Smart Infrastructure

Kenichi Soga

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CSIC Cambridge Centre for Smart Infrastructure and Construction

Cabinet Office

Government Construction Strategy

May 2011

Establishment of
“Infrastructure UK” in 2010

From 2010 to 2014

HM Treasury

National Infrastructure Plan 2014

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EPSRC Engineering and Physical Sciences Research Council

Innovate UK Technology Strategy Board

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National Infrastructure Plan

- **£466B ($700B)** for the next generation of infrastructure by 2020

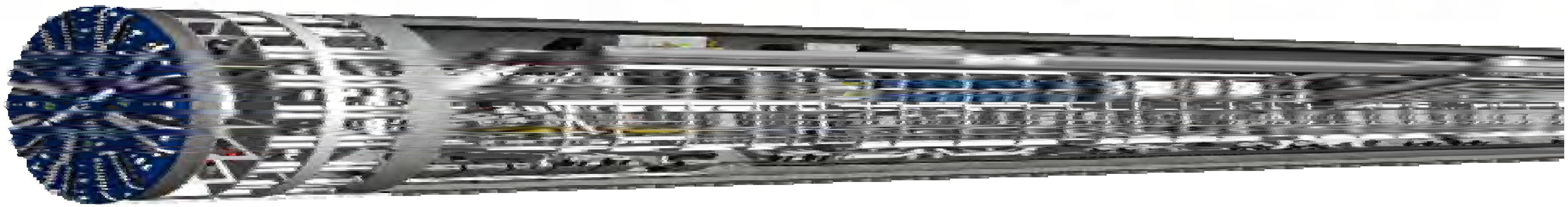
- "**High quality infrastructure is essential for supporting productivity growth.** Delivering the right infrastructure at a local, regional and national level, across the UK, is […] **key to the government's long-term economic plan**."

- **An export potential** for an international market that is valued at least **$57 trillion** in the period up to 2030.

- **A step-change** in the nation's approach to infrastructure investment.

Crossrail – New London Underground Line in London

- 118 km from east to west
- 37 stations
- 9 new stations (8 sub-surface)
- Increase London's rail-network capacity by 10%



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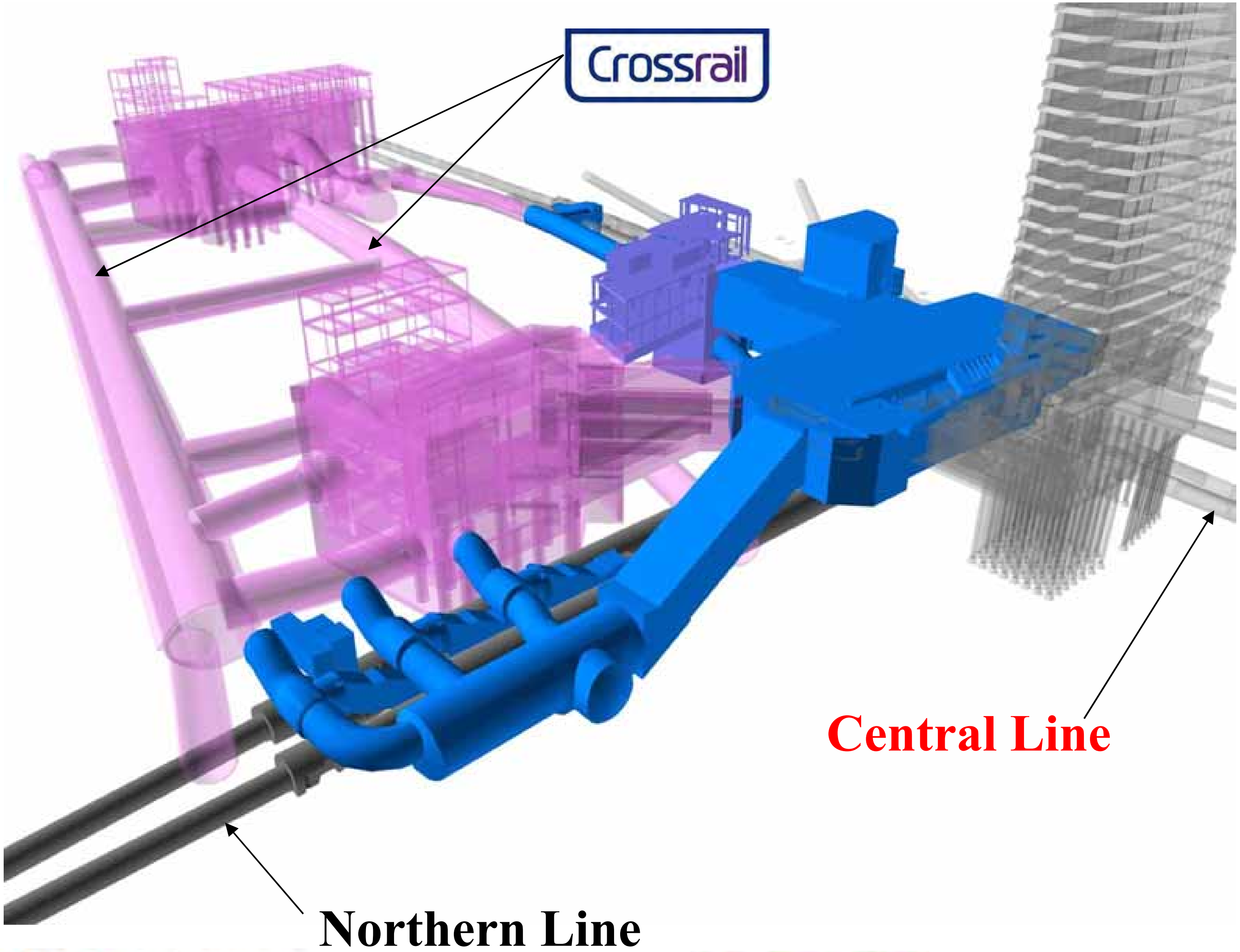
Tottenham Court Road (TCR)-Station Site



Source: Halcrow

Industrial Strategy (2013)

Construction Leadership Council (CLC)

Lower costs

33%

reduction in the initial cost of construction and the whole life cost of built assets

Faster delivery

50%

reduction in the overall time, from inception to completion, for newbuild and refurbished assets

Lower emissions

50%

reduction in greenhouse gas emissions in the built environment

Improvement in exports

50%

reduction in the trade gap between total exports and total imports for construction products and materials

Innovation and Productivity

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Innovate UK Technology Strategy Board

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CSIC Cambridge Centre for Smart Infrastructure and Construction

An Innovation and Knowledge Centre
Funded by EPSRC and Innovate UK

Robert Mair

Mission:

"Transform the future of infrastructure through smarter information"

Jennifer Schooling

Vision:

- **Enable step changes in construction practice**
- **Establish a world-leading sensing and monitoring industry**
- **Extend asset life & reduce management costs**

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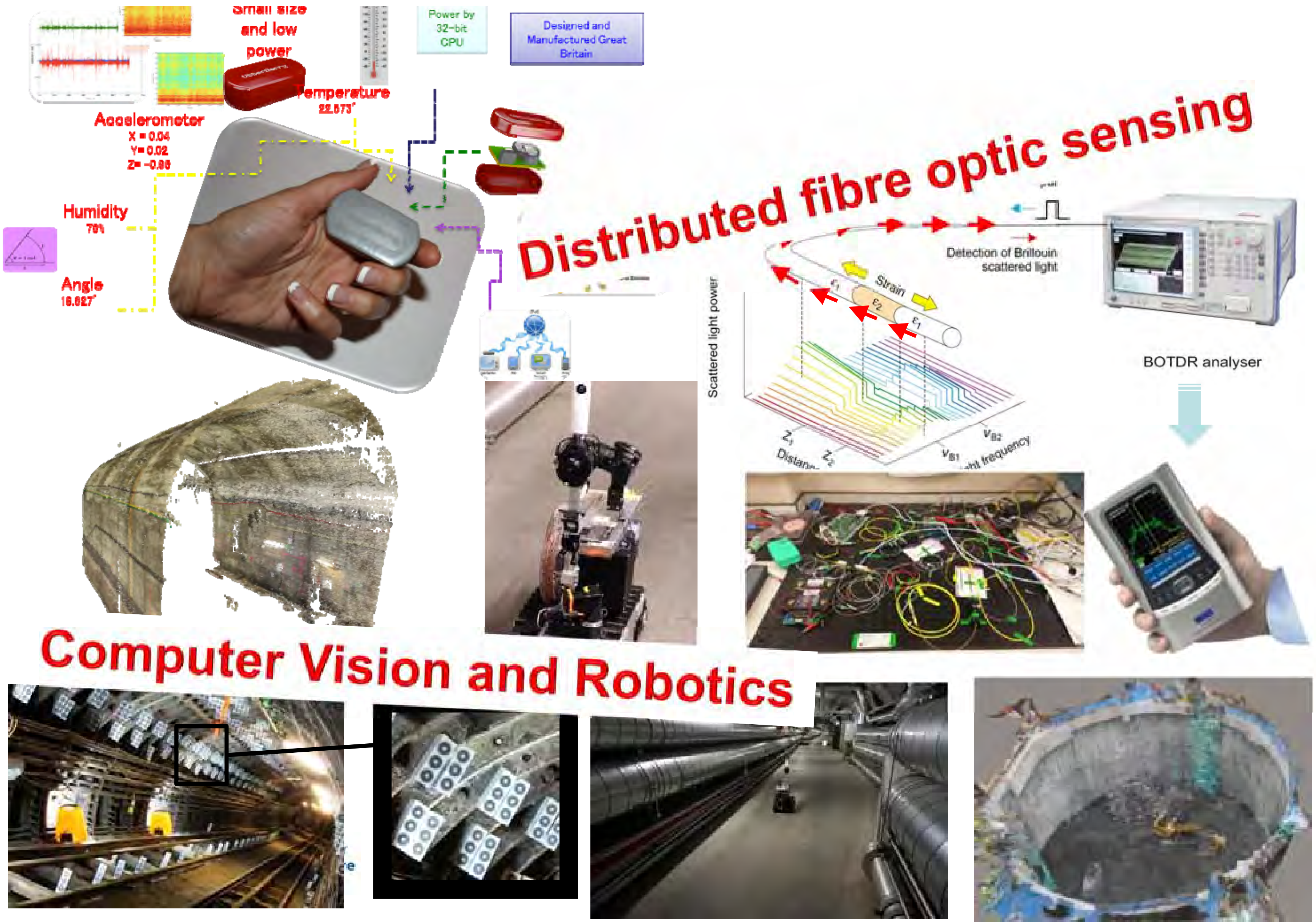
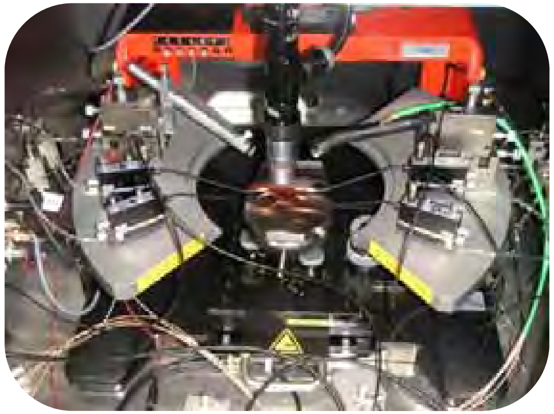
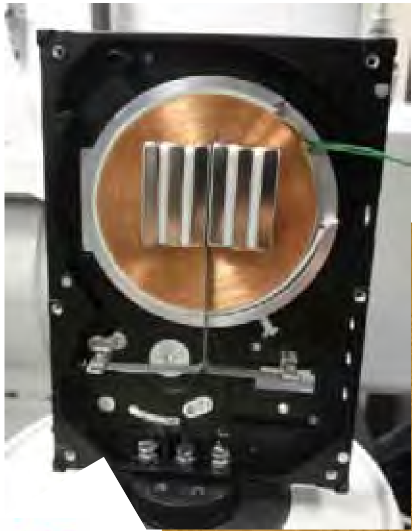
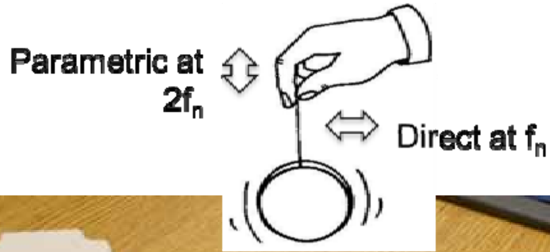
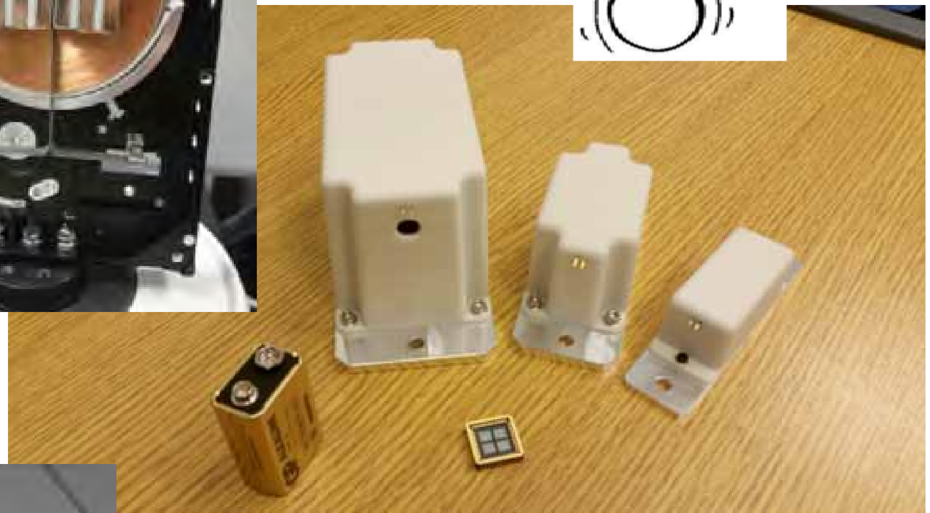
Ultra low power wireless sensor network

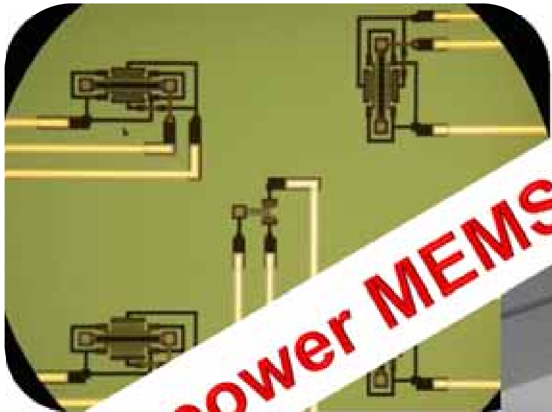




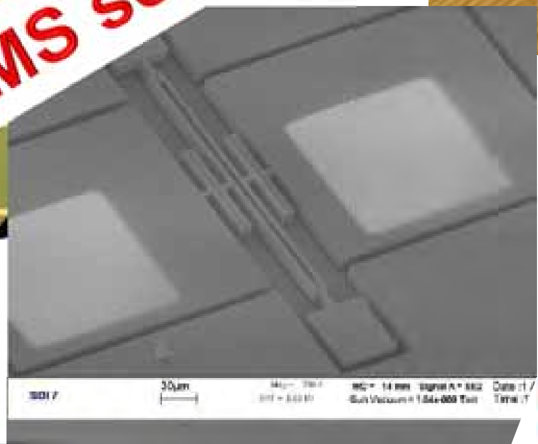


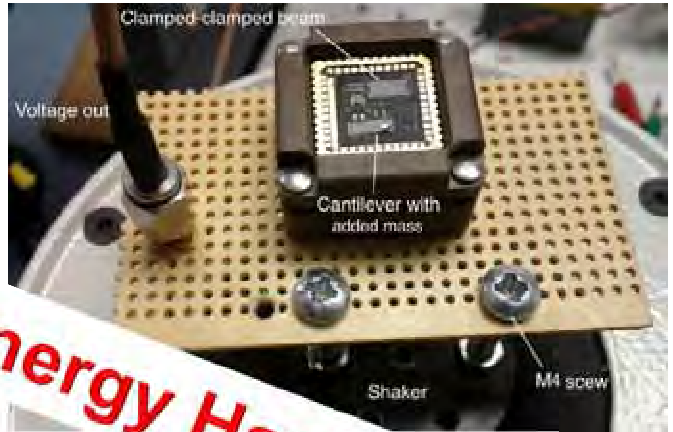






Low power MEMS sensors





Energy Harvesting

and Construction

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The smart infrastructure and construction industry

Owners & Operators		Consultants & Contractors		Technology & Information Suppliers	
Public Sector	Private Sector	Design, construction, operation	Instrumentation and monitoring	Large companies	SMEs

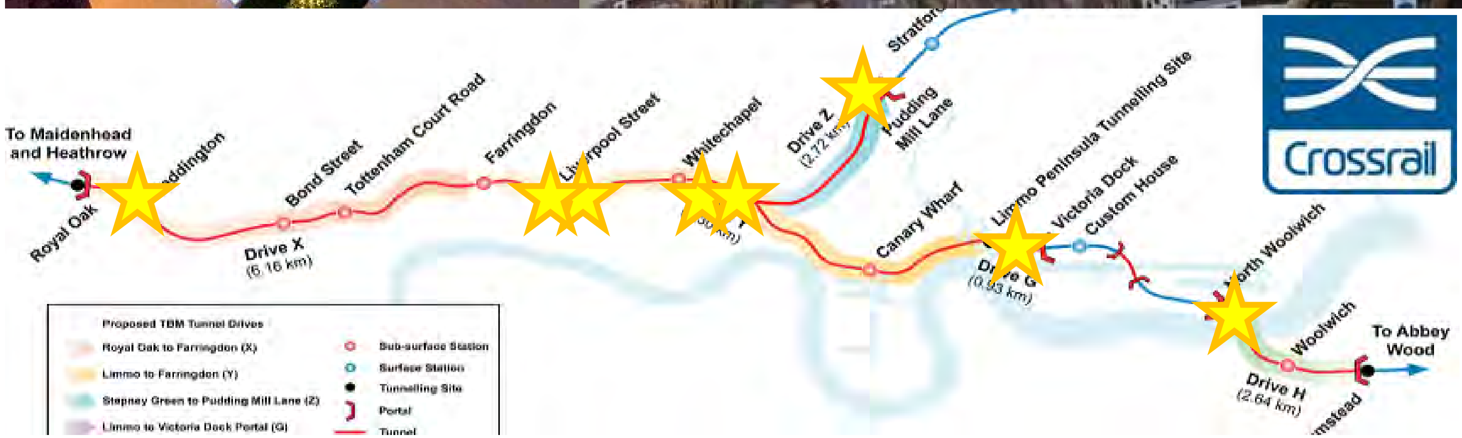
Crossrail
UNDERGROUND
Thames Water
NetworkRail
Tube Lines
CERN
Transport for London
nationalgrid
TRANSPORT SCOTLAND
highways england
HUMBER BRIDGE BOARD

ARUP
COSTAIN
ITM MONITORING
gi energy
SOLDATA
Geo Geotechnical Observations
LAING O'ROURKE
ch2m
Mott MacDonald
Cementation SKANSKA
ATKINS
WSP PARSONS BRINCKERHOFF
CAPITA SYMONDS

THALES
GE Aviation
COBHAM
TOSHIBA Leading Innovation
IBM
RolaTube

zühlke empowering ideas
RedBite
TOPCON
iMETRUM
Omnisense
GEOSENSE
Senceive

Field demonstrations & case studies



Crossrail

UNDERGROUND

London Bridge Station
200,000-250,000 passengers/day
55 million passengers per year

- Five Year Improvement Programme, while running its regular service
- Started in 2013
- For longer trains and more frequent services
- 50% increase in passenger
- 66% more space
- 24 trains per hour by 2018
- The largest concourse in the UK

COSTAIN TOPCON Network Rail

Sinan Acikgoz

Tim Embley

James Aitken

Jim Woodham

LBS is one of the oldest stations in London.

[1] retrieved from Alan Baxter & Partners, London Bridge Historical Study

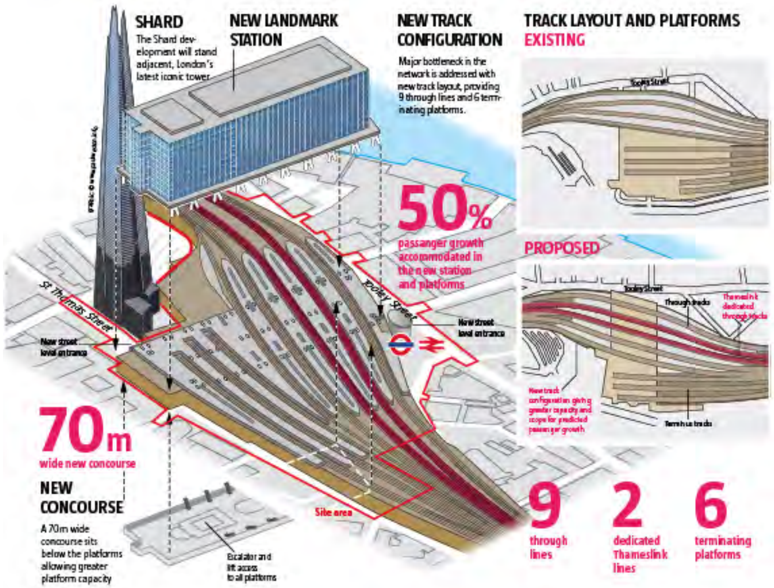
LBS was last redeveloped in 1970’s.

1972 Vision: “Two old railway stations will be merged into one with a higher capacity, giving easy interchange between buses, tube and trains – and direct access to all service from the spacious concourse with new bars, buffets and shops.”

2012 Vision: “The number of platforms will increase and track layout will accommodate higher capacity trains. At the same time, existing bus, train and underground services will be linked with the largest concourse in the UK which will offer a variety of retail services”

1972 vision

2012 vision



London Bridge Station

London Bridge station, one of the oldest train stations in the UK, is currently being redeveloped to increase its capacity.

Landmark structures nearby (e.g. The Shard)

Active train station above

Demolition of old masonry structures for new concourse

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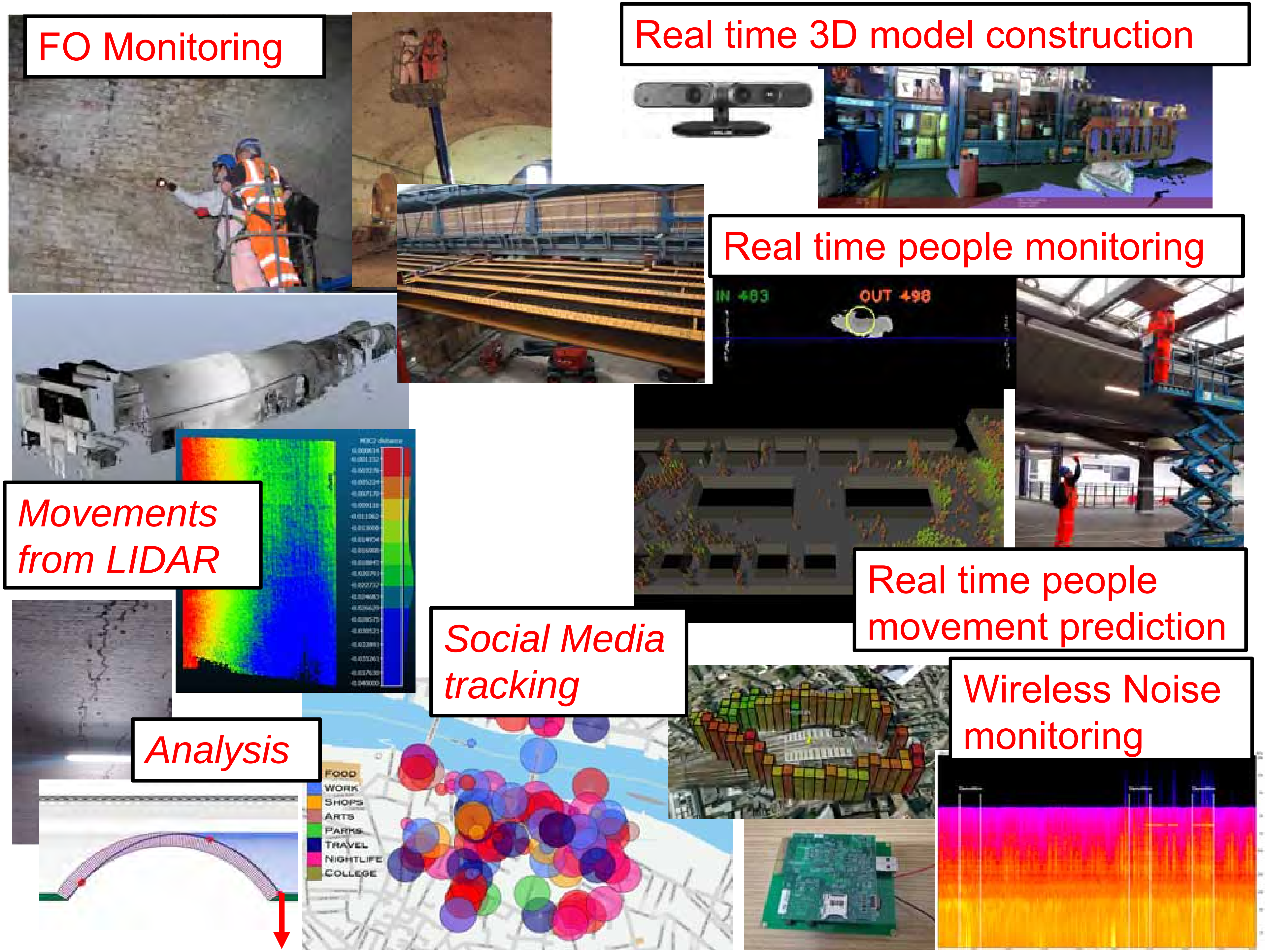
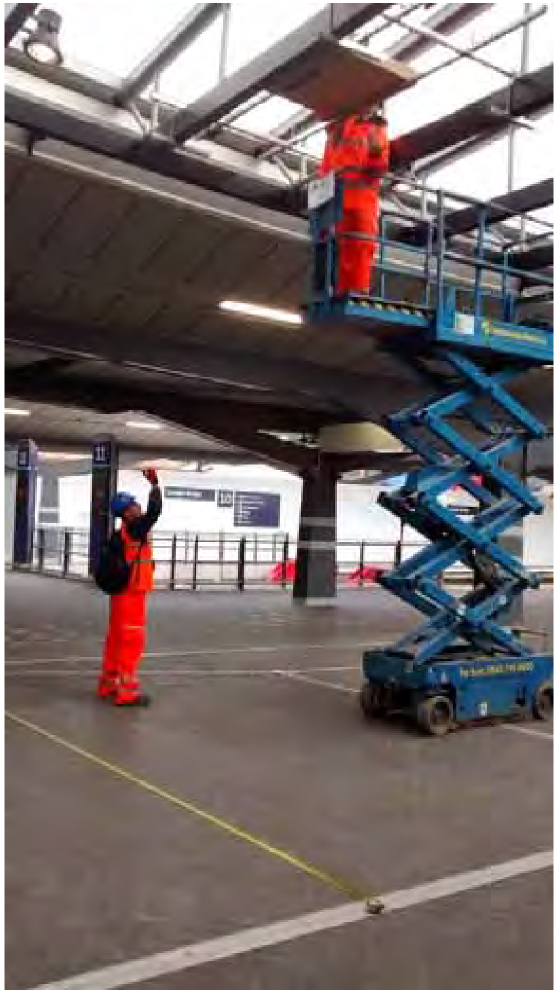
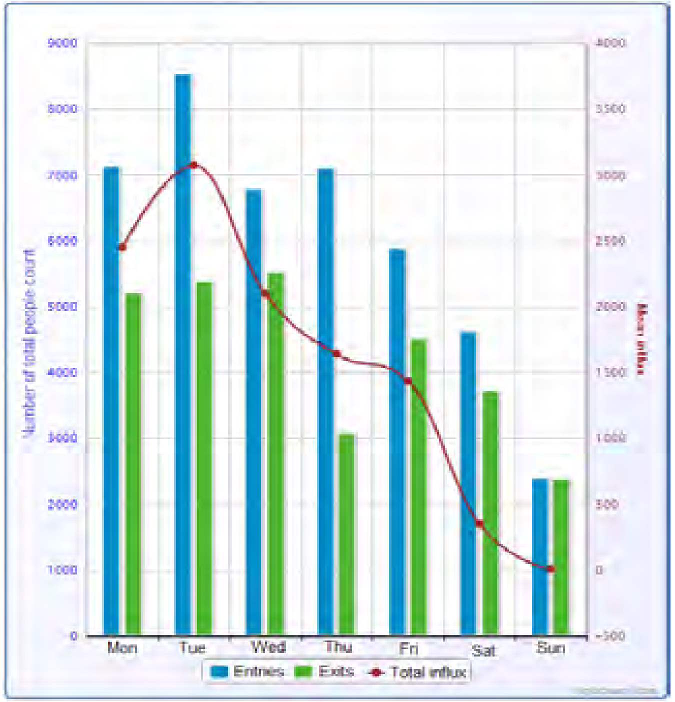


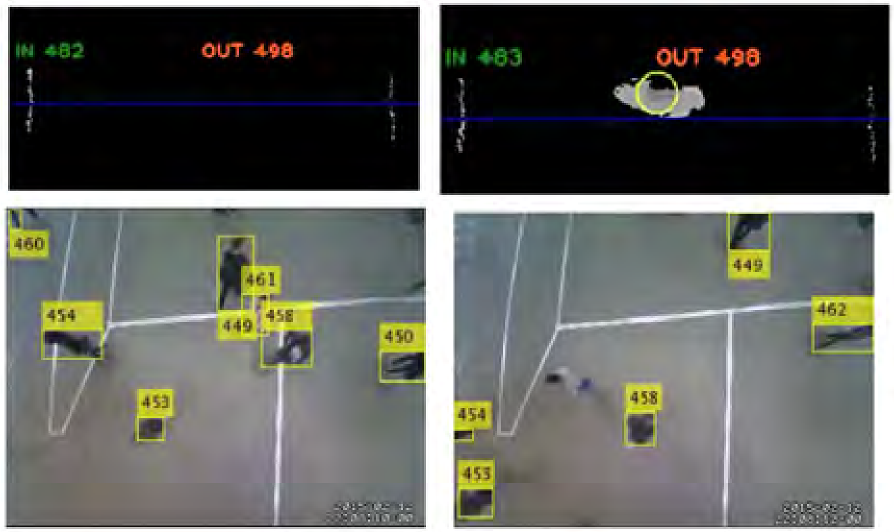
FO Monitoring
Real time 3D model construction
Real time people monitoring
IN 483
OUT 498
Movements from LIDAR
Real time people movement prediction
Social Media tracking
Wireless Noise monitoring
Analysis
Food
Work
Shops
Arts
Parks
Travel
Nightlife
College

Sensor deployment and live counting data



Counting data from 04/02/15-11/02/15





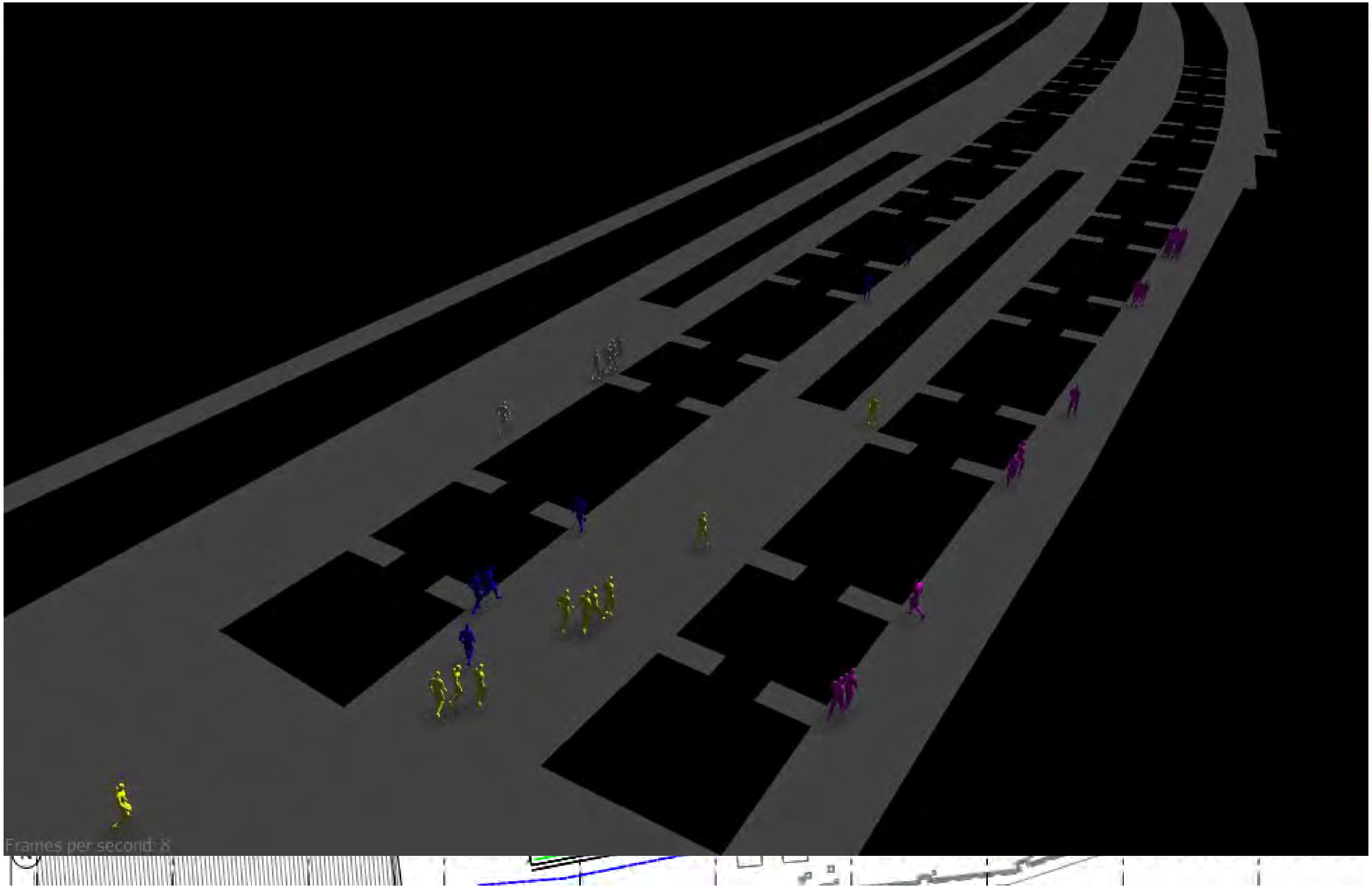
Stent, Martani, Jing

Zachariadis, Martani, Jing

Simulating people flows for temporary station layouts

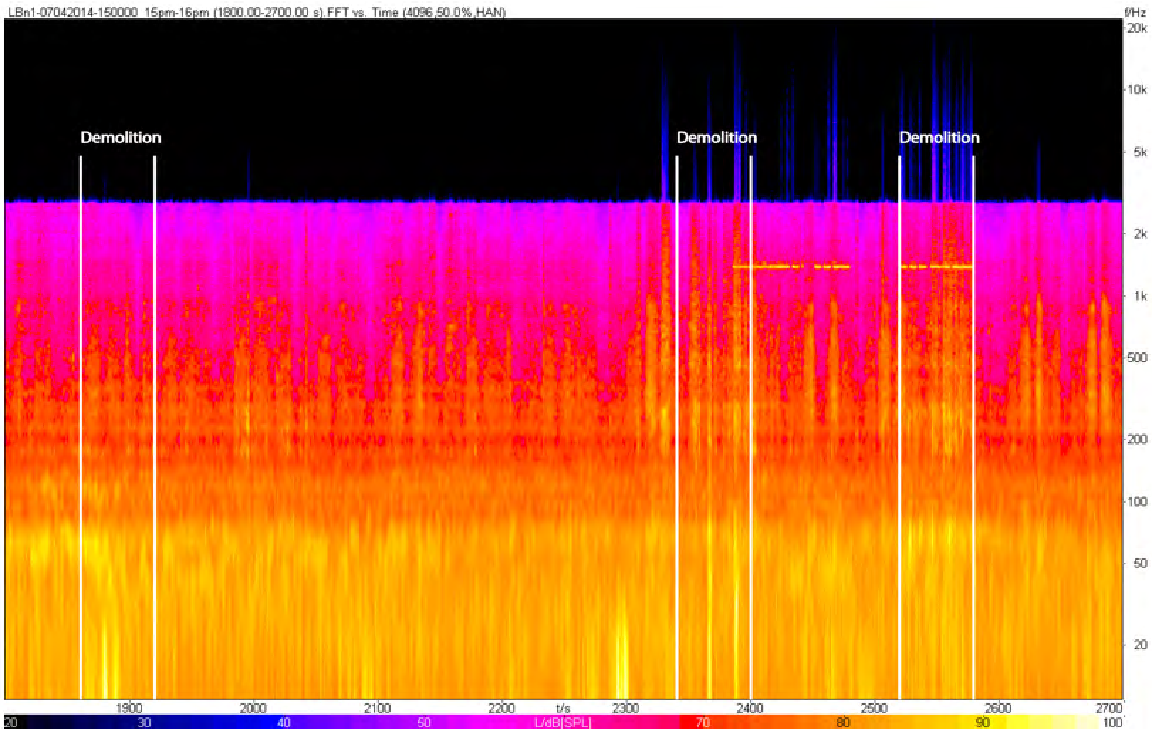
Hoarding line shown with

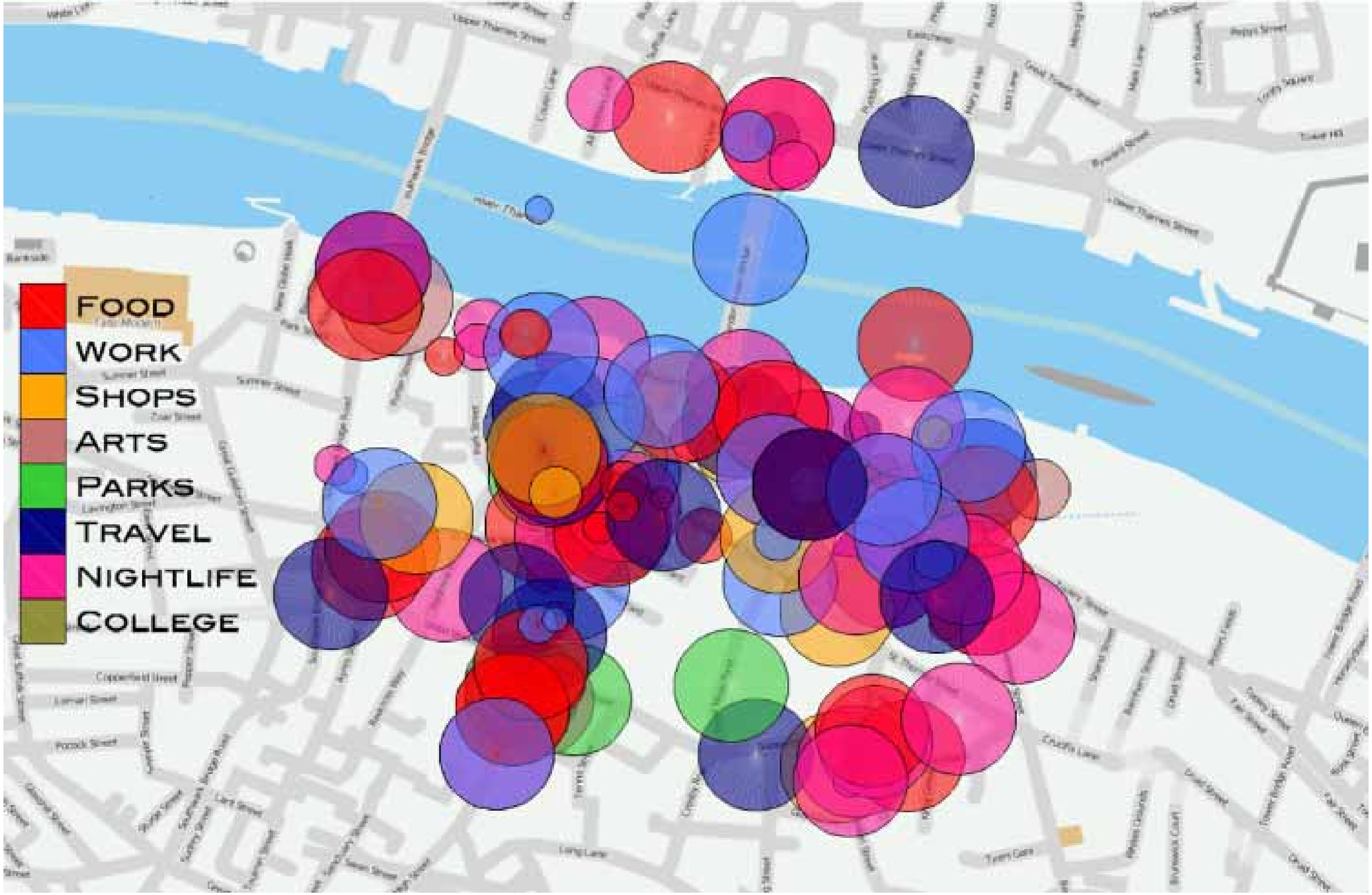
Sensor location shown with ★



Jize Yan

Wireless sensing and identification of noise




FOOD
WORK
SHOPS
ARTS
PARKS
TRAVEL
NIGHTLIFE
COLLEGE

BSI - Smart cities standard (PAS 182)

Monitoring a ‘complex infrastructure’

Surveying data from Costain for Arches and Tunnels

Rail track displacement data from Network Rail

Fibre optics data from CSIC

Design predictions from WSP

Cloud comparison data from CSIC

Can we link all this information to:

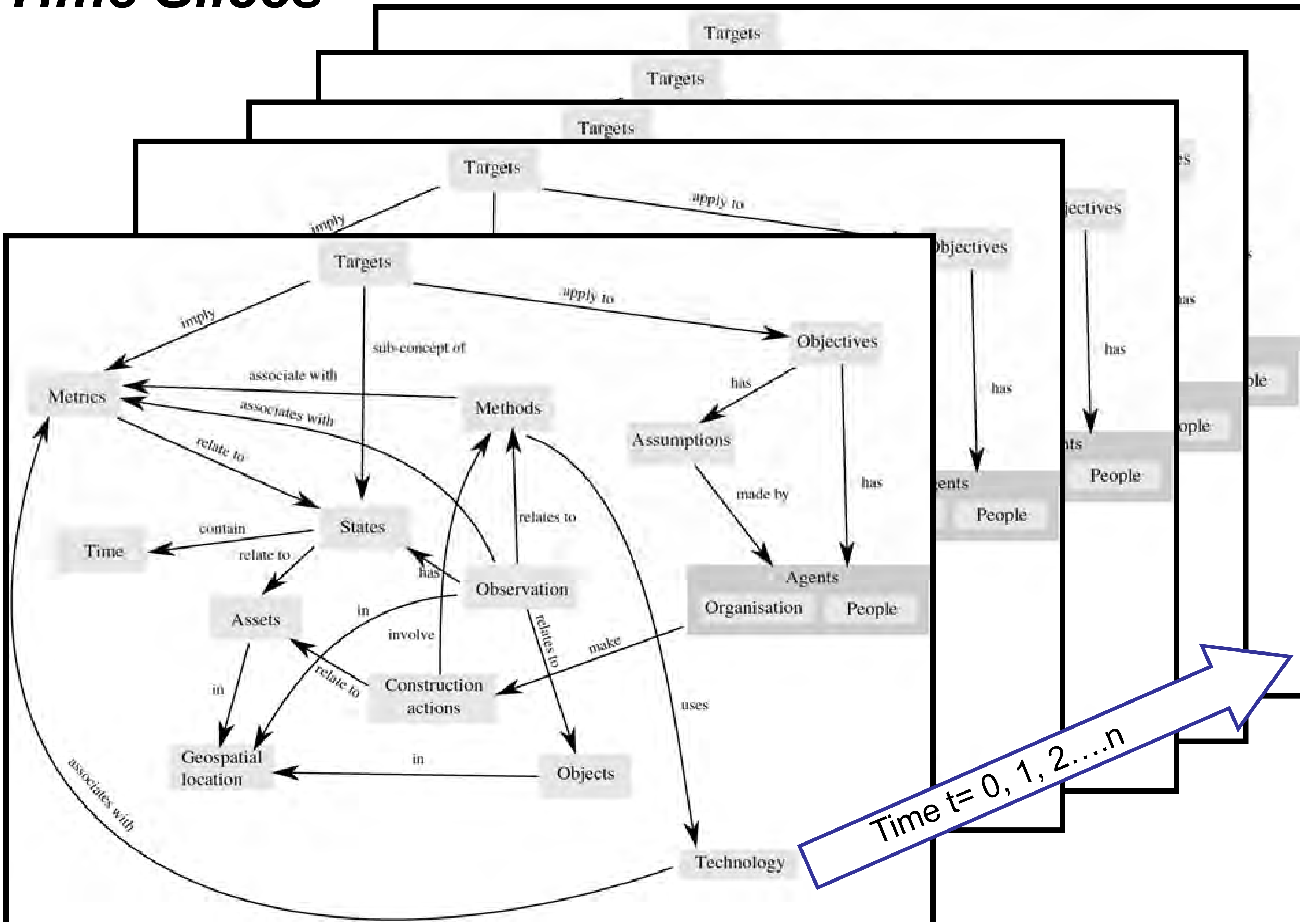
1) Retrieve a better understanding of response
2) Improve communication between agents

Krishna Kumar

Jennifer Schooling

Time Slices

Krishna Kumar



Westminster City, London

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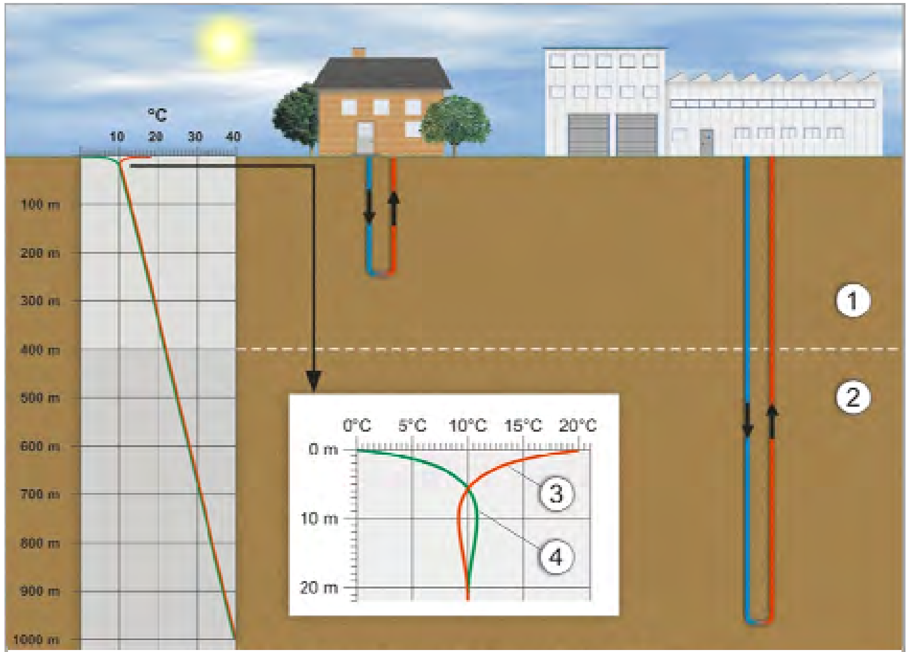
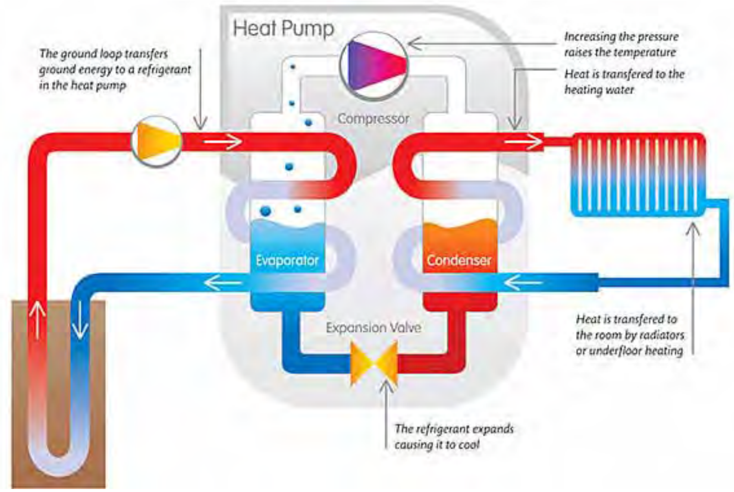
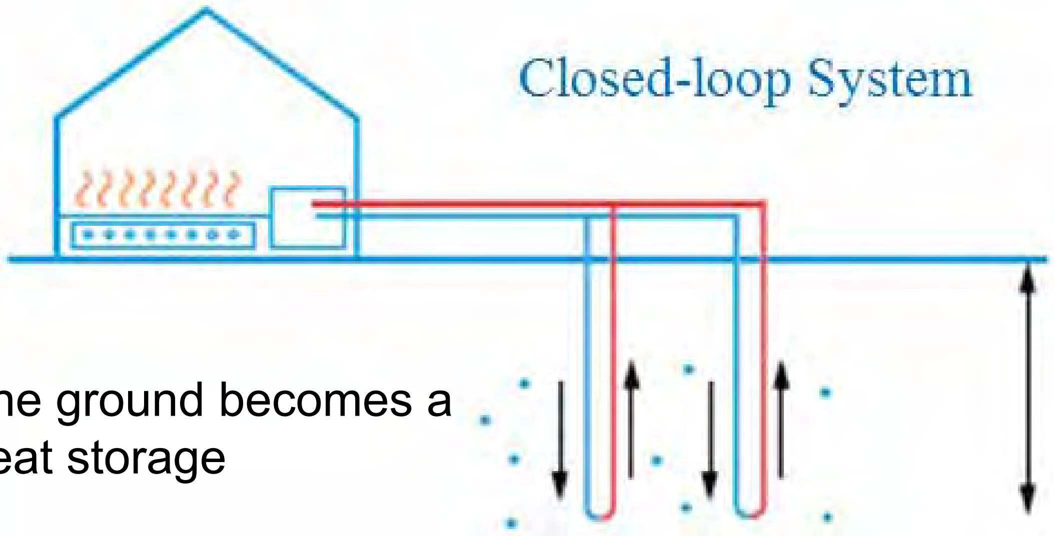
Ruchi Choudhary   Yi Zhang



1 Shallow geothermal energy; 2 Deep geothermal energy;
3 Temperature(Summer); 4 Temperature (Winter)

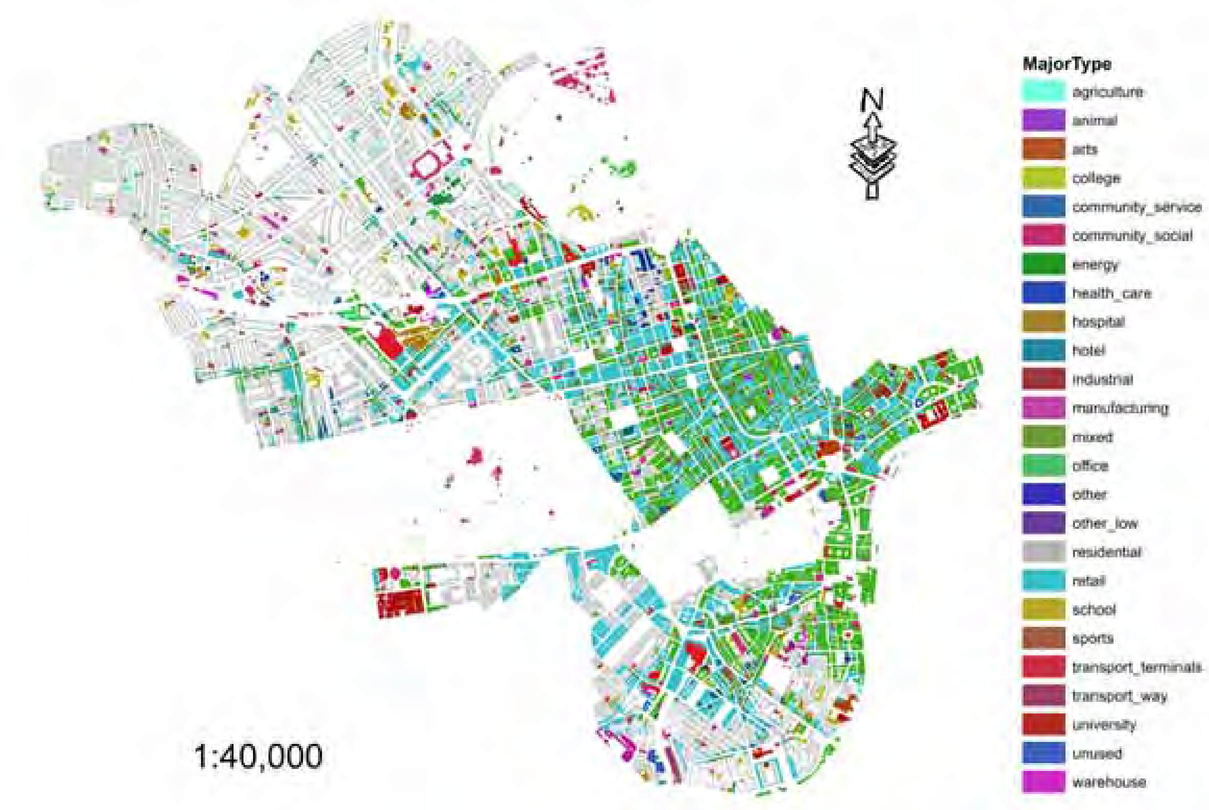


COP = >3.8



The ground becomes a heat storage

Case Study of Westminster



95,817 buildings

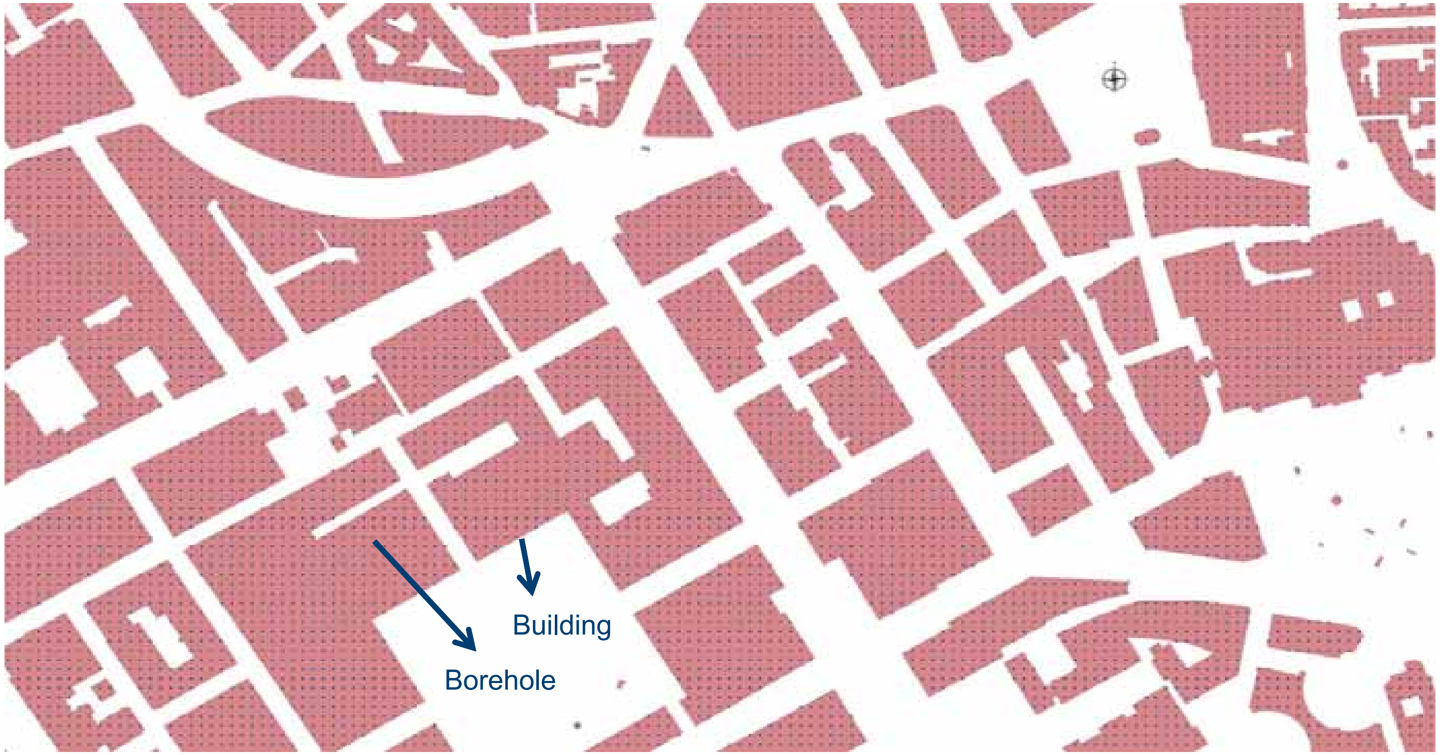
% of the floor area

- residences - 42%
- offices - 32%
- retail - 9%
- remaining - 17%
- (hotels, schools, hospitals and leisure facilities)

Scenario 1: Install Boreholes under Buildings

Minimum Distance between two closest boreholes should be 6 meters.

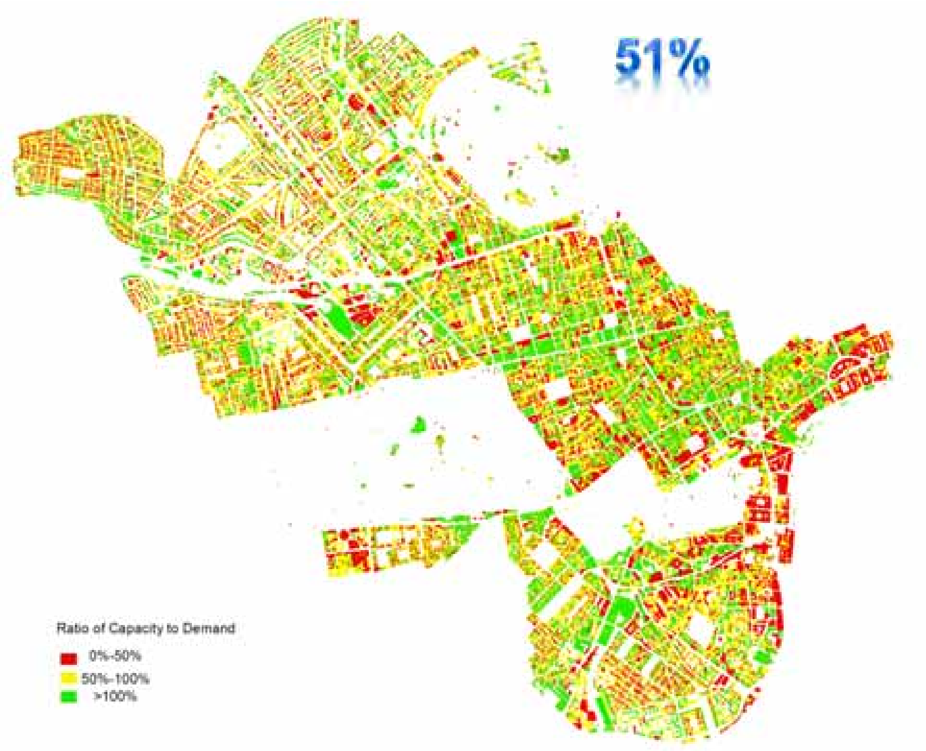
(6 meters refers to MIS by DECC)

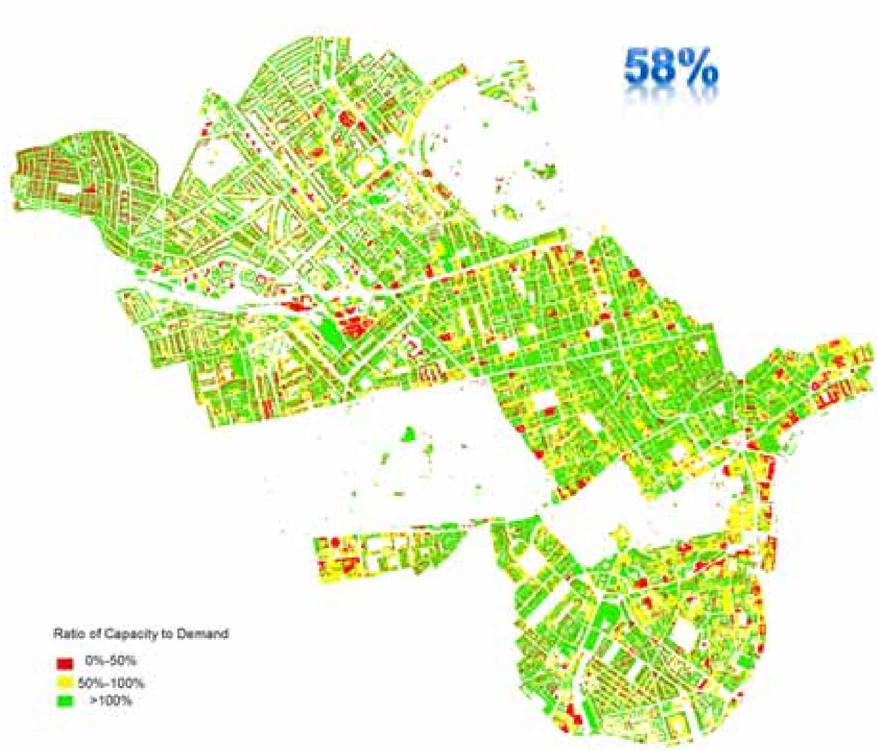


A corner of Westminster

Scenario 1: Ratio of Capacity to Demand Map

- Heating & Cooling
- Heating Only



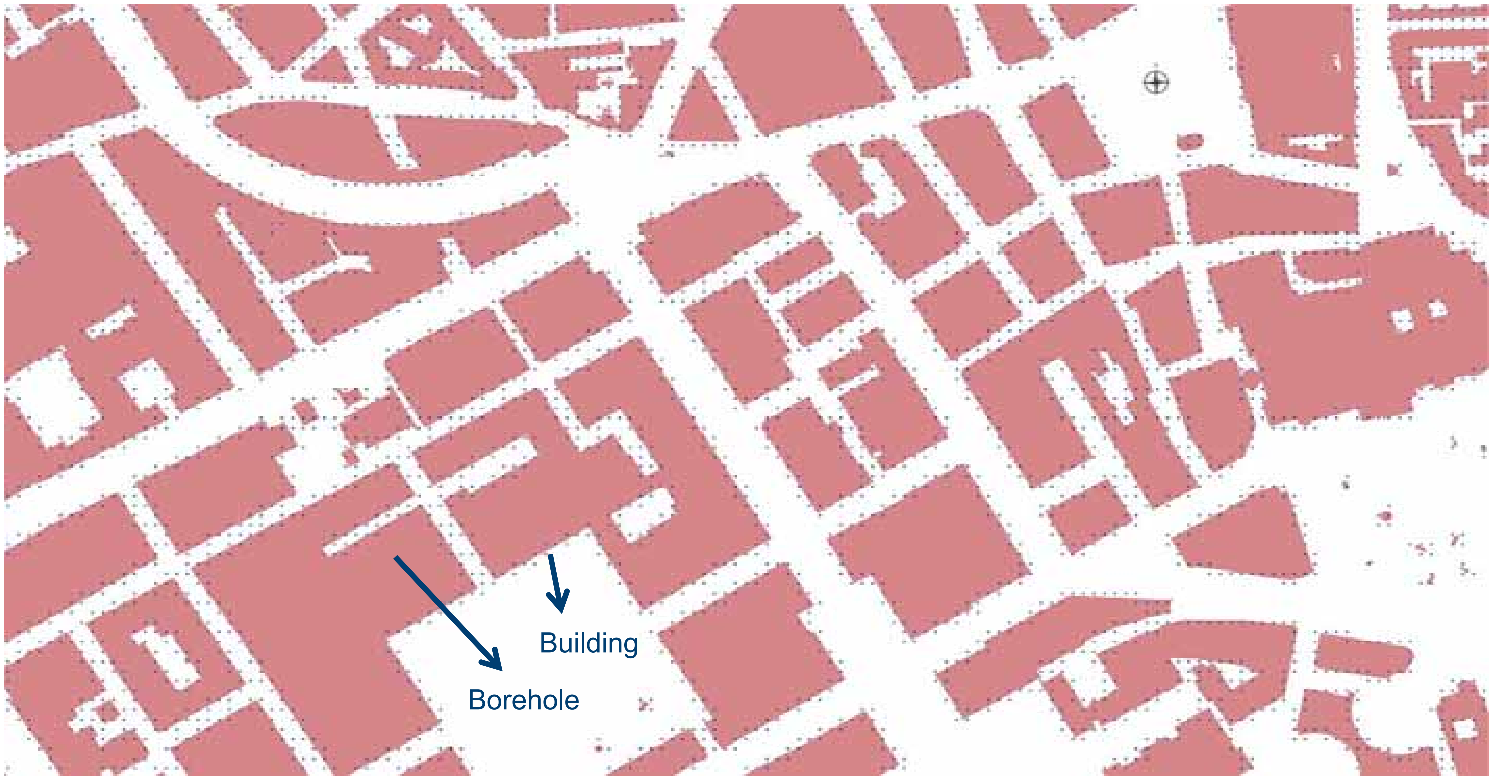


Borehole Length:150m

Scenario 2: Install Boreholes around Buildings

Minimum Distance between two closest boreholes should be 6 meters.

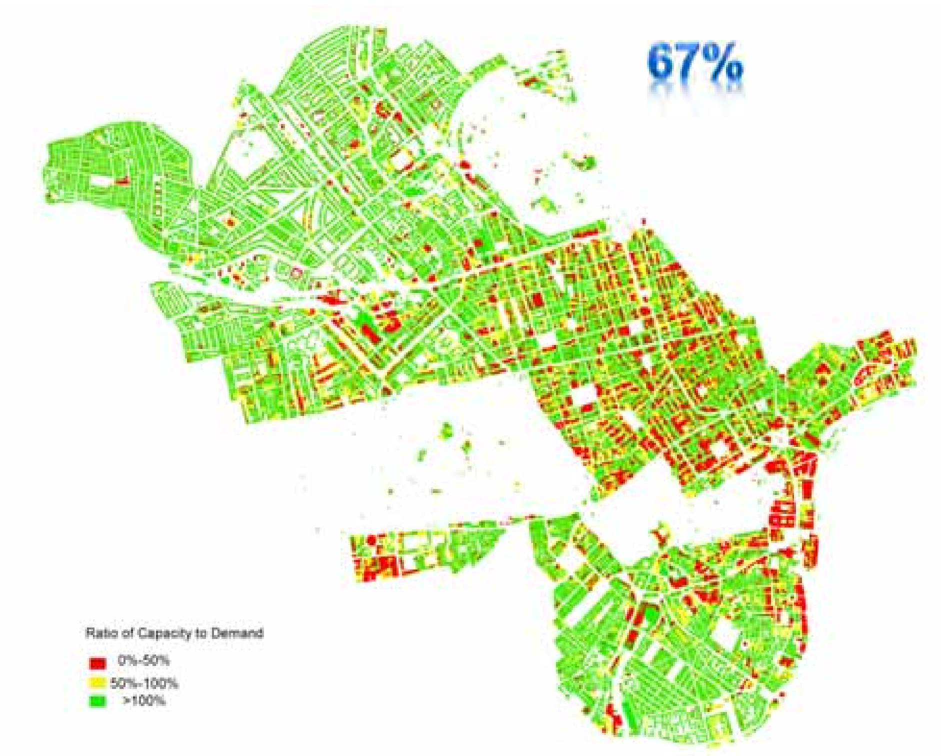
(6 meters refers to MIS by DECC)



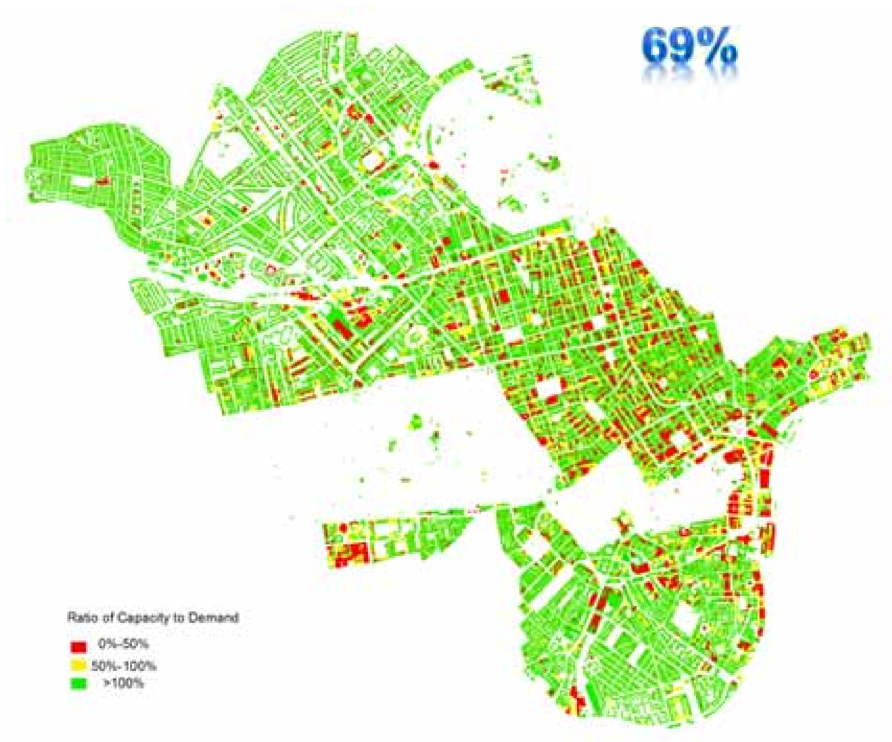
A corner of Westminster

Scenario 2: Ratio of Capacity to Demand Map

- Heating & Cooling



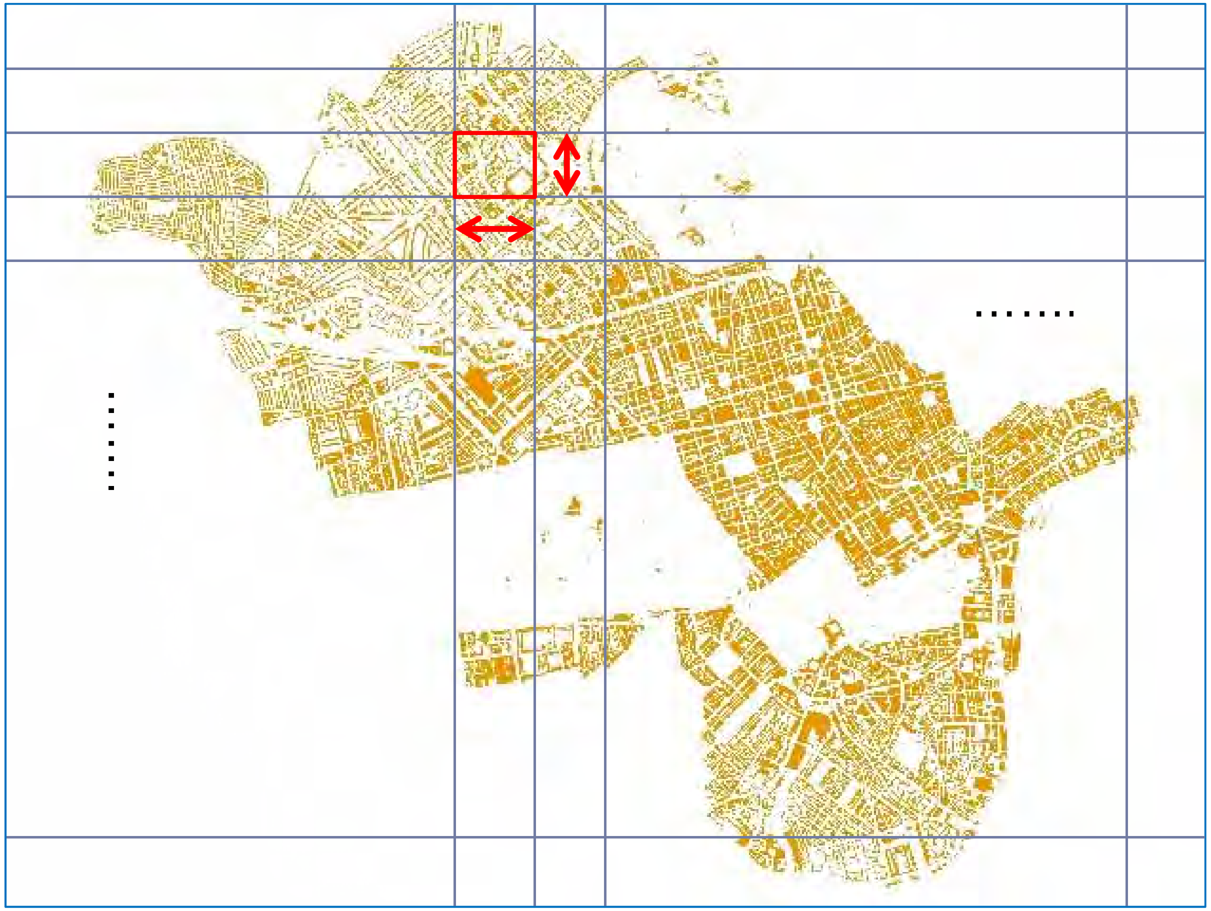
- Heating Only



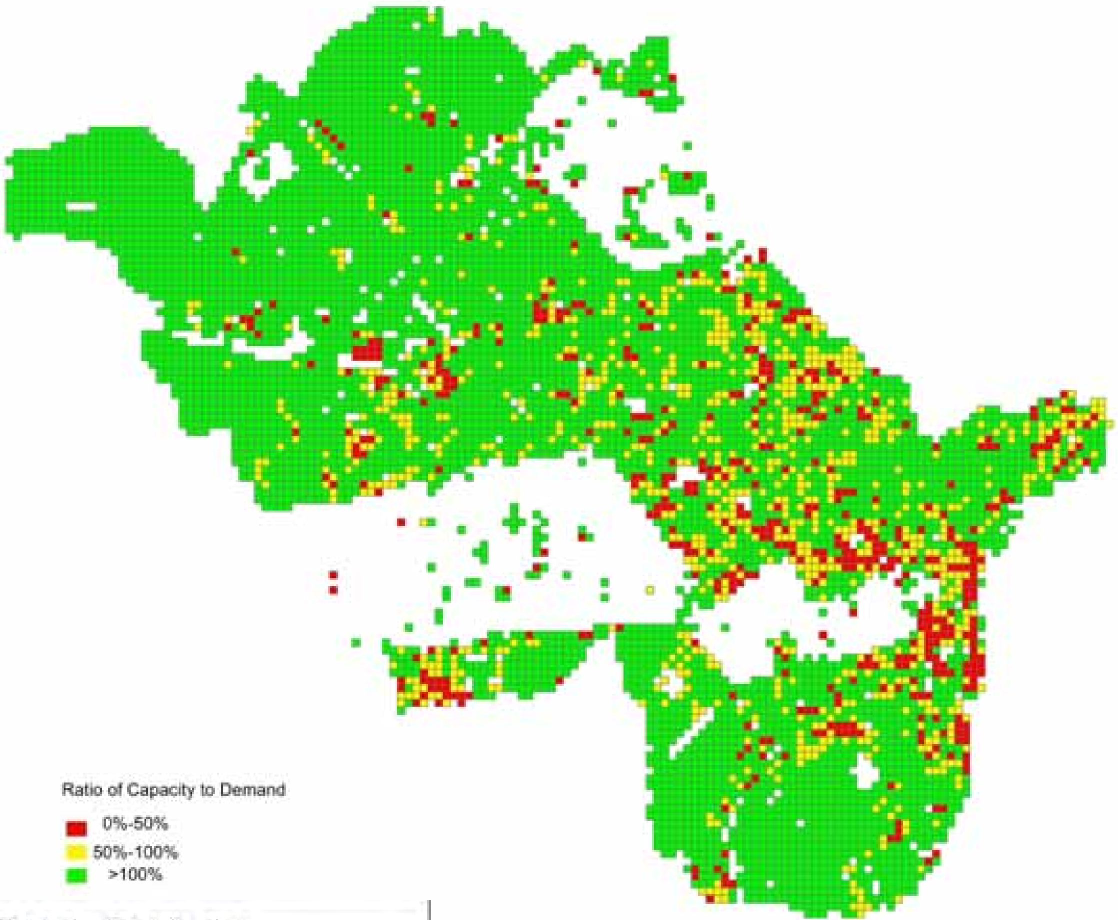
Borehole Length:150m

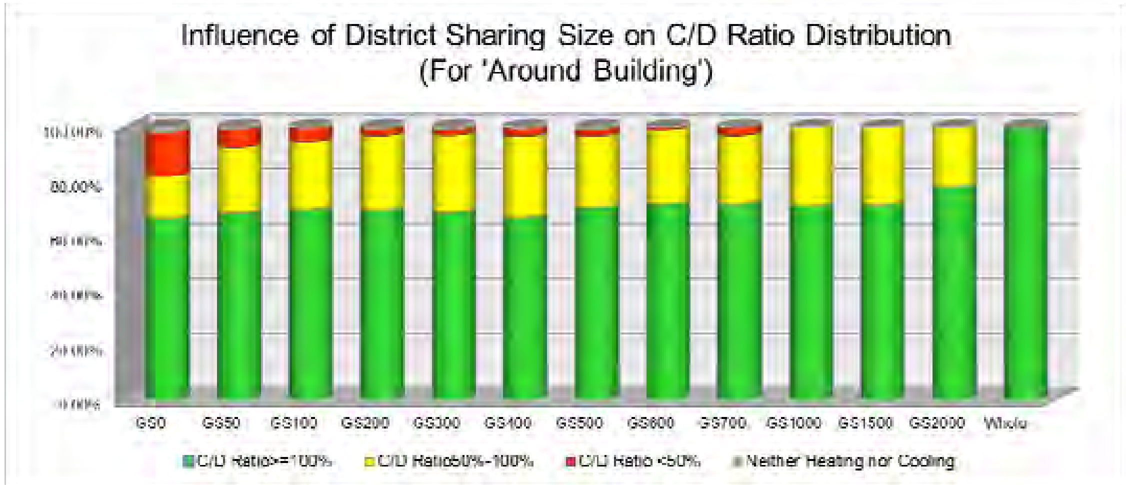
Parameter Analysis

Grid Size (GS) for District

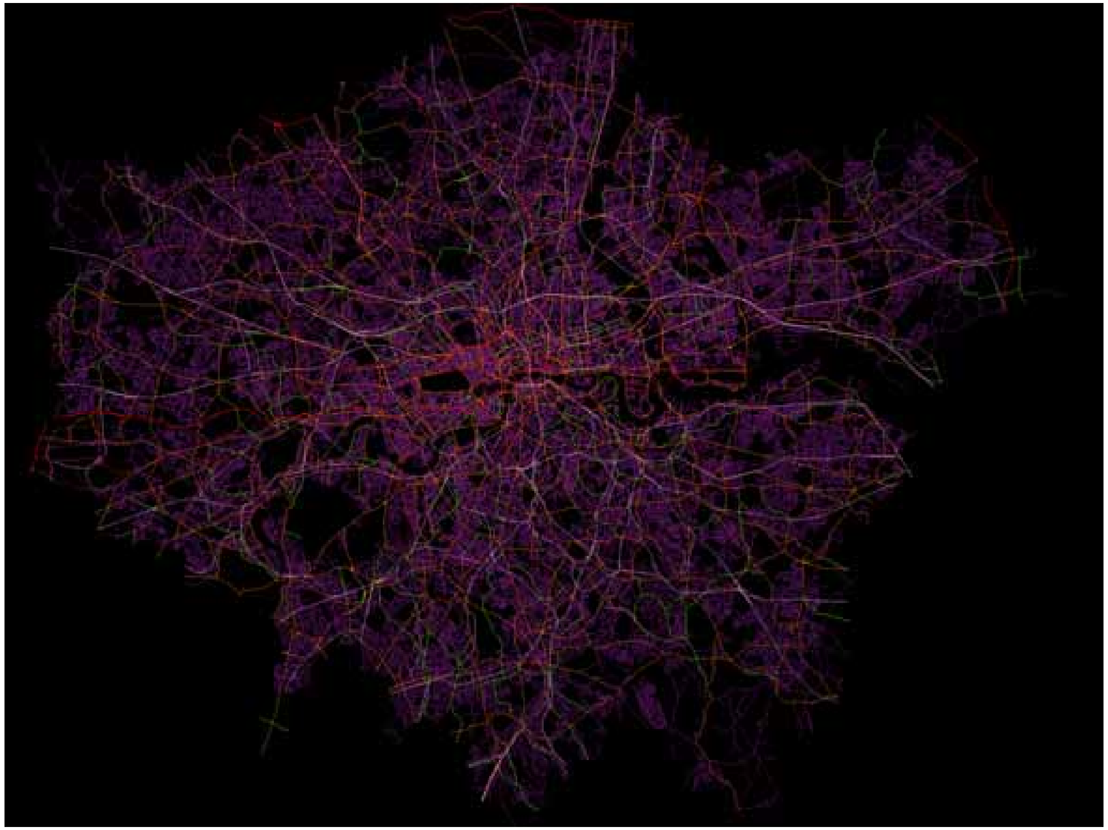


50 m x 50 m district heating





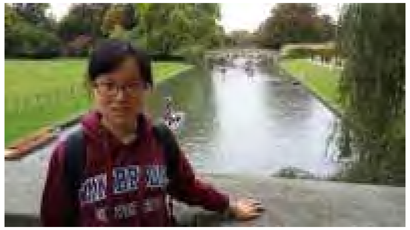
Real Time - Big Data - City Modelling



Gerry Casey

Peter Guthrie

Elisabete Silva



Bingyu Zhao

Krishna Kumar

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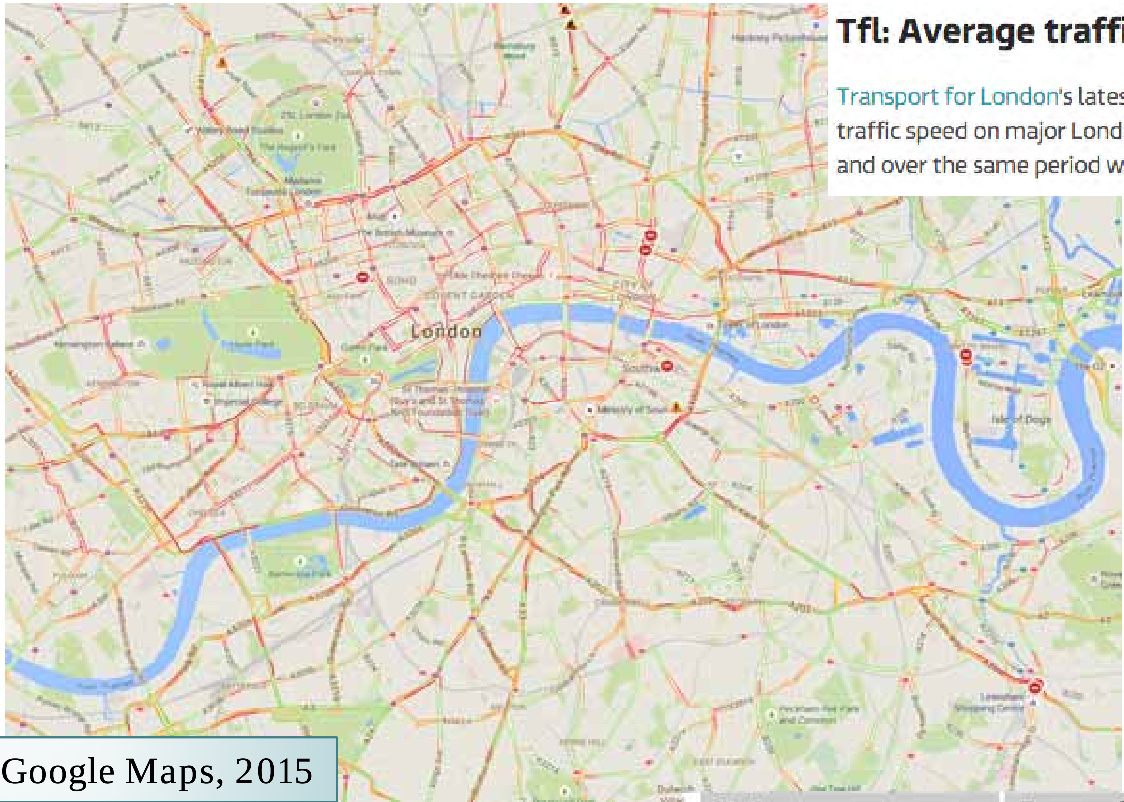
Crowd sourced traffic congestion



Google Maps, 2015

Tfl: Average traffic speeds are less than 20 mph in London

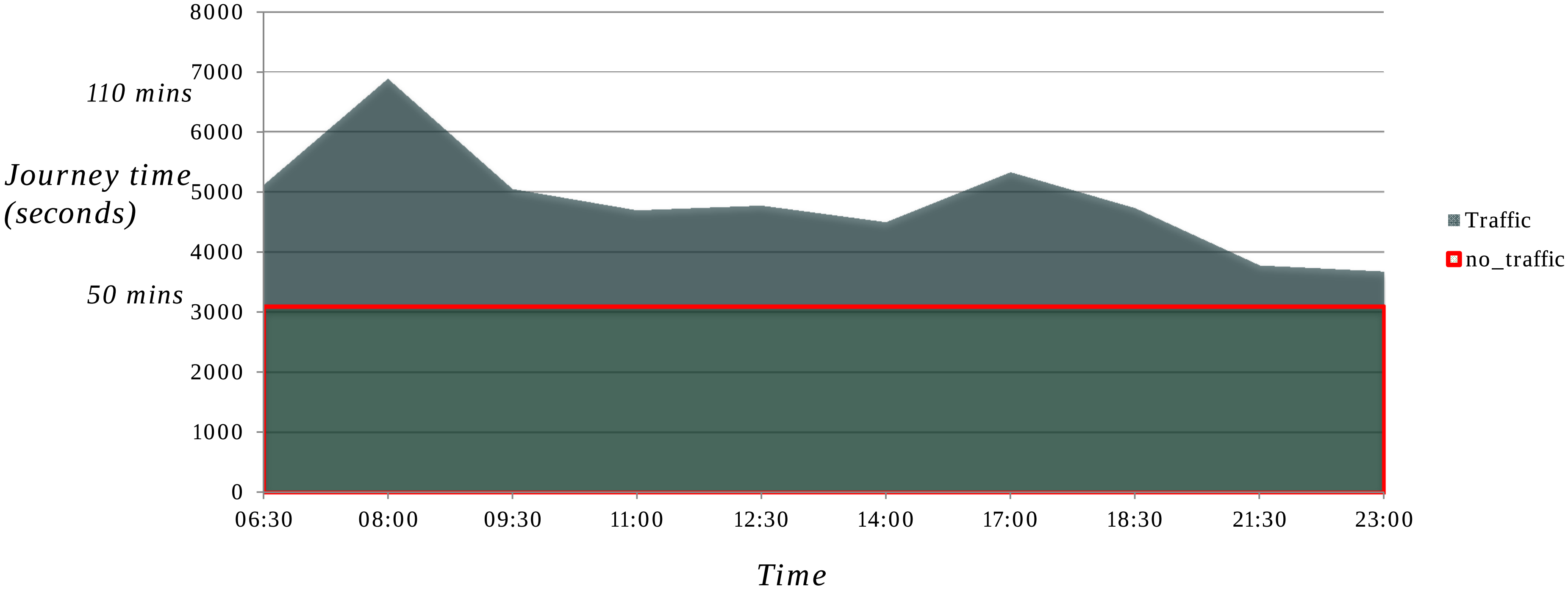
Transport for London's latest figures state that for the first quarter of 2011/2012 the average traffic speed on major London roads for the 12 hours between 7am to 7pm was 19.33 mph and over the same period was 8.98 mph across Central London.

TfL, 2012

Daily fluctuations (am to pm)
Weekdays to weekends
Month to month
Holidays
Weather
Incident propagation
(sporting events, closures etc)
New policies/infrastructure

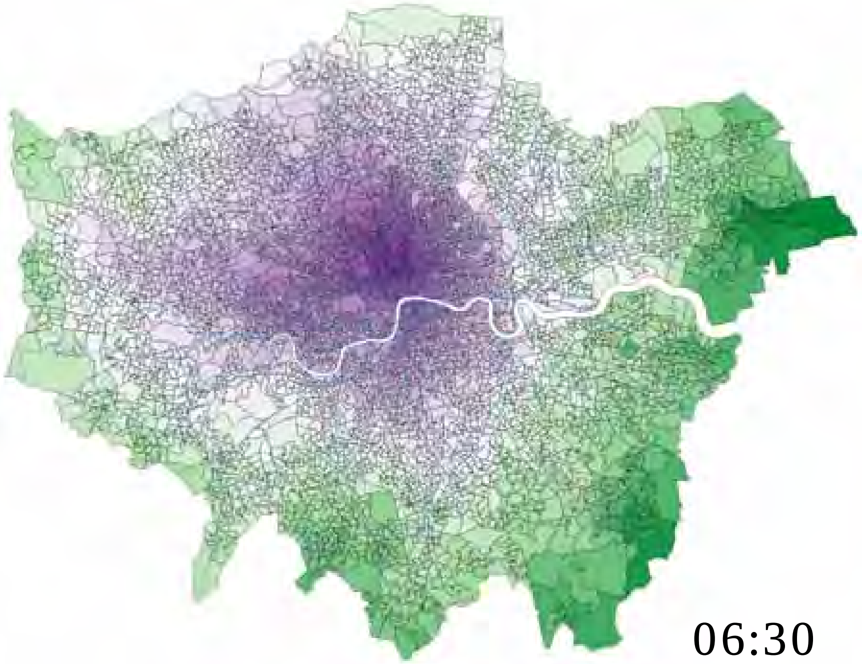
Data	Example	Source
Infrastructure	Nodes & links (including directions)	OS, Google
Junction	Turn restrictions, lane locations & junction costs	OS, Google
Traffic	Traffic congestion	Google
Real-time incidents	Accidents or road works	Waze, TfL
Financial	Fare costs	DfT, Operators (TfL, Eurosta etc)

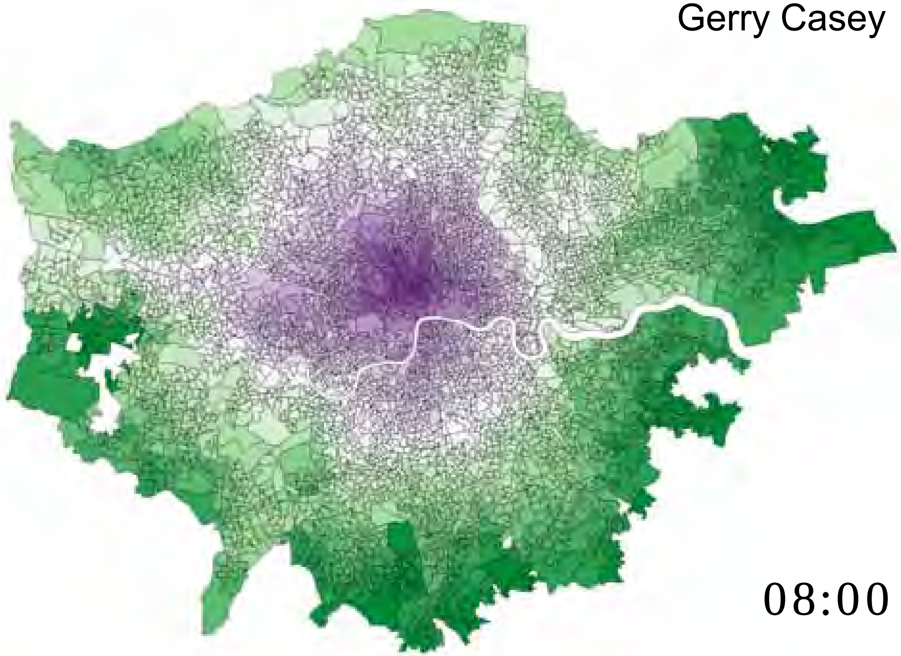
Downe to St Pancras International journey times

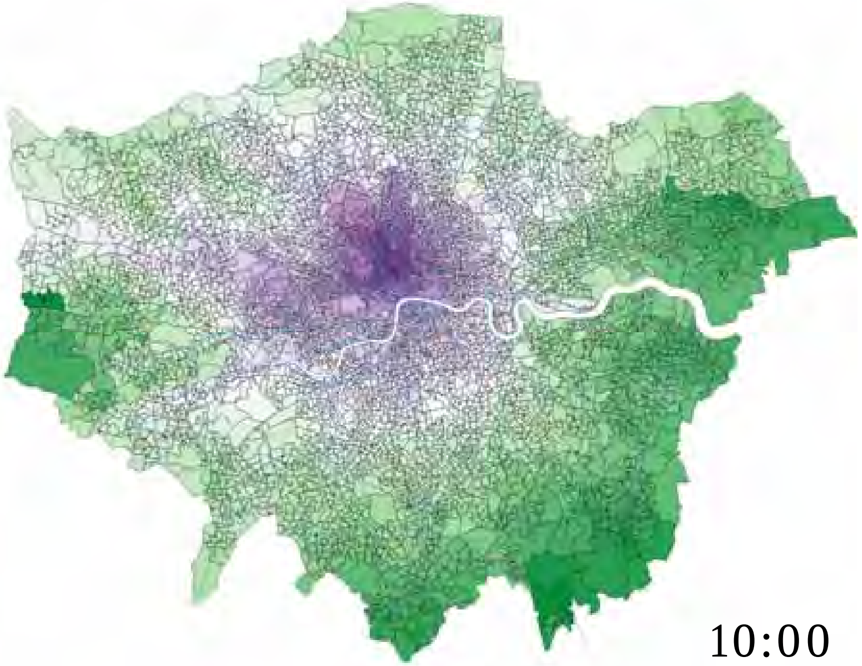


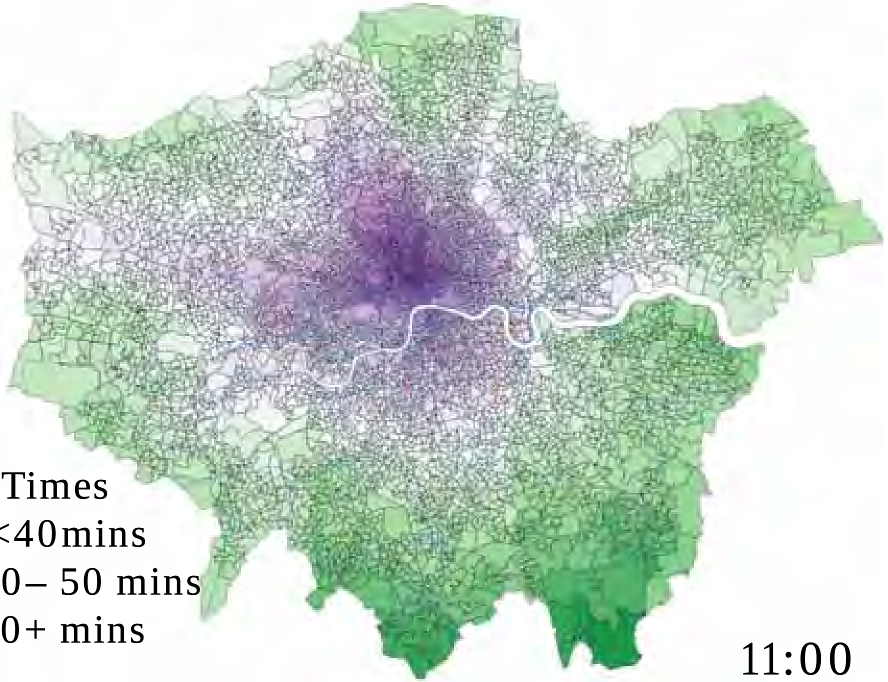
Gerry Casey

Gerry Casey



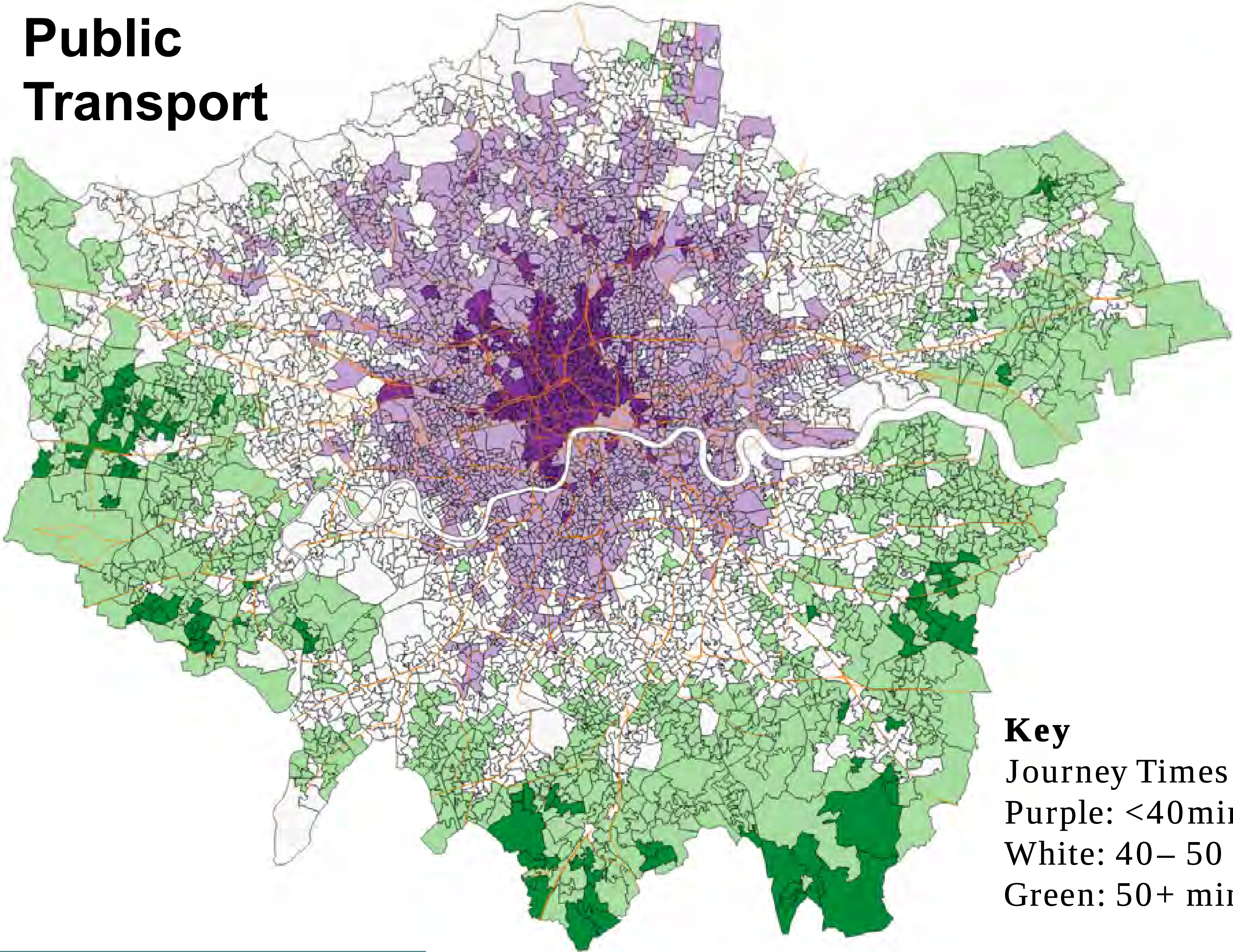






Key
Journey Times
Purple: <40mins
White: 40– 50 mins
Green: 50+ mins

Public Transport



Key
Journey Times
Purple: <40mins
White: 40– 50 mins
Green: 50+ mins

Transit to St Pancras - 08:00

Gerry Casey

Agent Based Model

- Modelling individual behaviours from multiple, heterogeneous, distinct agents

- Stochastic rather than deterministic

- Modelling how people use HS1 to travel to mainland Europe

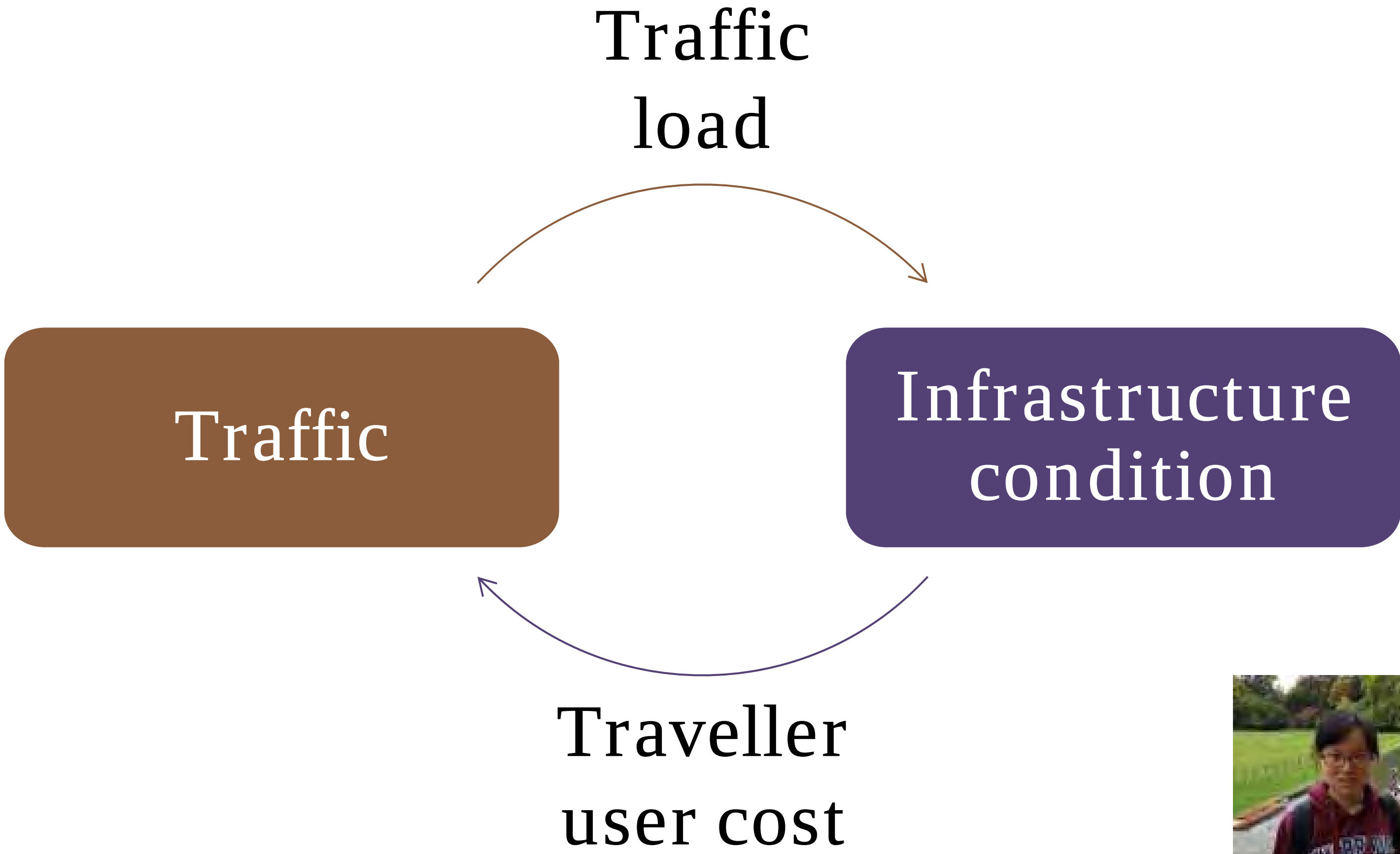
- Understanding how it has been historically used
  - Airplane versus Waterloo versus St Pancras
  - Carbon saving, etc..

- Many other things!

Elisabete Silva

Gerry Casey

From traffic to infrastructure



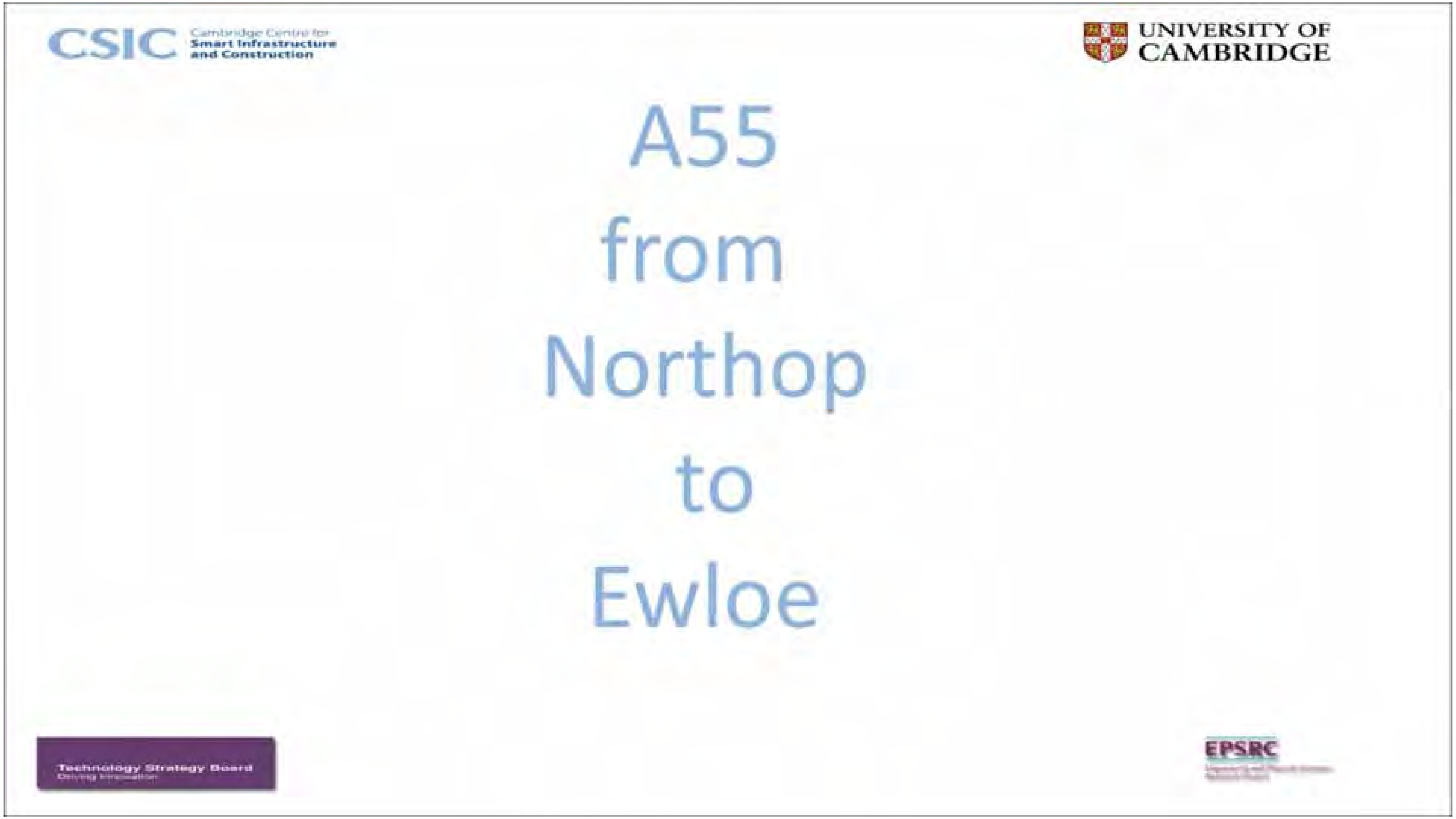
Bingyu Zhao

Transport infrastructure degradation leads to

- Bad visual impression
- Poor riding quality
- High fuel consumption
- Increased waste emission
- Threats to public safety
- More maintenance effort

Road in good condition (left) and with degradation (right)

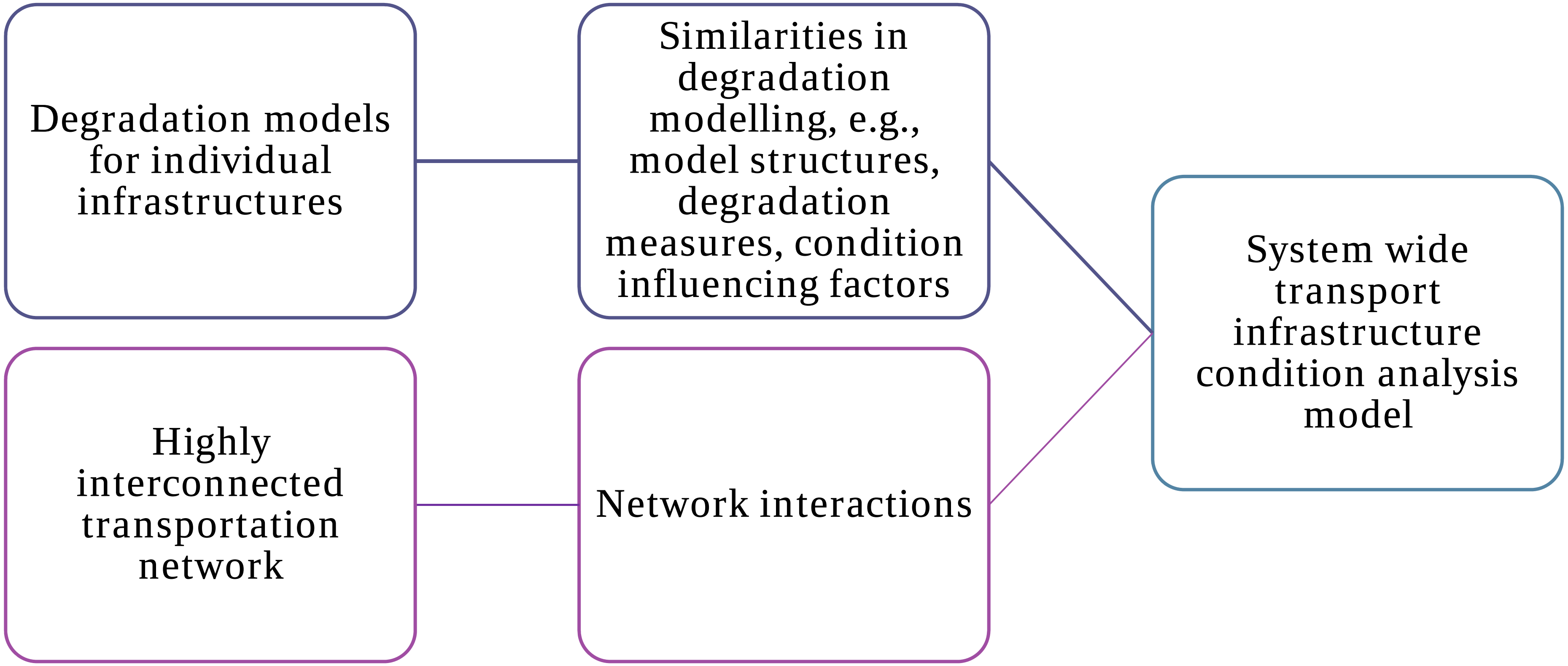
Rail defects are direct cause of Hatfield derailment in 2000



Infrastructure condition inspection using smart technology

Video provided by Dr Simon Hartley, CSIC, University of Cambridge

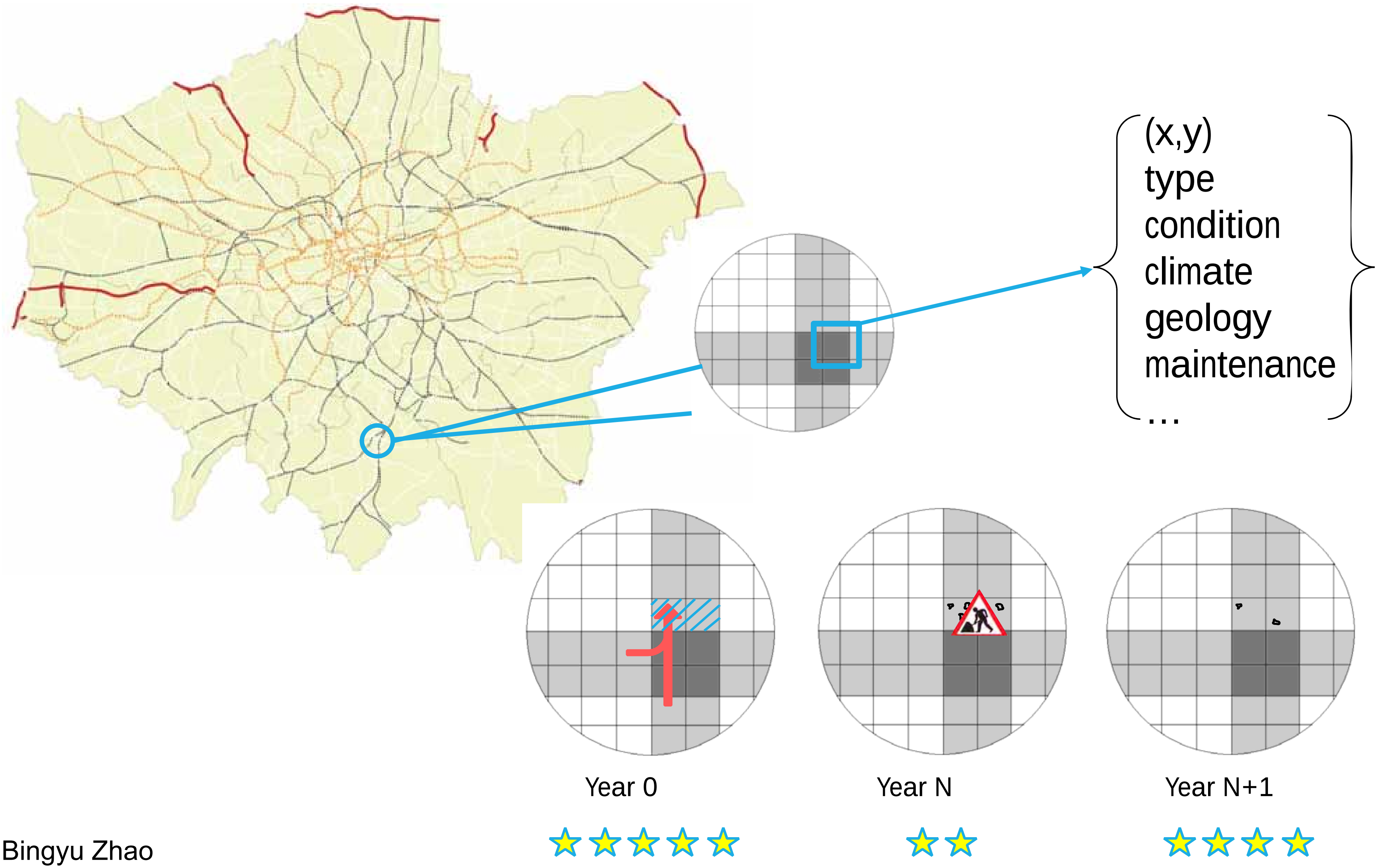
The need of system wide degradation analysis



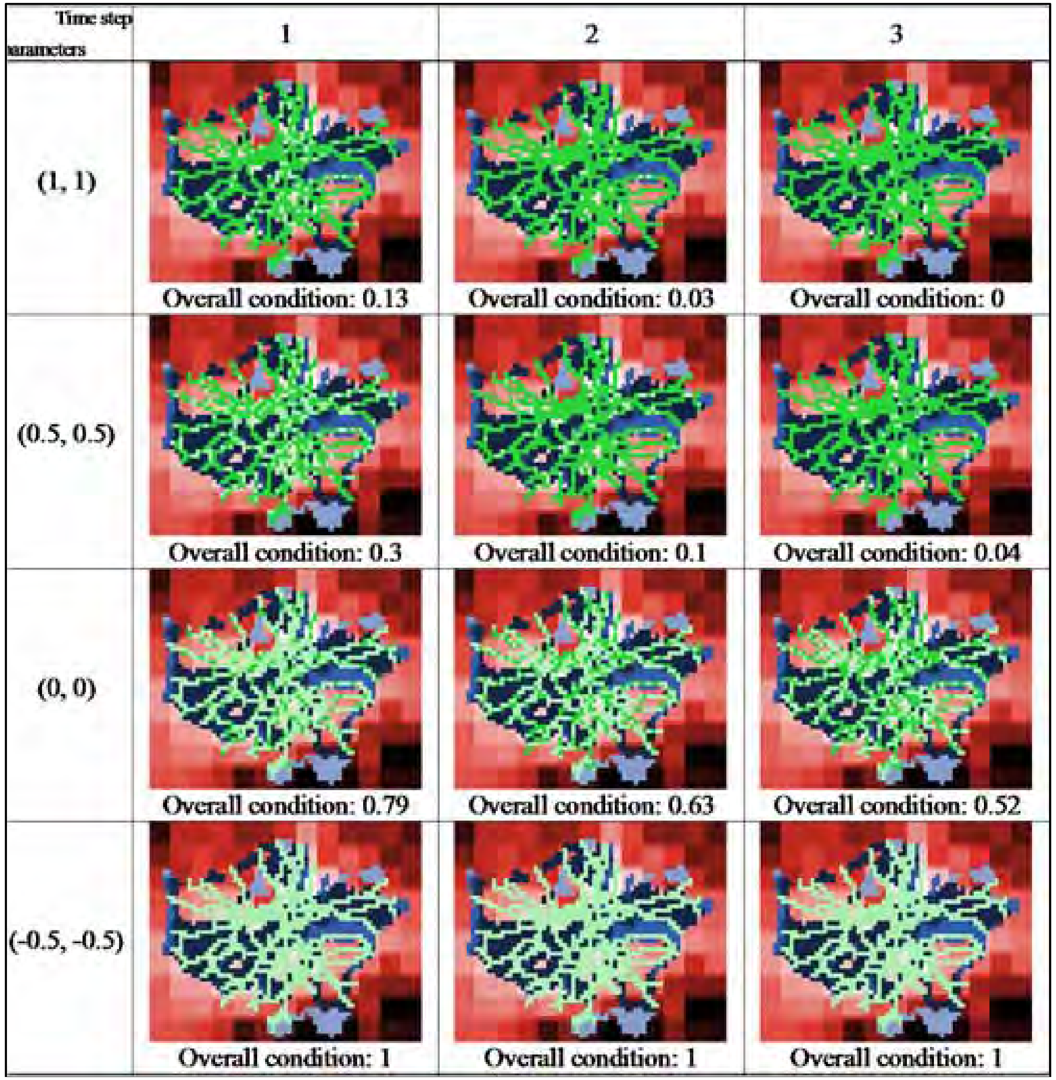
Summary of transport infrastructure degradation models in the literature

	Road	Railway (including tram)
Empirical models	ASSHTO guide for design of pavement structures (ASSHTO, 1993) PARIS (European Commission, 1999) HDM-4 (Kerali, 2000)	INNOTRACK (INNOTRACK programme, 2009) TCDD (Jovanovic et al, 2012)
Mechanistic-empirical (M-E) models	MEPDG (ARA, Inc., 2004) WLPPM/LTPPM (Collop & Cebon, 1995)	TU Graz (Veit, 2007) MAINLINE (MAINLINE consortium, 2012)
Stochastic models	ADOT (Golabi, Kulkarni, & Way, 1982) HIPS (Busch, Holst, & Christiansen, 2010) HMEP (Highway Maintenance Efficiency Program, 2012)	Melbourne Tram (Yousefikia, 2014) Markov (Prestcott et al., 2013) Petri Net (Andrews, 2012) SNCF exponential (Quiroga et al., 2012) SNCF gamma (Meier-Hirmer et al., 2009)

Cellular Automata (CA) + Agent Based Modelling



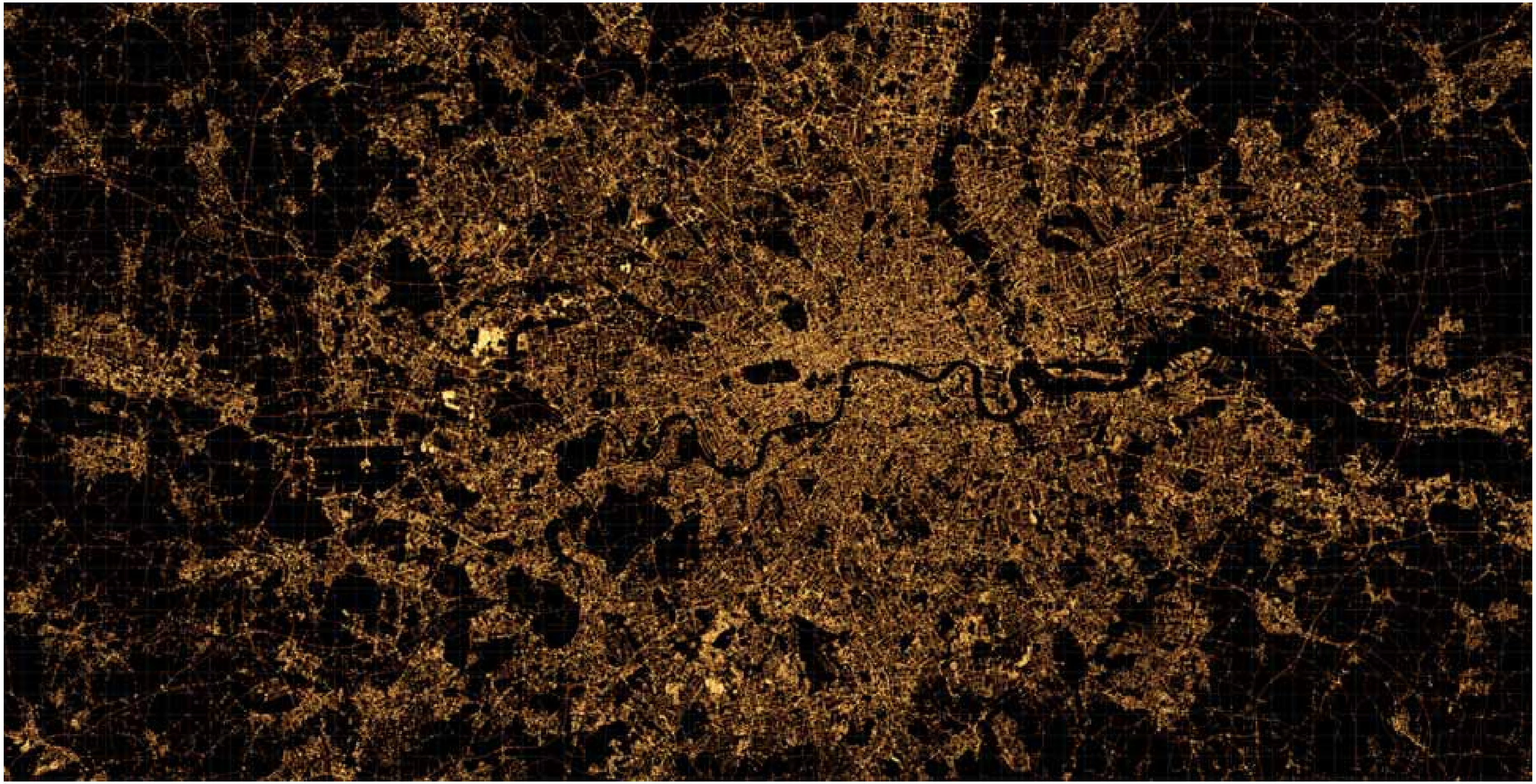
Case study: London railway network degradation simulation



Netlogo

Bingyu Zhao

CSIC - Open source city scale simulator - Prototype



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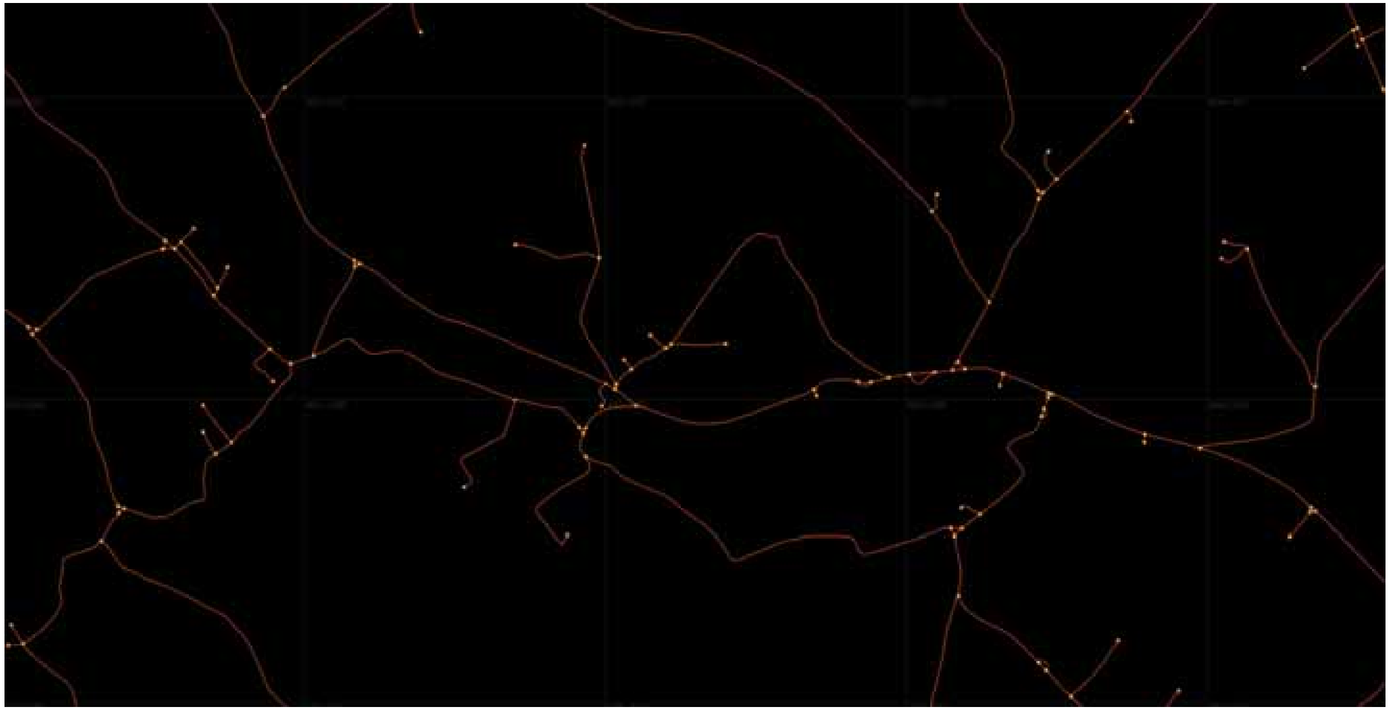

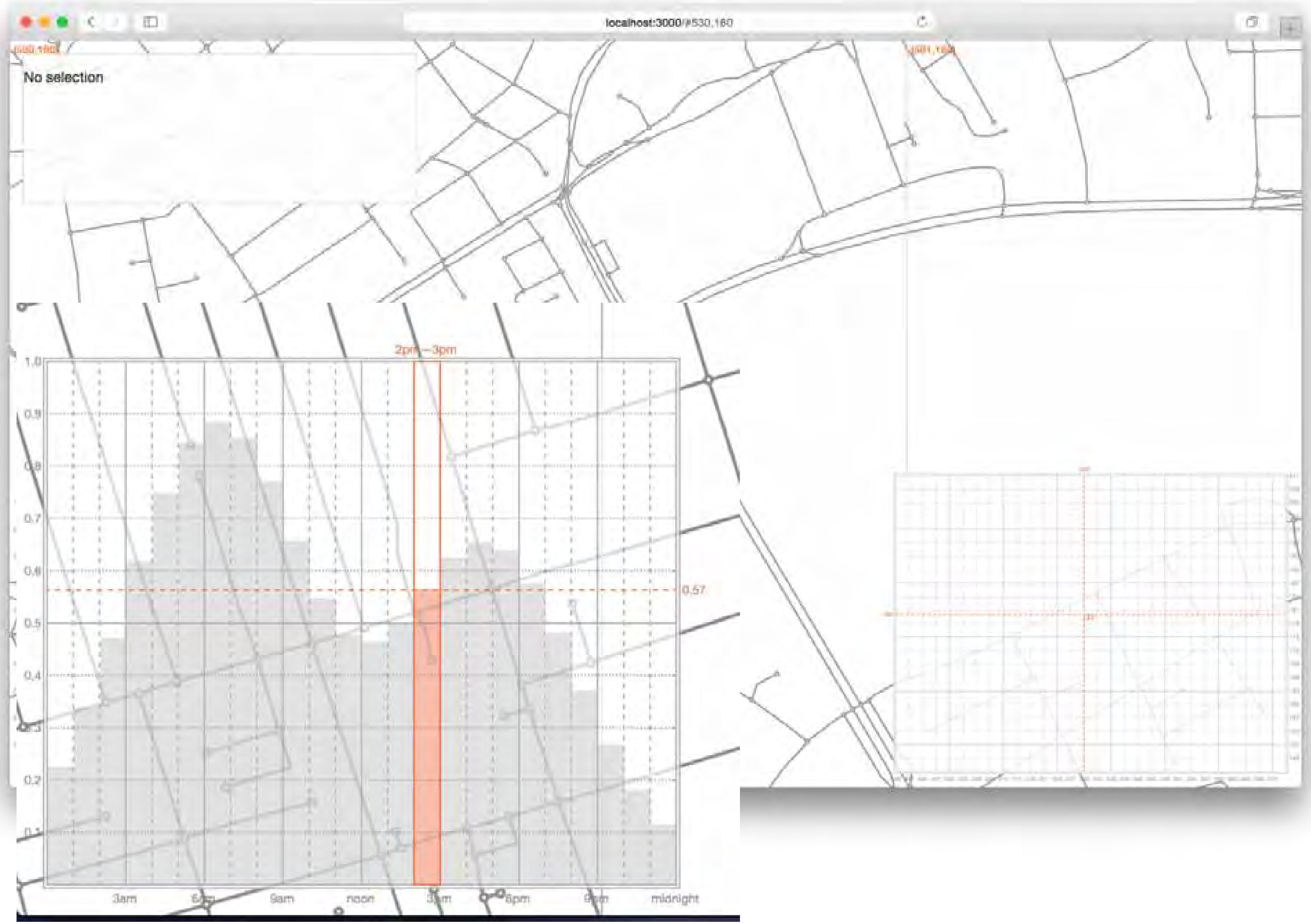
localhost:3000/#530,160
No selection
2pm – 3pm
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.2
0.57
3am
9am
noon
6pm
midnight


Sensors
Asset
City
Thank you