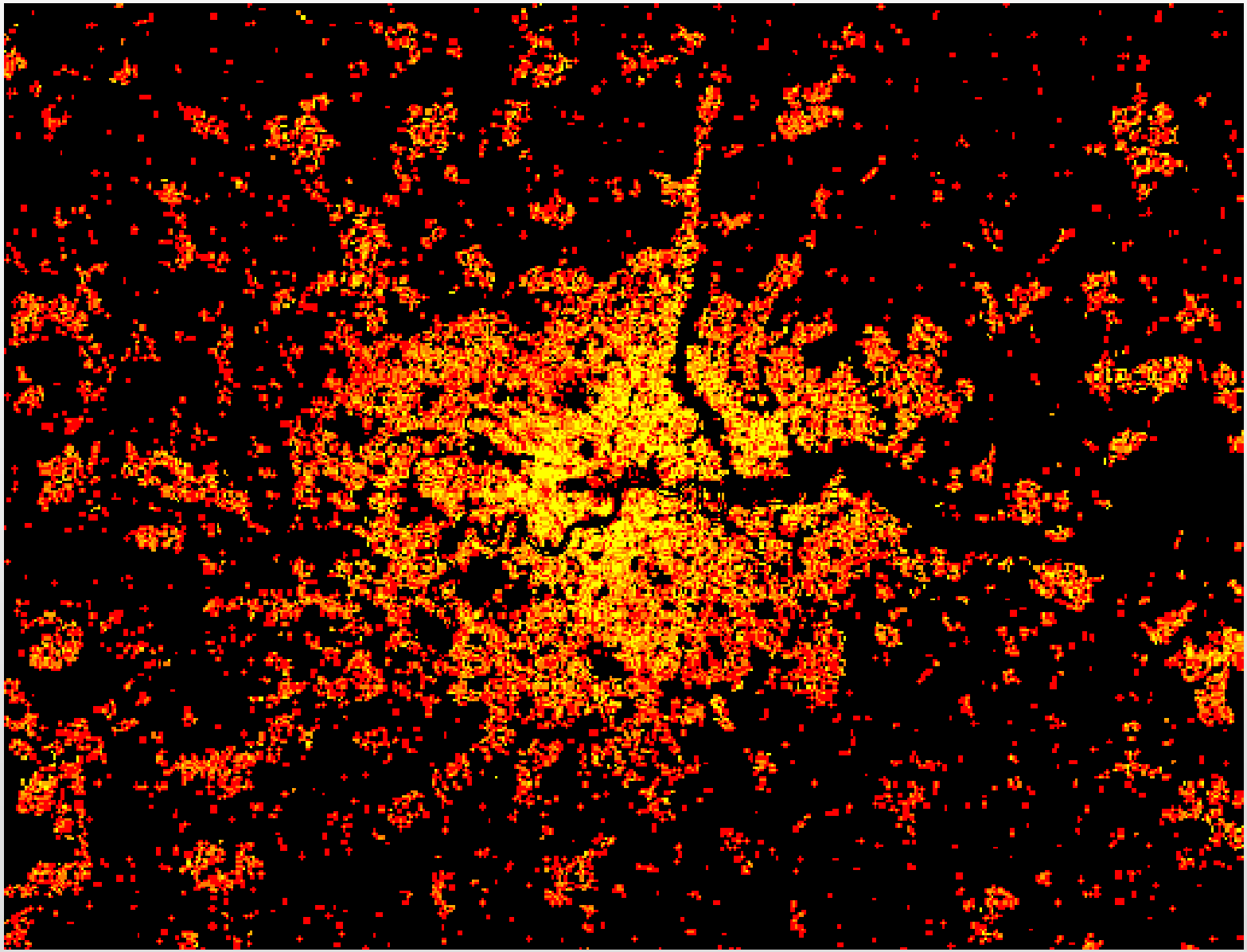
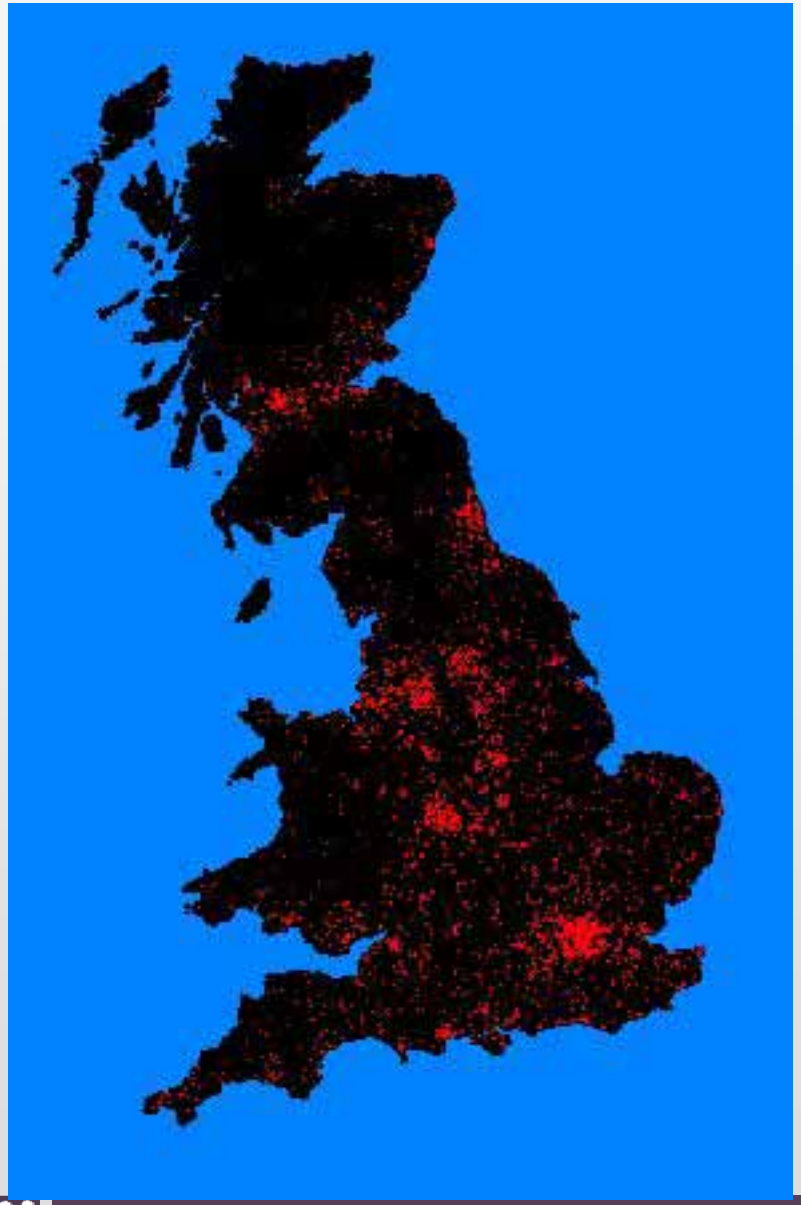
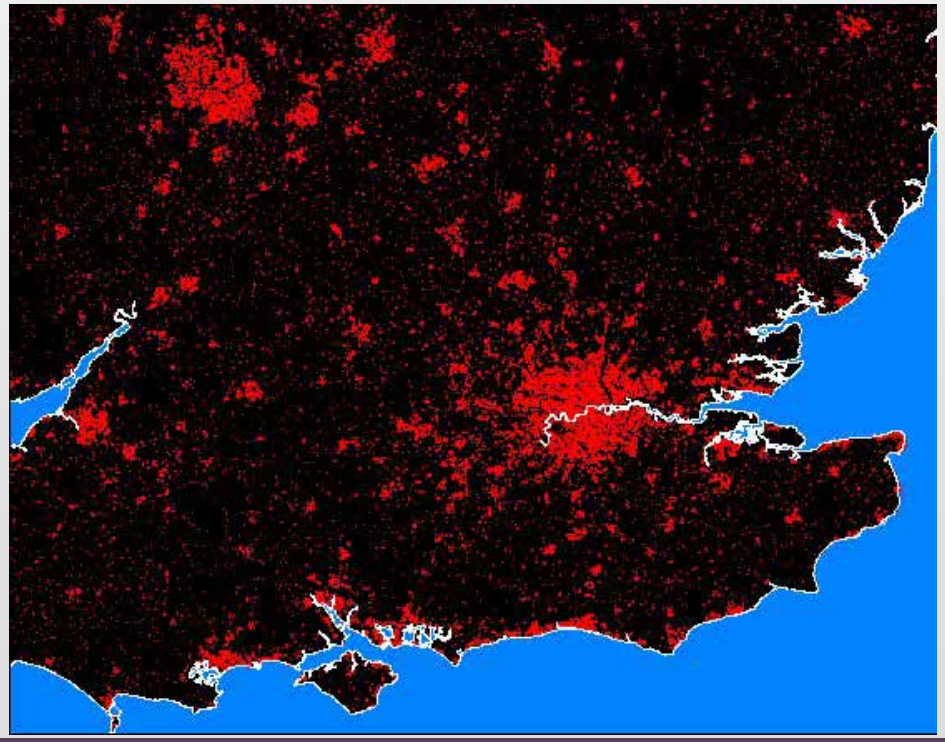
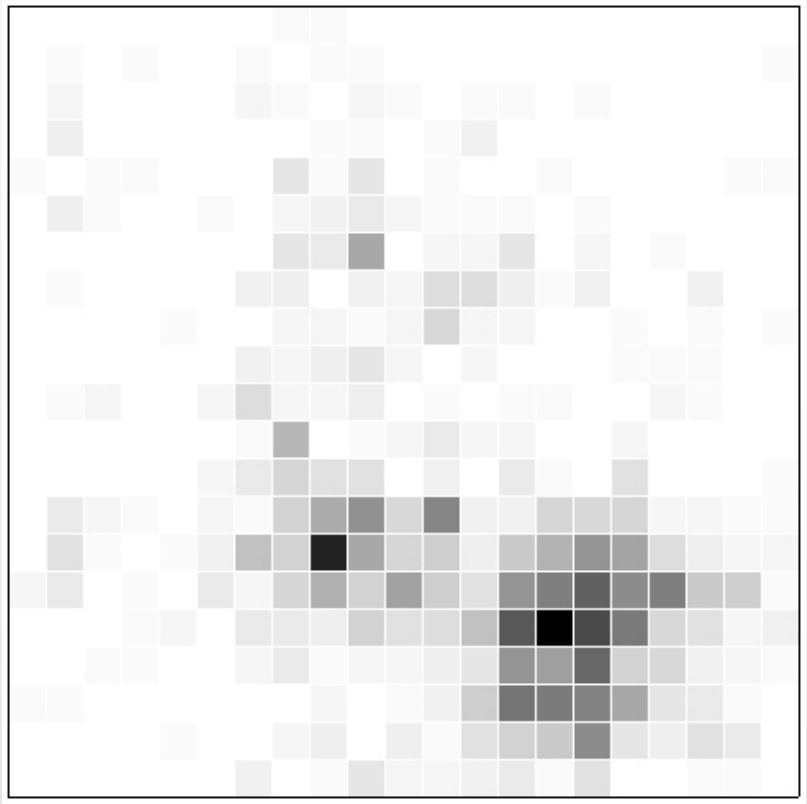


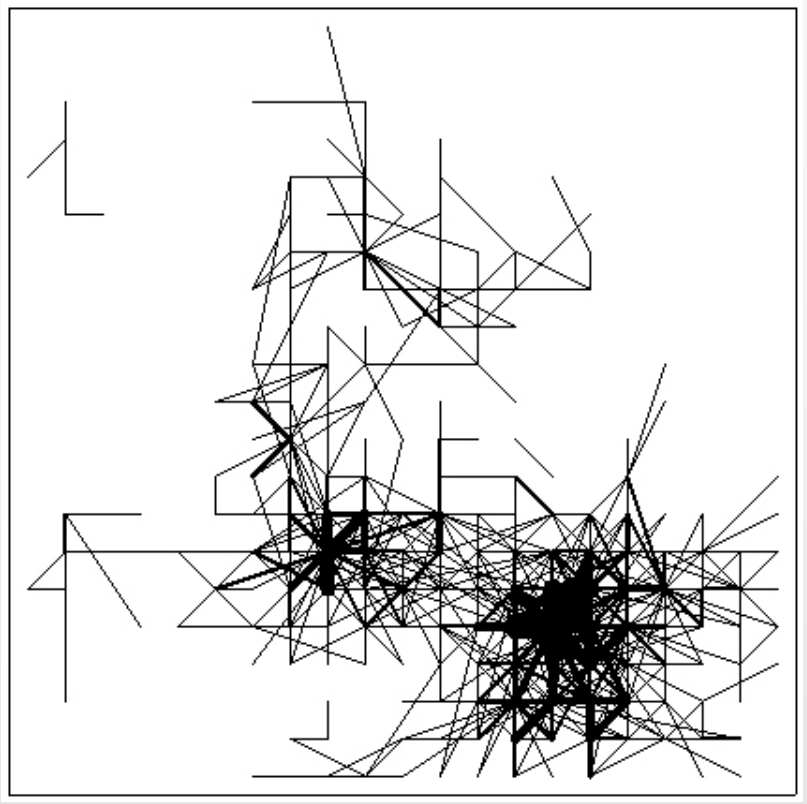


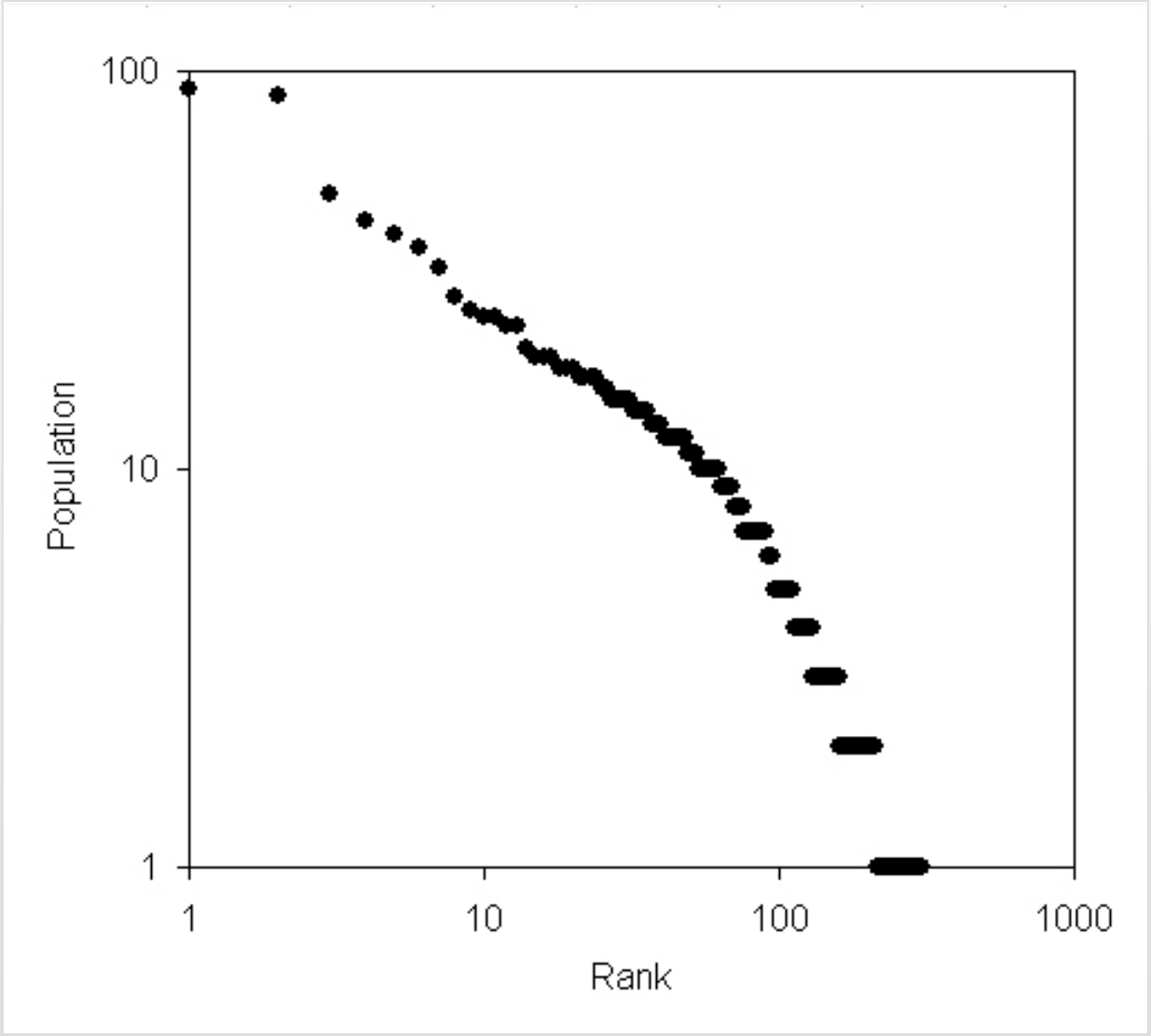


These clusters scale geometrically and their organization is ‘fractal’. This is fractal geometry where objects of the same shape exist at all scales



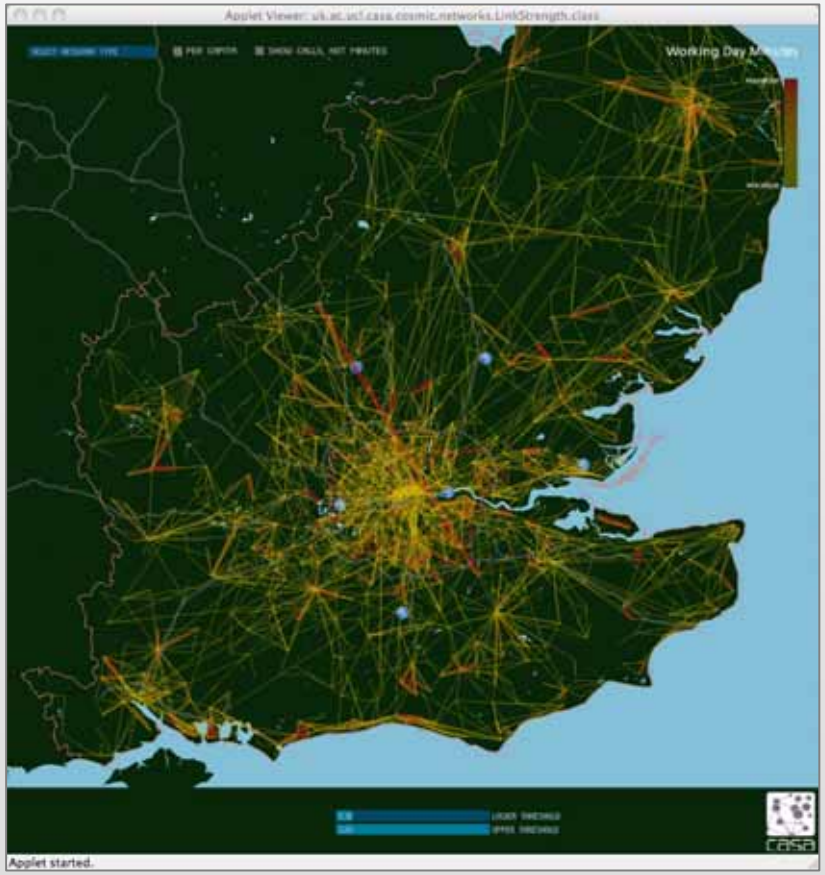


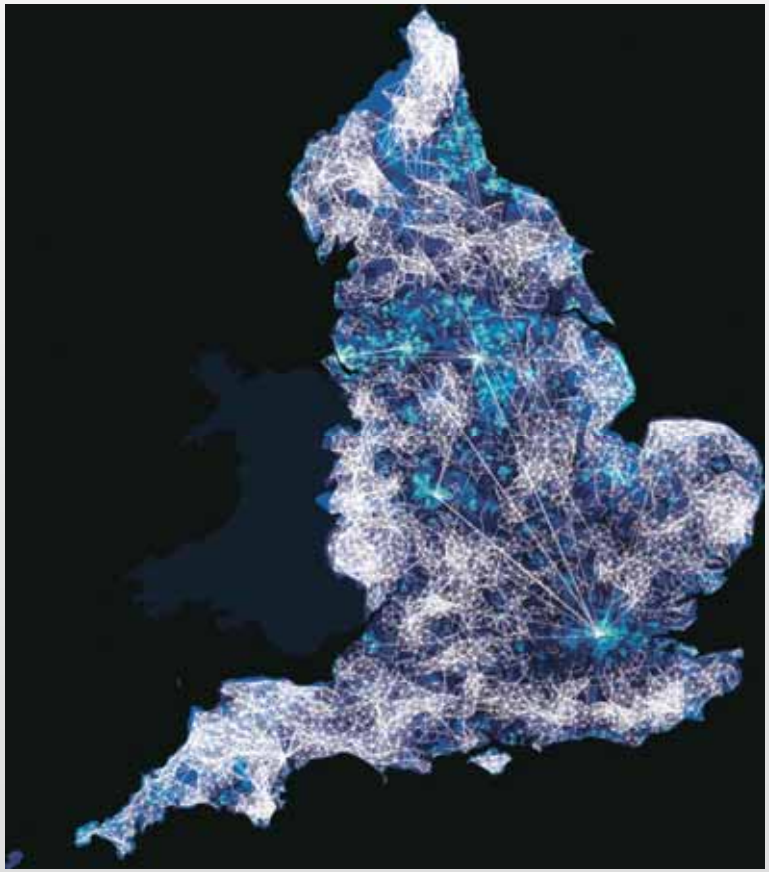



100
10
1
Population
1
10
100
1000
Rank

Network Data in the COSMIC project

CASA Telecoms – see article in PLoS ONE Wednesday this week





CASA Subway Data – London Tube, and London data generally

See forthcoming paper in PLoS ONE

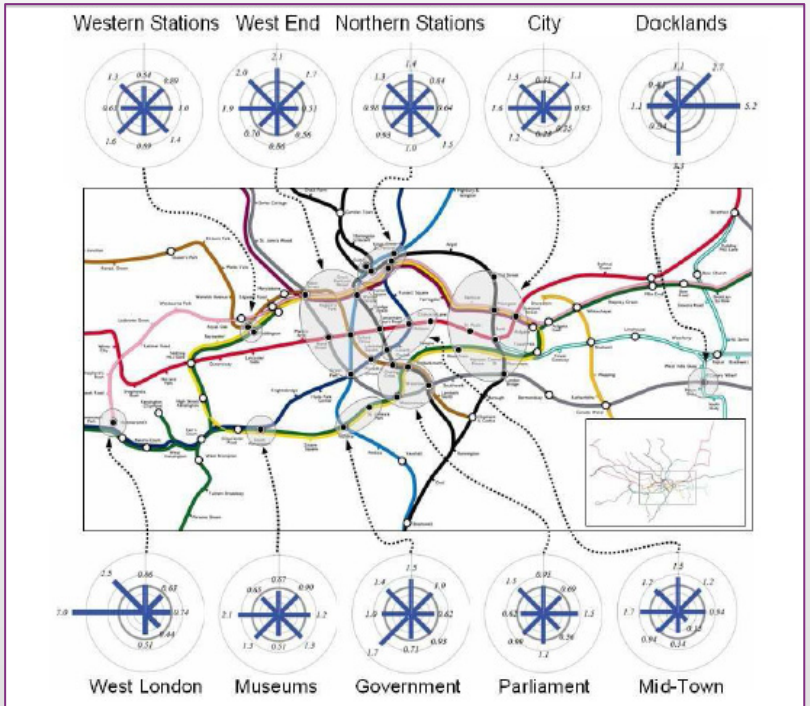
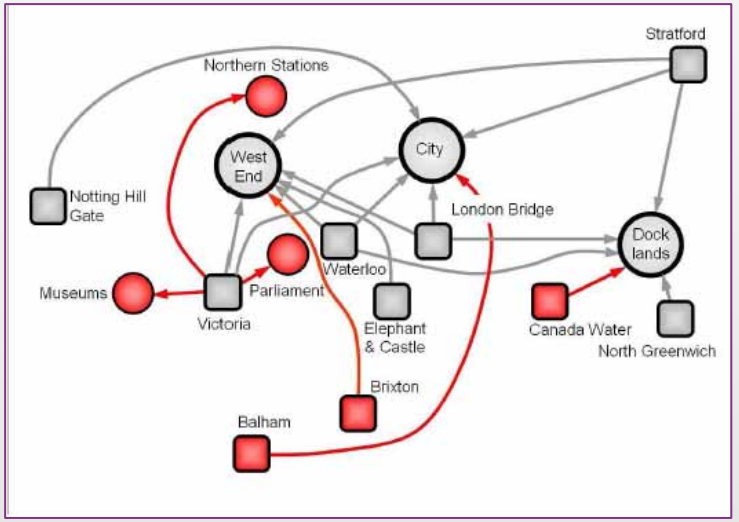
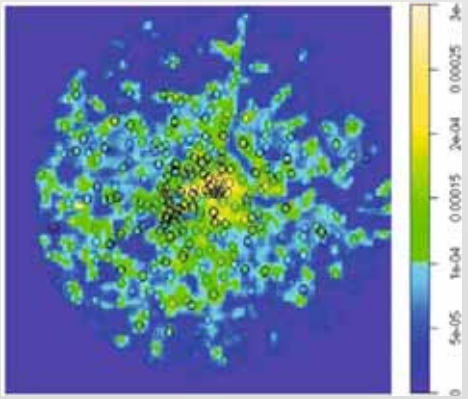
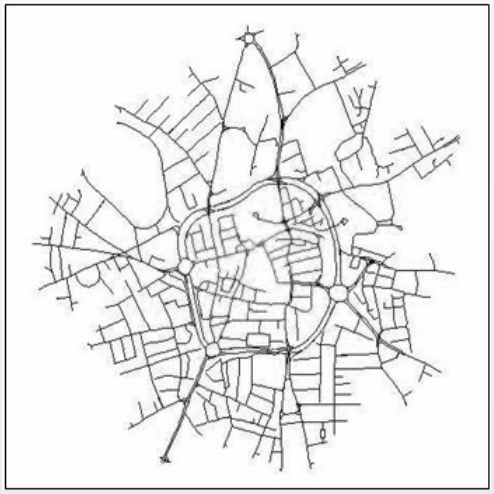
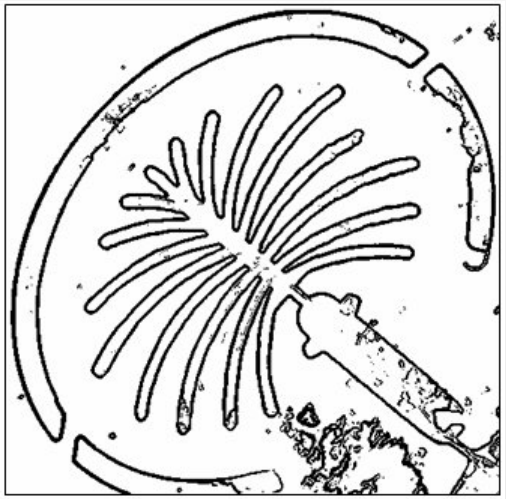


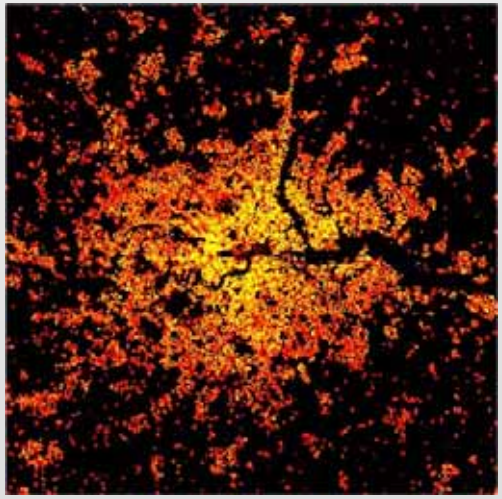
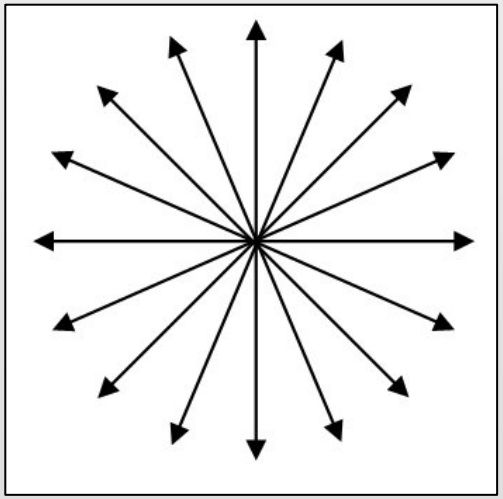
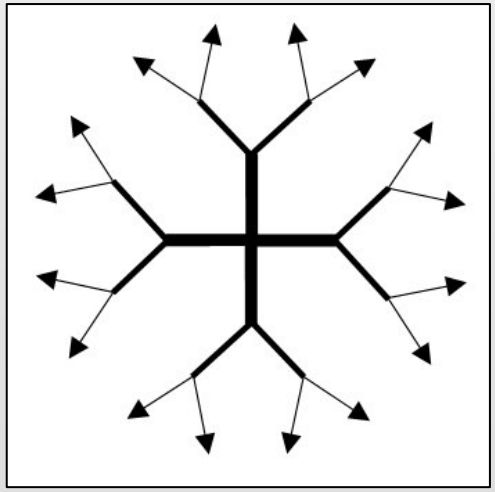
Figure 4. The London subway (tube) system: polycenters and basins of attraction. In the inset, we show the entire tube network while in the main figure, we zoom in on the central part of London. We represent the ten most important polycenters defined in the dendrogram of Figure 3, and show the corresponding propensity to anisotropy comparing actual flows with the null model defined in the text. A propensity of 1 means that there is no deviation in a given direction with respect to the null model. Circles correspond to various levels of identical propensity values: the thicker circle in the middle corresponds to 1, inner circles correspond to propensities of 0.2 and 0.5, and outer circles to 2 and 5. The anisotropy is essentially in opposite directions from the center, thus showing a strong bias towards the suburbs for peripheral centers essentially, rather than for central centers. Moreover, most stations control their own regions and seem to have their own distinctive basins of attraction.

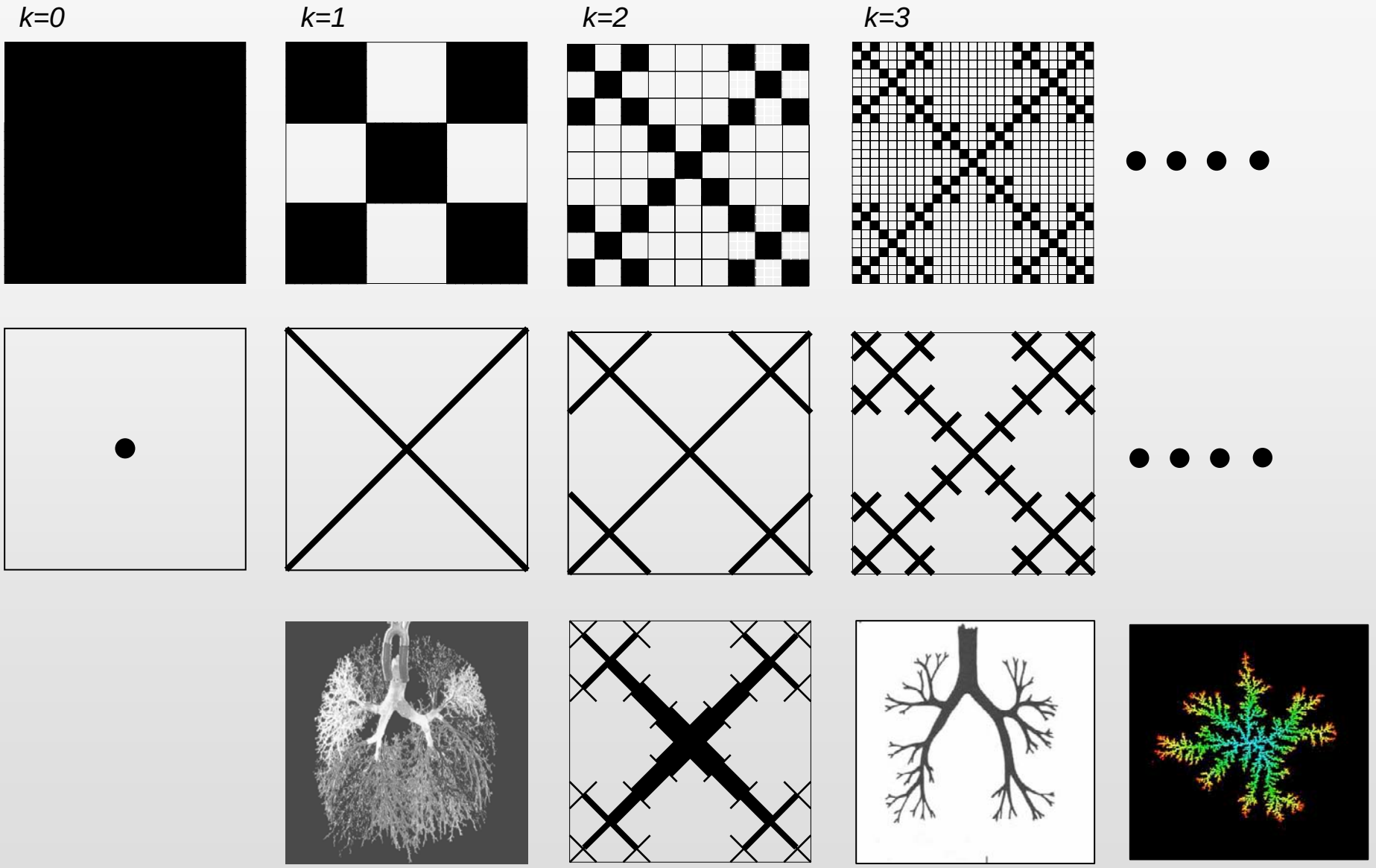




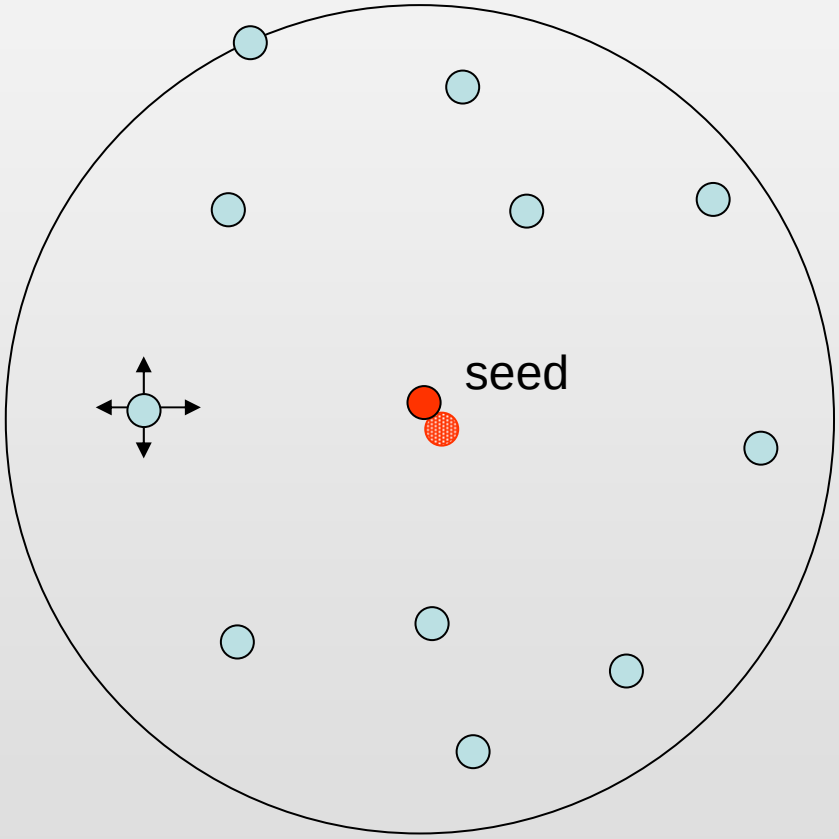
Growing Networks

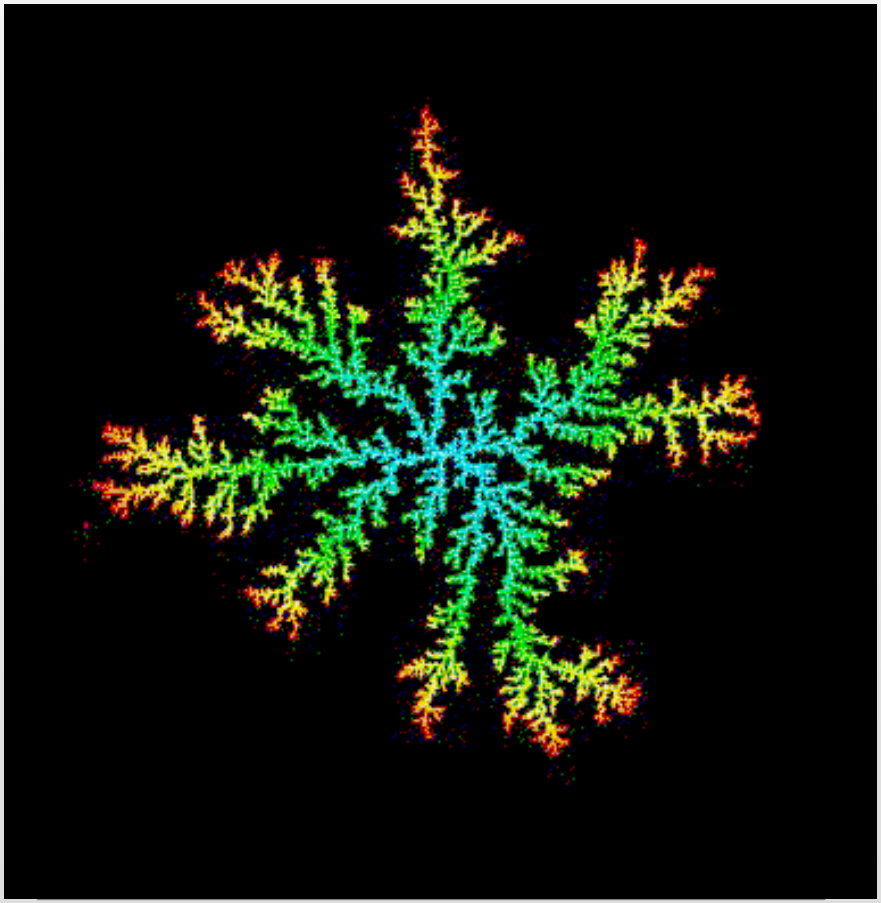



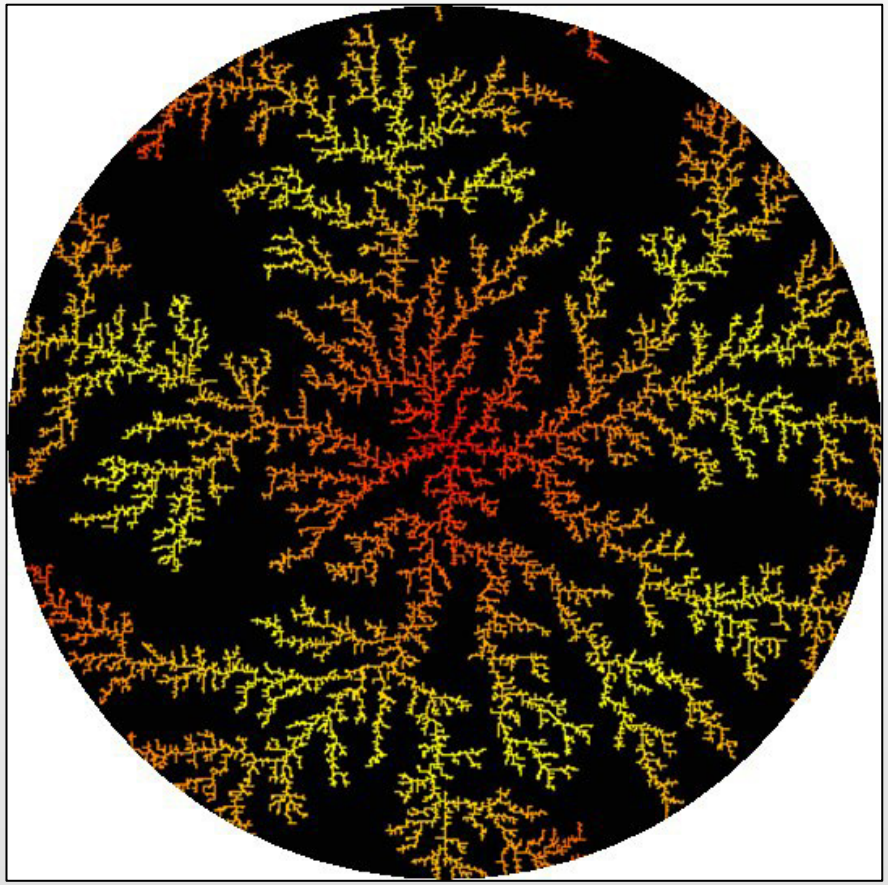




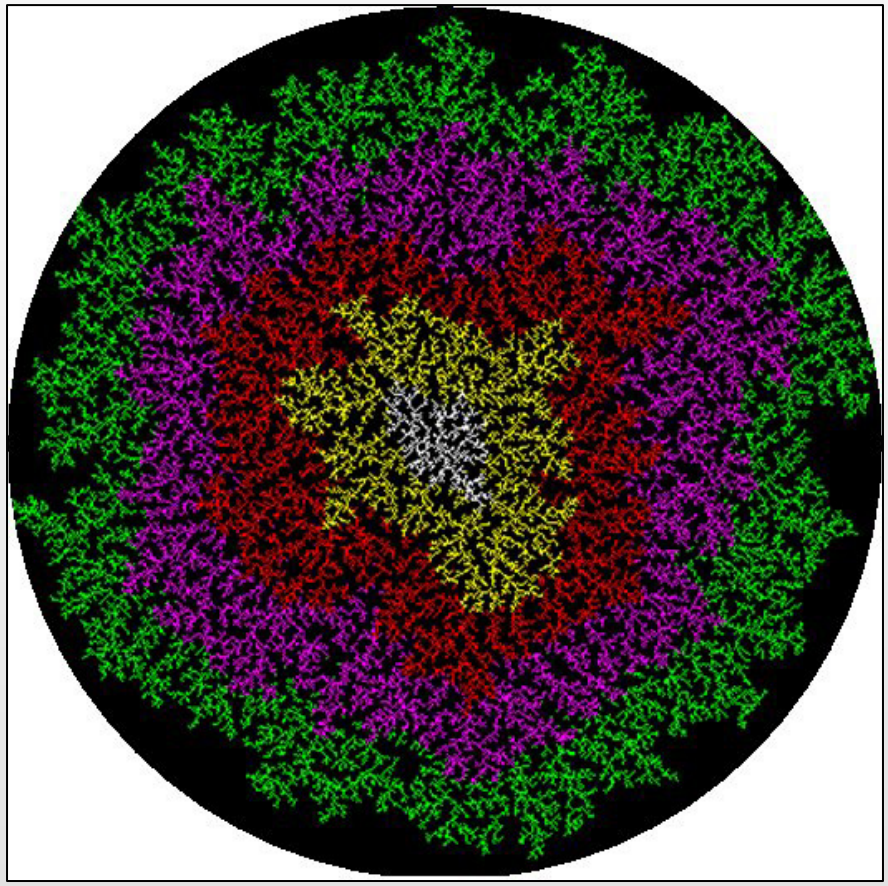

k=0
k=1
k=2
k=3

In essence, this is random walk in space which is can be likened to the diffusion of particles ○ around a source ● but limited to remain within the influence of the source – the city









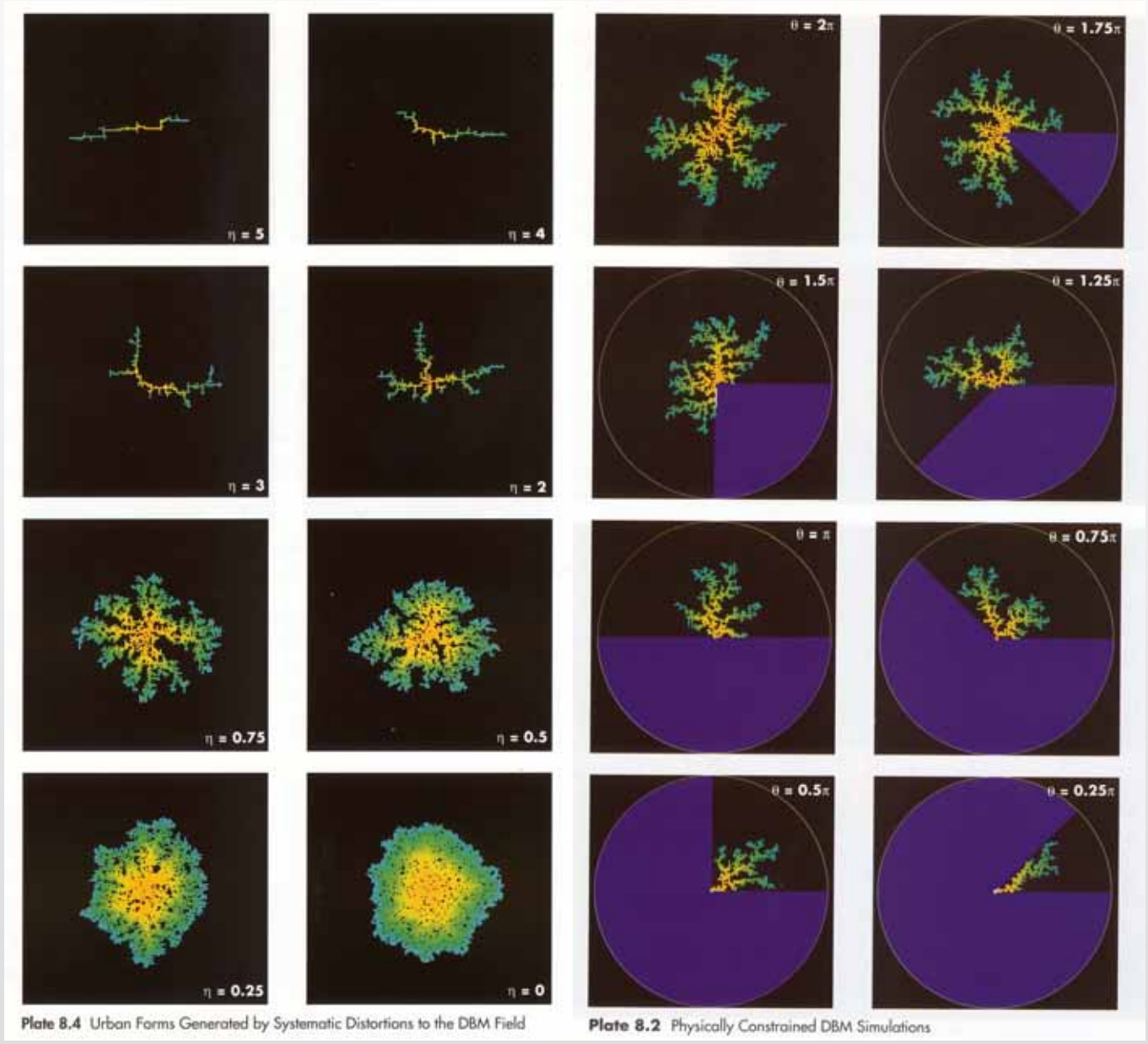


Plate 8.4 Urban Forms Generated by Systematic Distortions to the DBM Field

Plate 8.2 Physically Constrained DBM Simulations

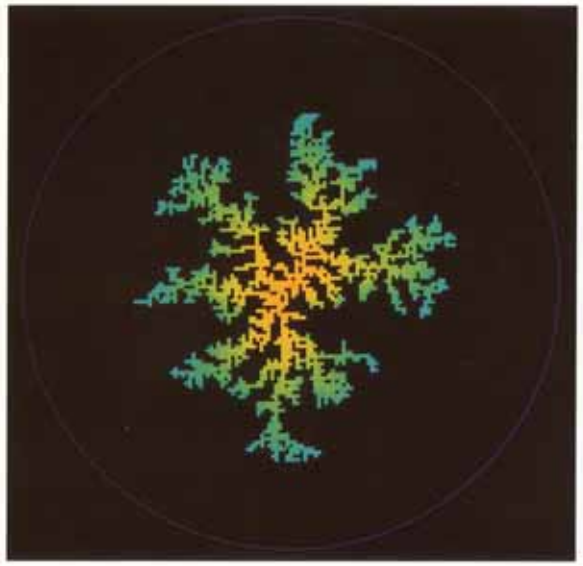
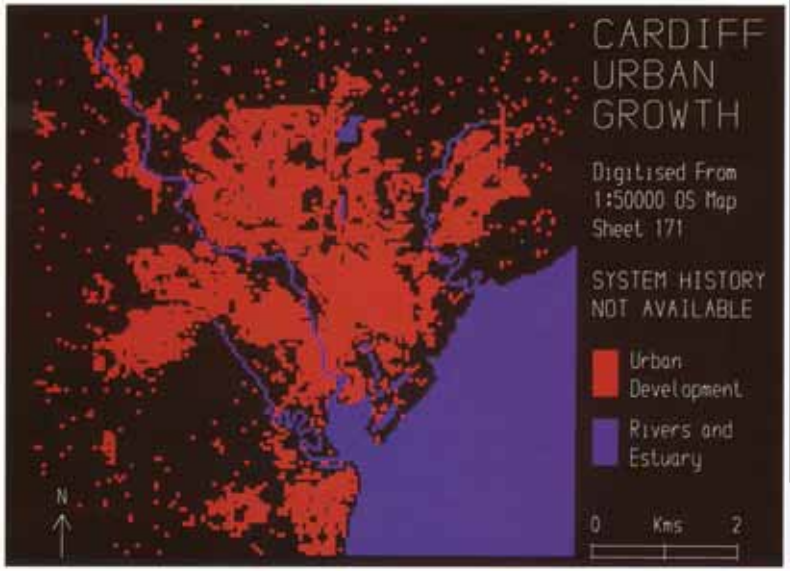


Plate 8.3 *(left)* The Baseline Simulation η =

Plate 8.5 *(below)* The Urban Area of Cardiff.



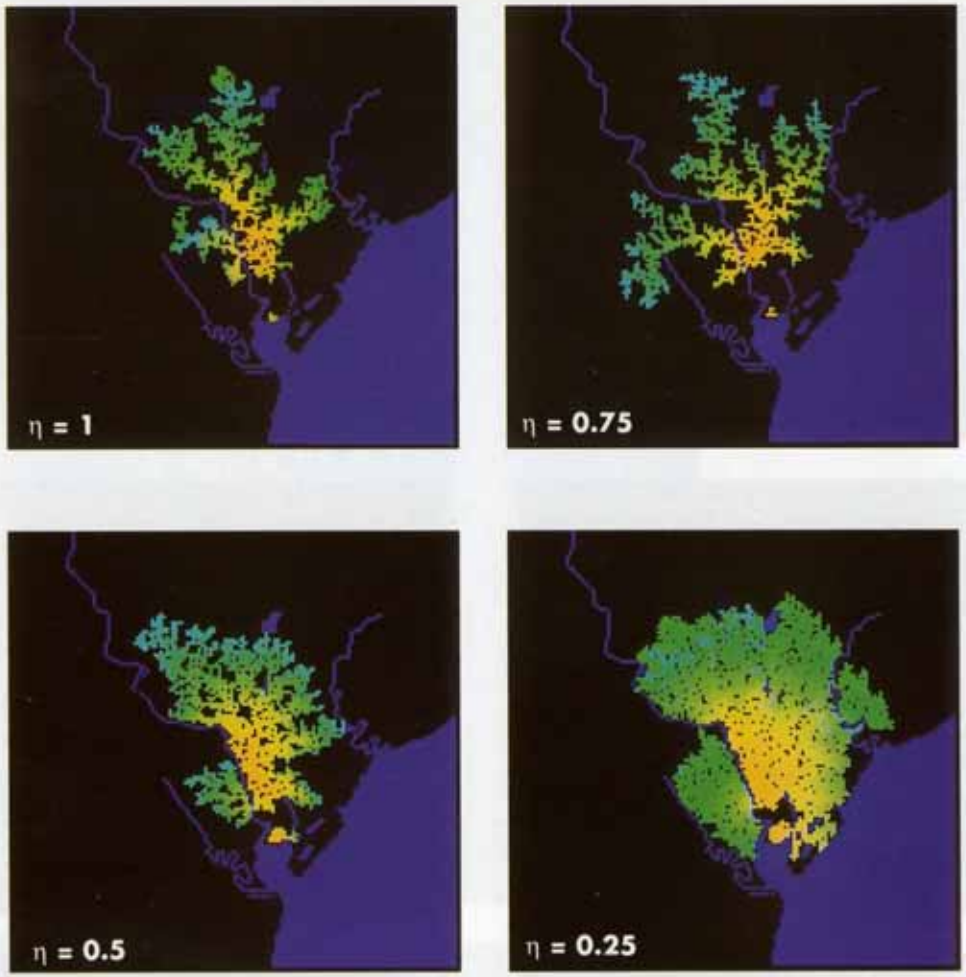


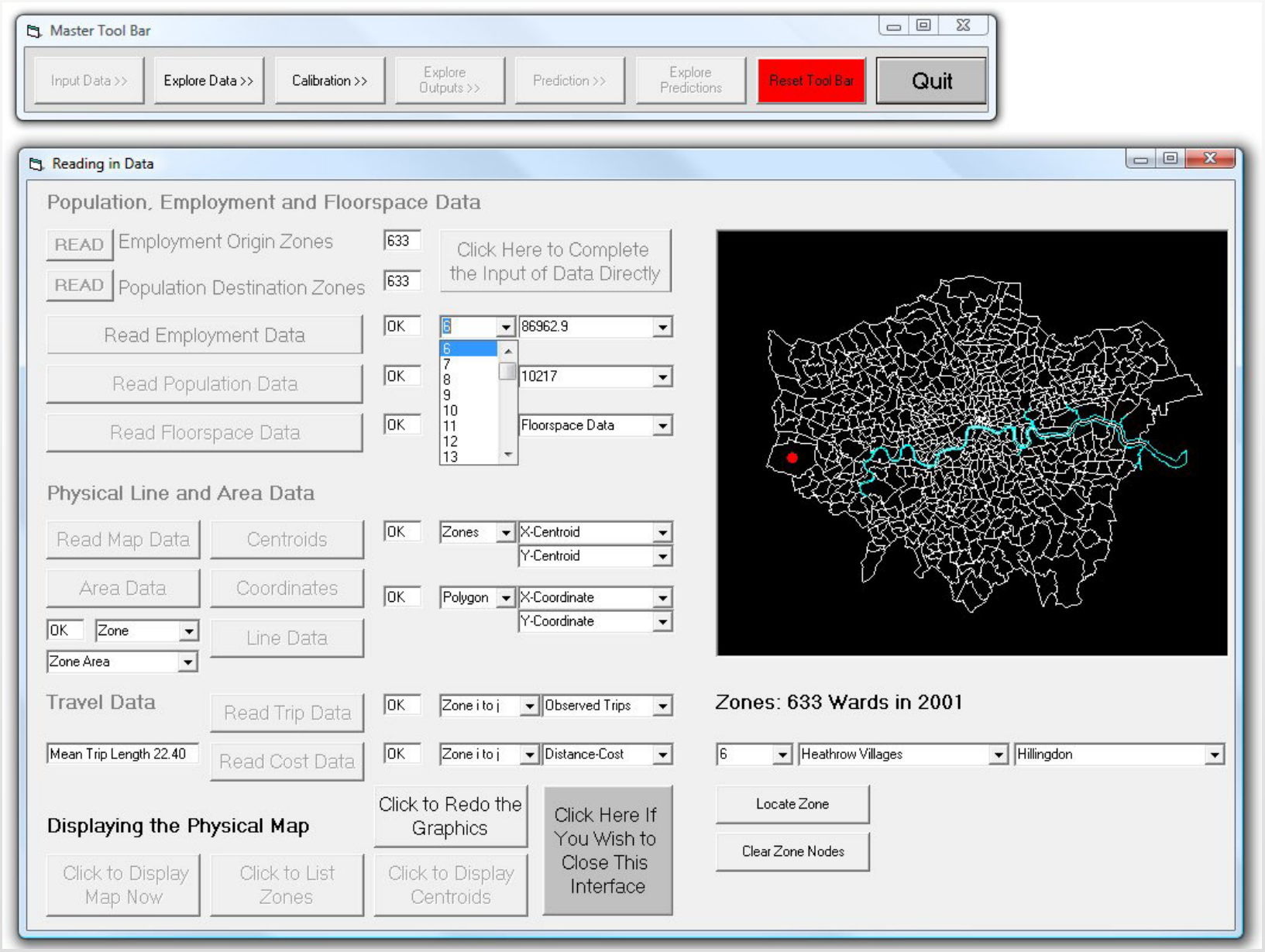
Plate 8.6 Simulating the Urban Growth of Cardiff

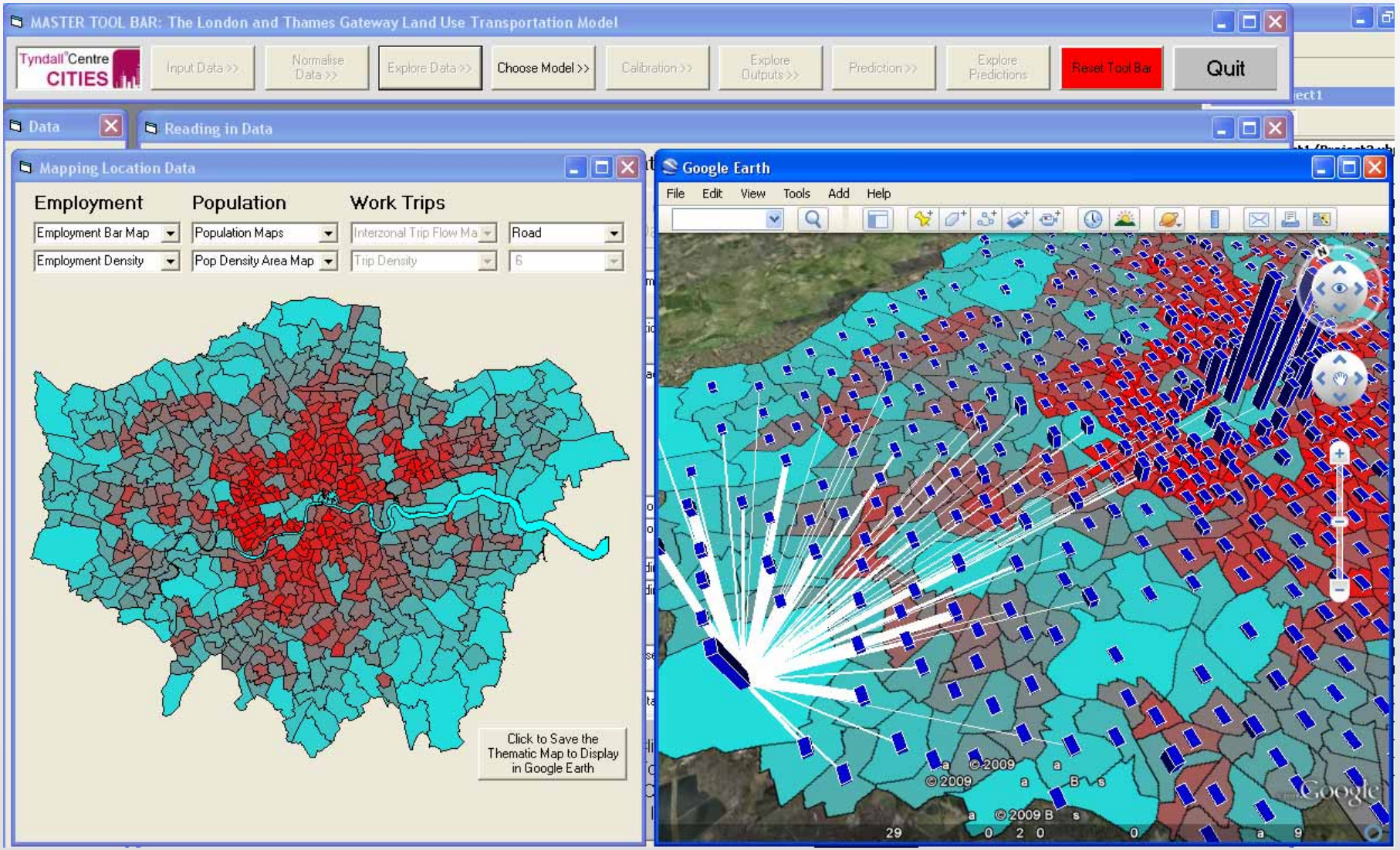
Flows on Networks: Scale Again – Local to Global

There is an enormous amount of work on spatial interactio, largely separated from the underlying networks but conceived in terms of gravitational models – which lie at the origins of social physics

Many of these models are being developed in our group and I simply illustrate some snaps from our London land use transport model that we have built for the Tyndall Centre Climate Change Cities project

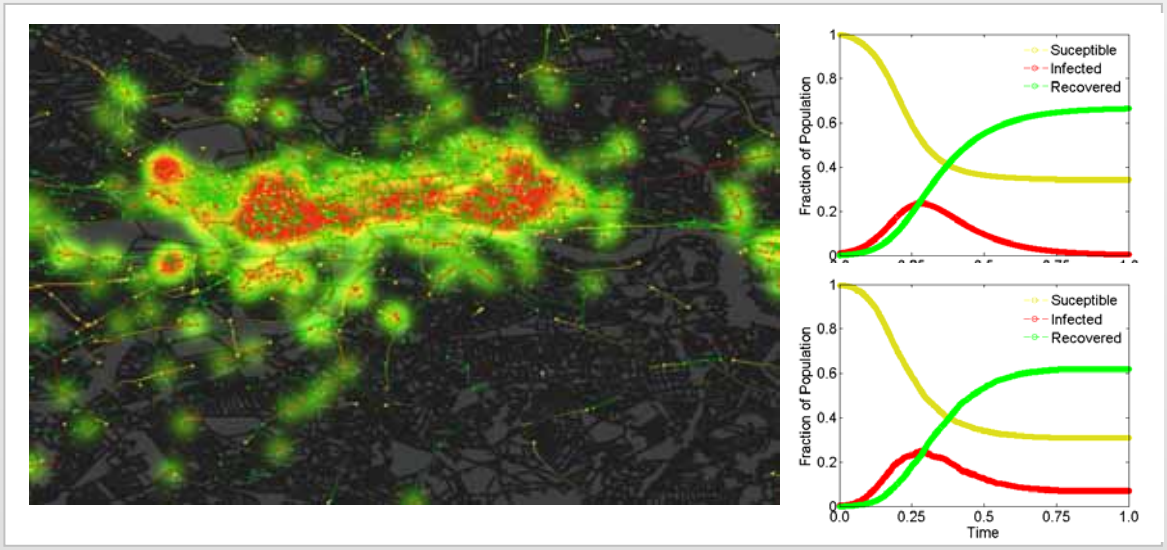
These models predict flows on fixed networks – which we have seen earlier for London


Master Tool Bar
Input Data >>
Explore Data >>
Calibration >>
Explore Outputs >>
Prediction >>
Explore Predictions
Reset Tool Bar
Quit
Reading in Data
Population, Employment and Floorspace Data
READ
Employment Origin Zones
633
READ
Population Destination Zones
633
Click Here to Complete the Input of Data Directly
Read Employment Data
OK
6
86962.9
6
7
8
9
10
11
12
13
Read Population Data
OK
10217
Read Floorspace Data
OK
Floorspace Data
Physical Line and Area Data
Read Map Data
Centroids
OK
Zones
X-Centroid
Y-Centroid
Area Data
Coordinates
OK
Polygon
X-Coordinate
Y-Coordinate
OK
Zone
Line Data
Zone Area
Travel Data
Read Trip Data
OK
Zone i to j
Observed Trips
Mean Trip Length 22.40
Read Cost Data
OK
Zone i to j
Distance-Cost
Zones: 633 Wards in 2001
6
Heathrow Villages
Hillingdon
Displaying the Physical Map
Click to Redo the Graphics
Click Here If You Wish to Close This Interface
Locate Zone
Clear Zone Nodes
Click to Display Map Now
Click to List Zones
Click to Display Centroids

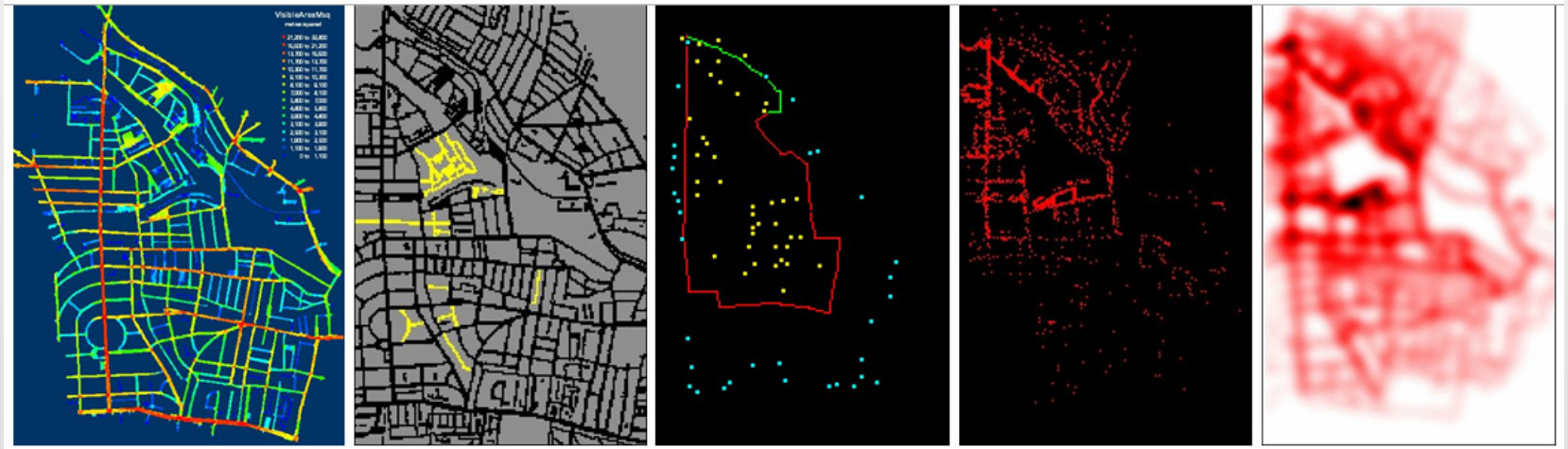

MASTER TOOL BAR: The London and Thames Gateway Land Use Transportation Model
Tyndall Centre CITIES
Input Data >>
Normalise Data >>
Explore Data >>
Choose Model >>
Calibration >>
Explore Outputs >>
Prediction >>
Explore Predictions
Reset Tool Bar
Quit
Data
Reading in Data
Mapping Location Data
Employment
Population
Work Trips
Employment Bar Map
Employment Density
Population Maps
Pop Density Area Map
Interzonal Trip Flow Ma
Trip Density
Road
6
Click to Save the Thematic Map to Display in Google Earth
Google Earth
File
Edit
View
Tools
Add
Help
©2009
Google

The Mathematics and Beyond

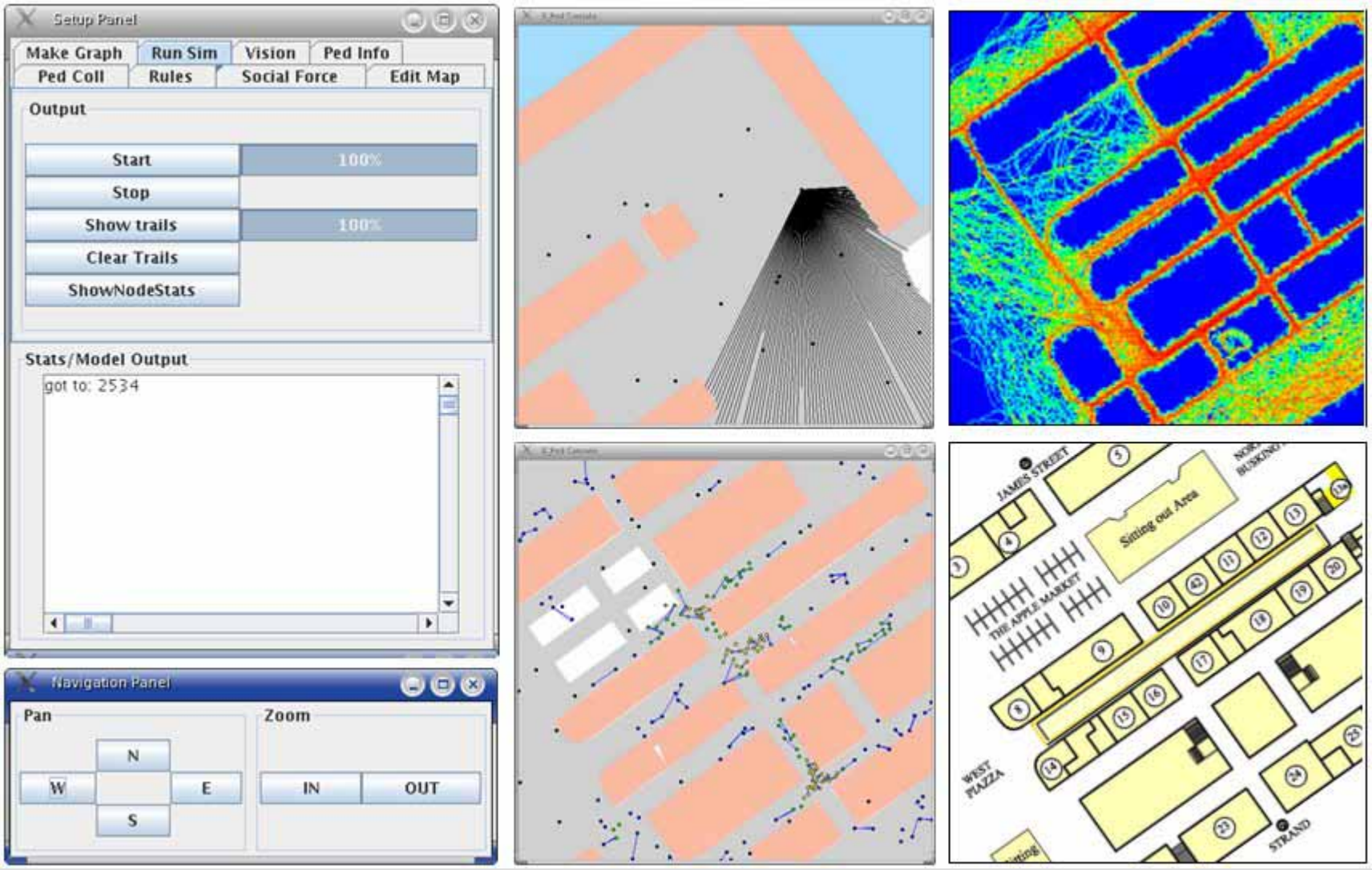
Basically we are building various models of processes on such networks – we want to develop some diffusion models of disease on networks, like the spread of the common cold in enclosed transportation spaces – like the tube.



http://www.ajohansson.com/london_epidemics.avi



Above: Crowd Scenes and Emergency Vehicles at Hajj and in Notting Hill: Below: Our ABM of the Notting Hill Carnival



John Ward's ABM of Tourists & Shoppers in Covent Garden

My Indulgent and Final Example

London Bikes Project

Scraping Data: The London Bikes Experiment

Locally called Boris's Bikes

4200 bikes, 340 stations, access via online registration or by paying on a credit card at the local bike station – so all online data

City	Official Name	Installed	System	# of Bikes
London	Barclays Cycle Hire	July 2010	Bixi	4,300
Barcelona	Bicing	March 2007	Bikemi	4,200
Milan	Bikemi	December 2008	Bicing	1,100
Saragossa	Bizi	May 2008	Bicing	800
Girona	Girocleta	September 2009	TNT	100
Washington DC and Arlington	Capital Bikeshare	September 2010	Bixi	650
Montreal	Bixi	May 2009	Bixi	4,200
Minneapolis	Nice Ride	June 2010	Bixi	600
Denver	B-cycle	April 2010	B-cycle	350
Melbourne	Bike Share	June 2010	Bixi	400

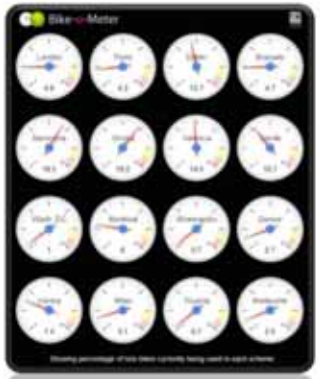
Let's Visualise Them!

```
'id:"([0-9]+?)".*?name:"(.+?)".*?lat:"(.+?)".*?long:"(.+?)".*?nbBikes:"([0-9]+?)".*?
nbEmptyDocks:"([0-9]+?)".*?installed:"(.+?)".*?locked:"(.+?)".*?temporary:"(.+?)".*?'
```

- Obtain the data from the operators' websites
  - Some provide XML/JSON/KML
  - Lots of Regex parsing
  - Velib-based systems require two stages
- Store it for analysis
- Stick it on a map
  - OpenLayers has some nice vector styling for points
  - OpenStreetMap-based background
  - Charts of historical trends via the Google Chart API

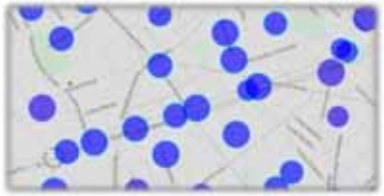
Bike-o-Meter
casa.ucl.ac.uk/bom

- 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 ☺

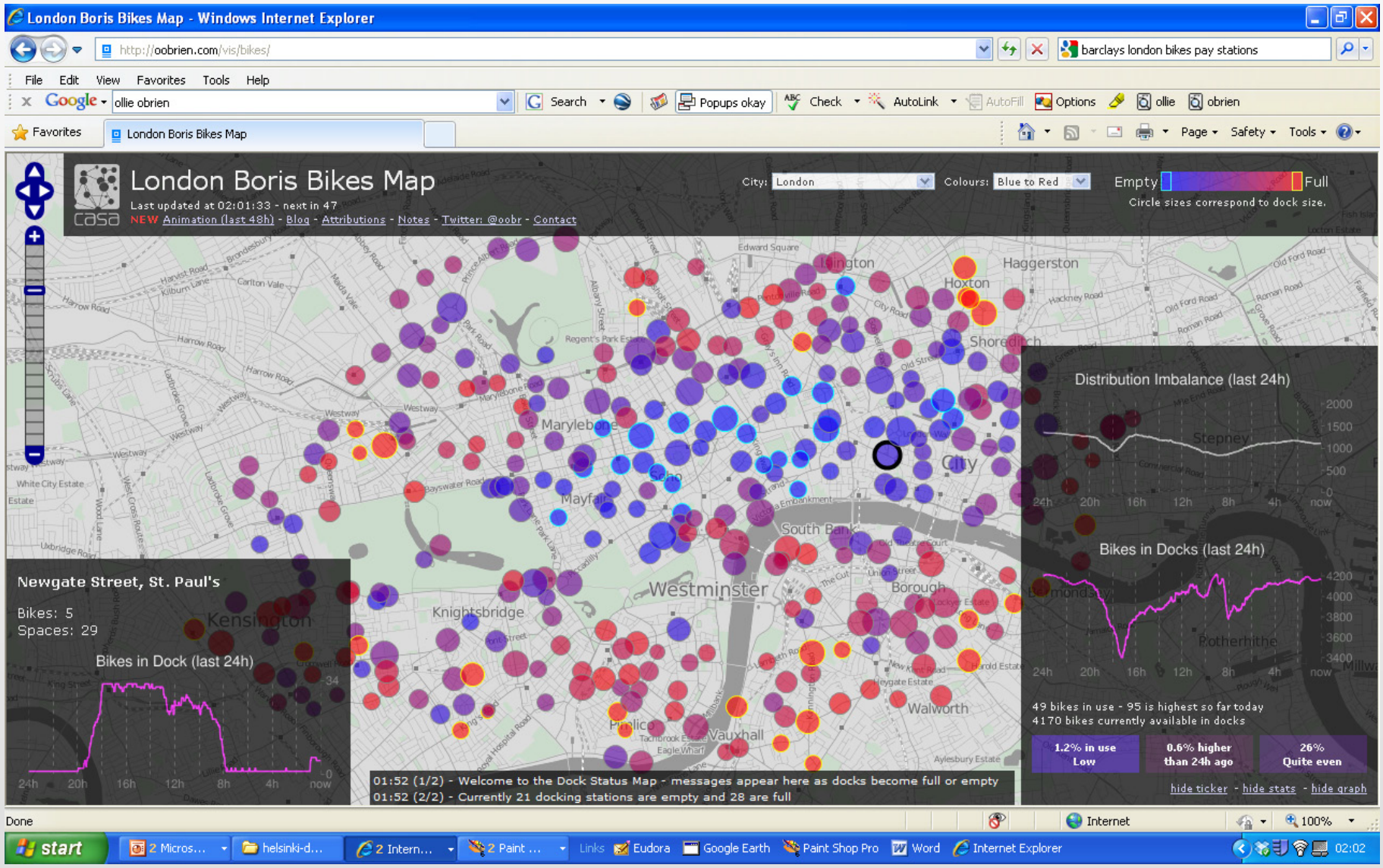


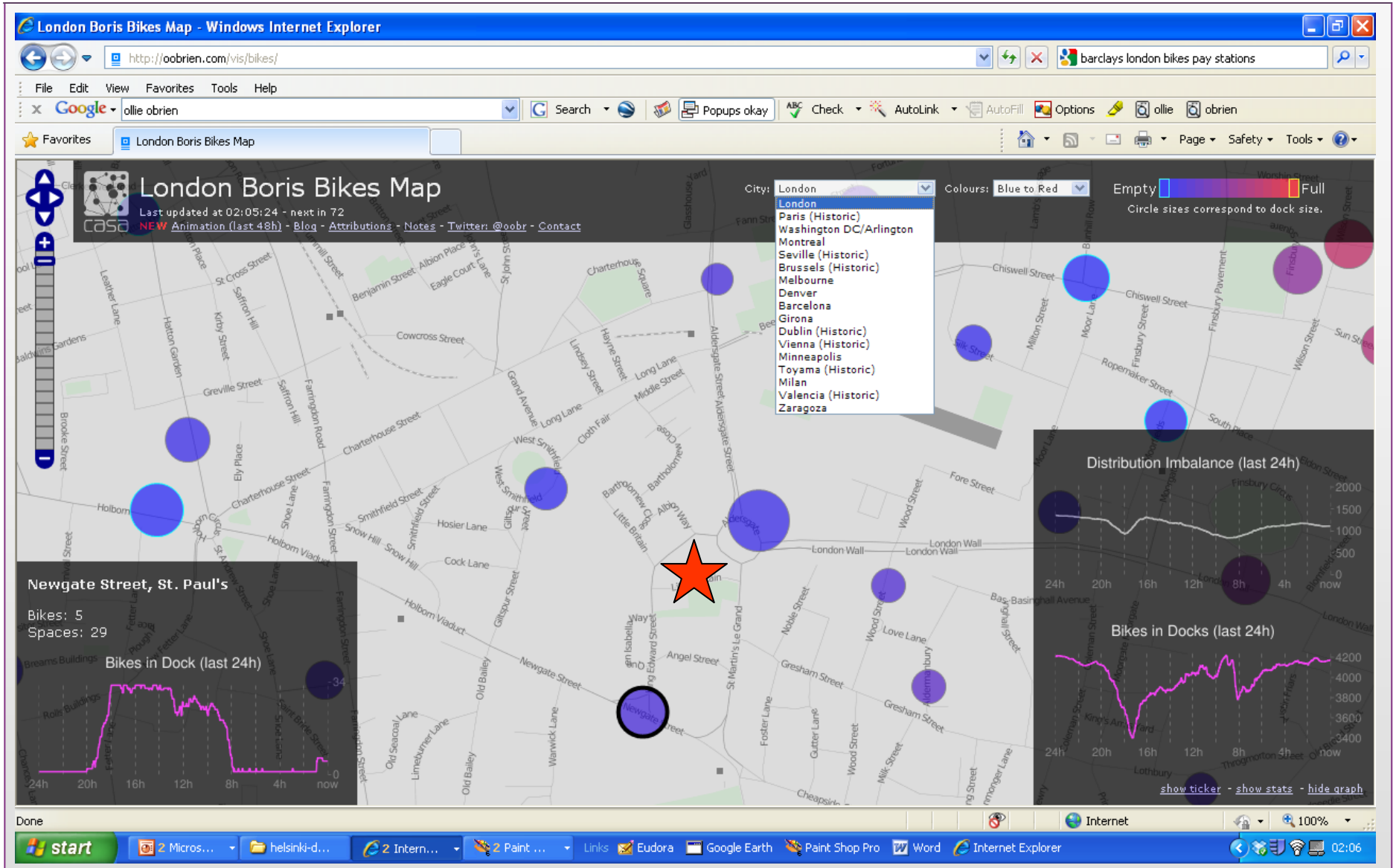
Bike/Dock Ratio

- No of bikes per 100 docks
  - Based on max availability at around 5am ("no" usage)
  - Averaged over a few weeks



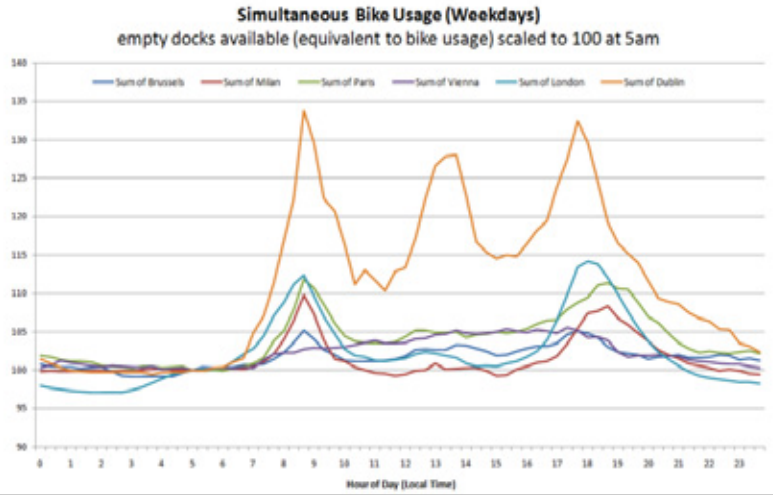
City	Ratio/100
Melbourne	60
London	**56**
Montreal	56
Denver	54
Milan	52
Dublin	51
Minneapolis	50
Toyama	50
Barcelona	49
Washington DC	49
Girona	48
Paris	47
Vienna	47
Brussels	46
Seville	42
Valencia	39
Average	**50**


London Boris Bikes Map - Windows Internet Explorer
http://oobrien.com/vis/bikes/
barclays london bikes pay stations
File Edit View Favorites Tools Help
ollie obrien
Favorites
London Boris Bikes Map
Page Safety Tools
London Boris Bikes Map
Last updated at 02:01:33 - next in 47
NEW Animation (last 48h) - Blog - Attributions - Notes - Twitter: @oobr - Contact
City: London
Colours: Blue to Red
Empty Full
Circle sizes correspond to dock size.
Distribution Imbalance (last 24h)
Bikes in Docks (last 24h)
Newgate Street, St. Paul's
Bikes: 5
Spaces: 29
Bikes in Dock (last 24h)
49 bikes in use - 95 is highest so far today
4170 bikes currently available in docks
1.2% in use
Low
0.6% higher than 24h ago
26% Quite even
hide ticker - hide stats - hide graph
01:52 (1/2) - Welcome to the Dock Status Map - messages appear here as docks become full or empty
01:52 (2/2) - Currently 21 docking stations are empty and 28 are full
Done
Internet
100%
start
Eudora
Google Earth
Paint Shop Pro
Word
Internet Explorer
02:02

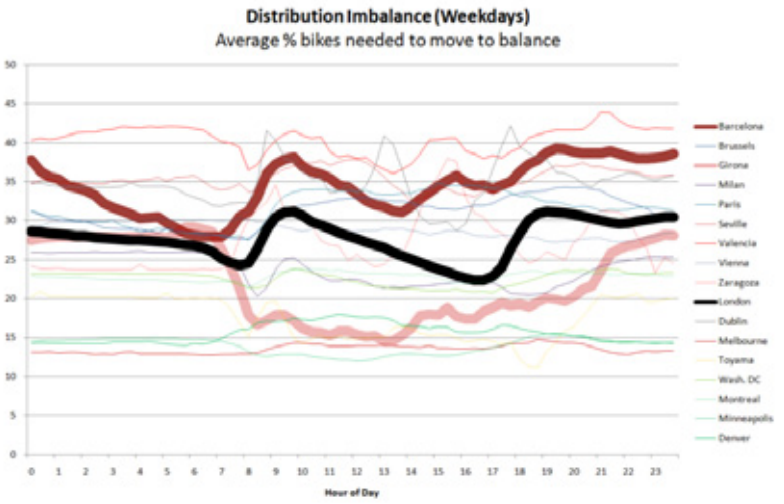


As yet no records of demand from people logging on, so no management capabilities, but could happen probably from an App based software but maybe from the server

Weekday Use – 1. Europe ex-Spain

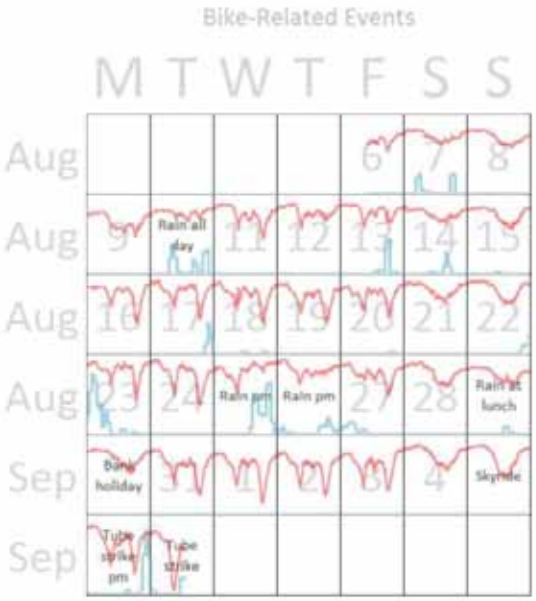


Redistribution Effectiveness



More Analysis

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



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casa.ucl.ac.uk/bom

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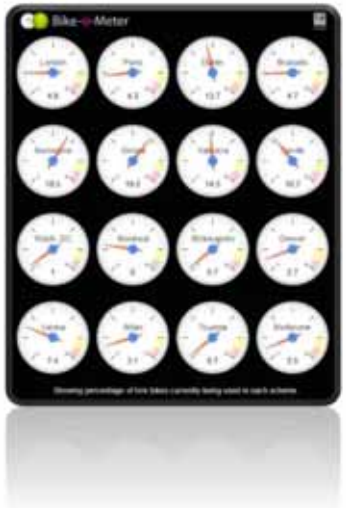
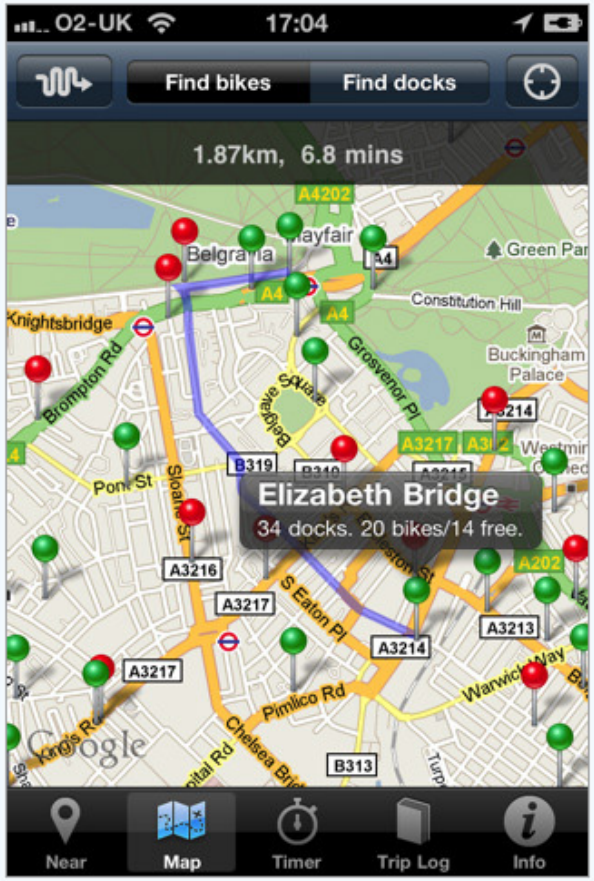
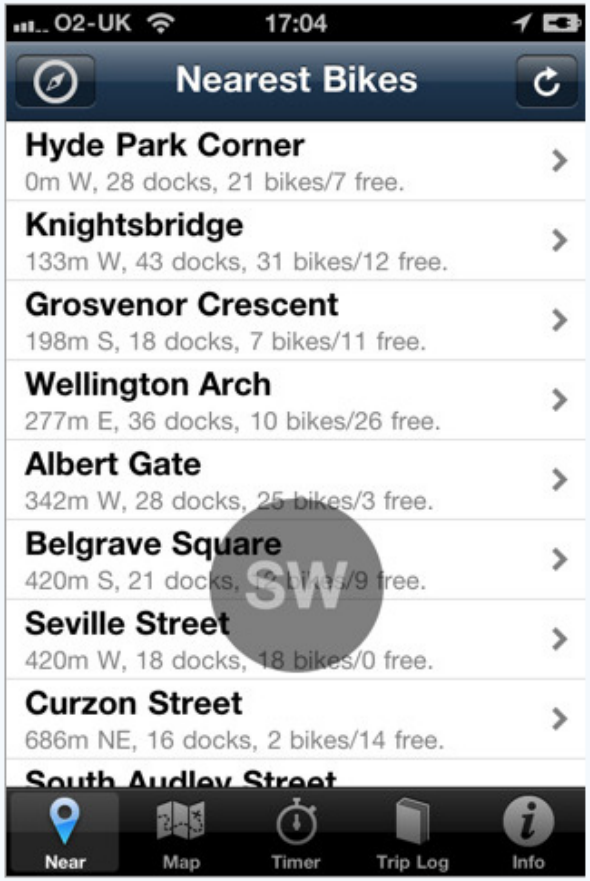
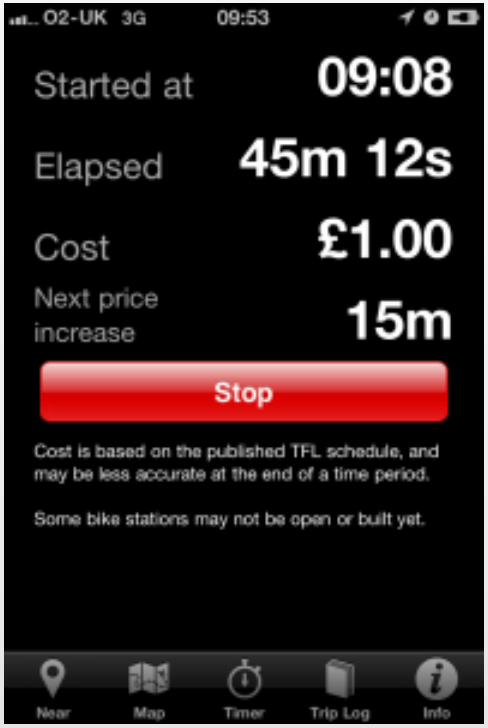


iPhone Screenshots

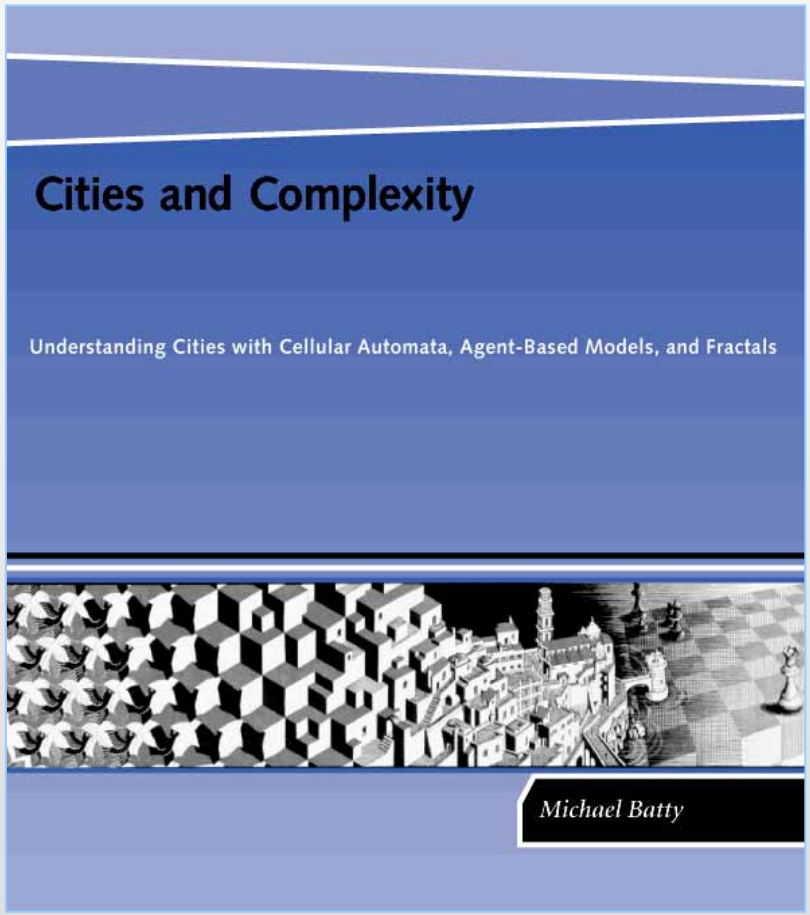




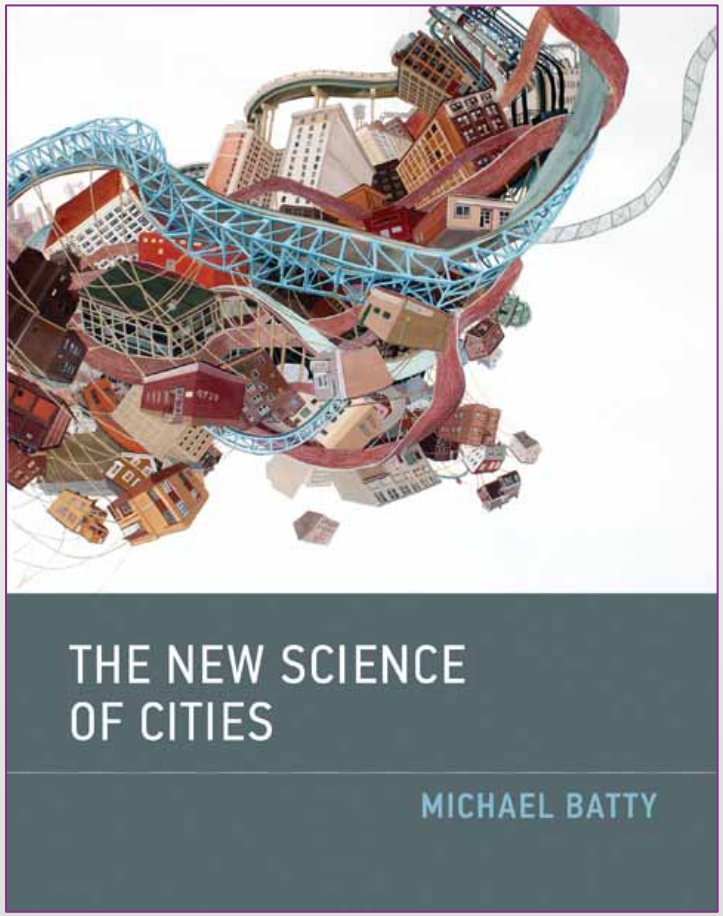


http://oobrien.com/vis/bikes/

Some references which are accessible



MIT Press, 2005



MIT Press, 2013

If there is time,

Questions

www.casa.ucl.ac.uk