Investigating the Performance of Transport Infrastructure Using **Real-Time Data** and a **Scalable Agent-Based Model**

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CSIC Cambridge Centre for Smart Infrastructure & Construction

PEER

CSIC Cambridge Centre for **Smart Infrastructure & Construction**

“Transform the future of infrastructure through smarter information”

Infrastructure Clients (Owners and Operators)

Crossrail, Underground, Thames Water, Tube Lines, Transport for London, highways england, NetworkRail, Transport Scotland, Humber Bridge Board, nationalgrid

Consultants, contractors and asset managers

ARUP, ITM Monitoring, Cementation Skanska, Laing O'Rourke, Mott MacDonald, ch2m, Costain, Geo Geotechnical Observations, gi energy, Soldata, Atkins, WSP Parsons Brinckerhoff, Capita Symonds

Technology & information supply chain

RedBite, Topcon, Thales, Senceive, Omnisense, Toshiba Leading Innovation, IBM, zühlke, GE Aviation, Cobham, iMetrum, GeoSense, RolaTube™

Knowledge partners

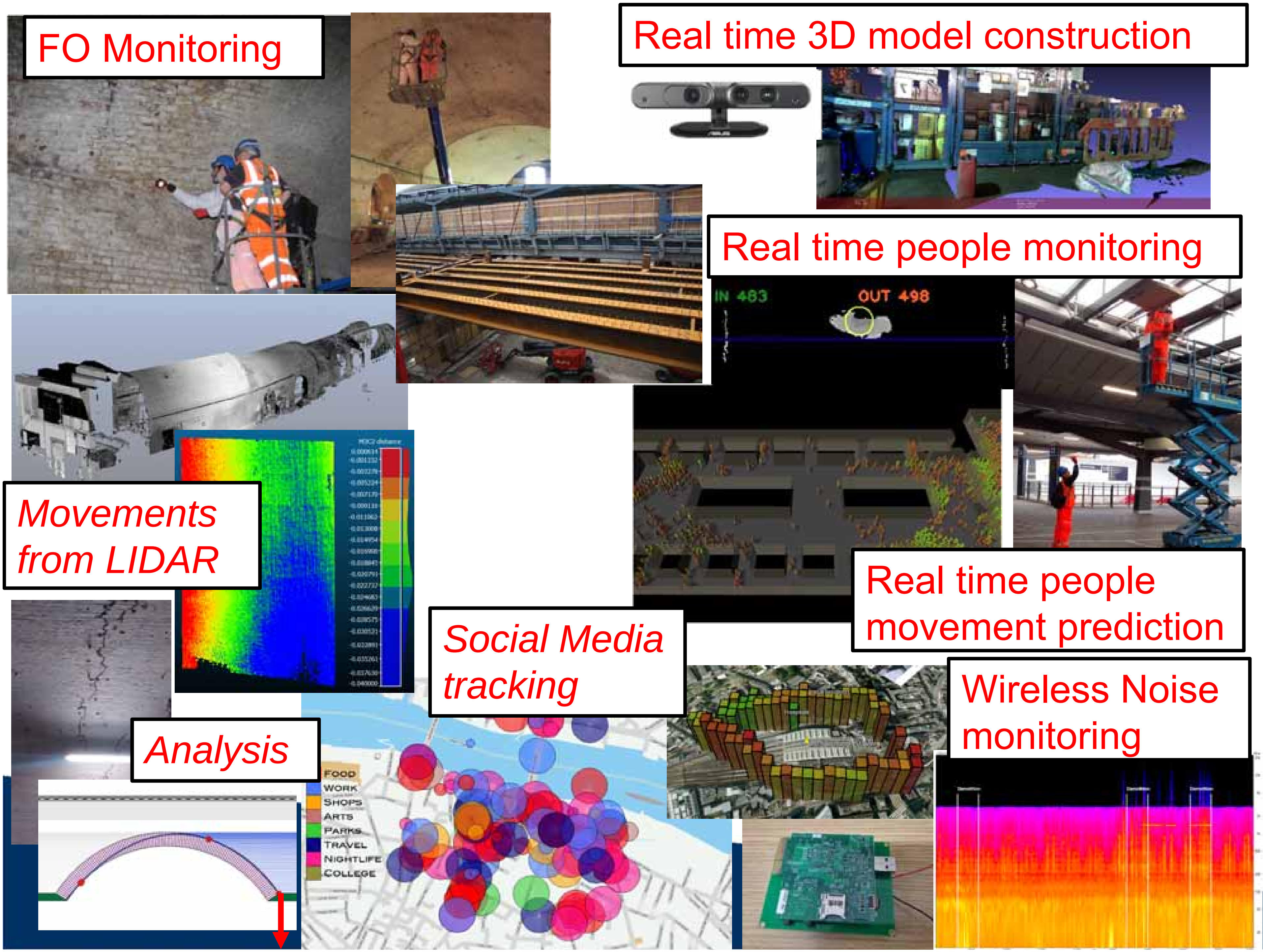
CERN, The University Of Sheffield, ciria, bre, Infrastructure UK, Imperial College London, City University London, RICS, TRL, UCL

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

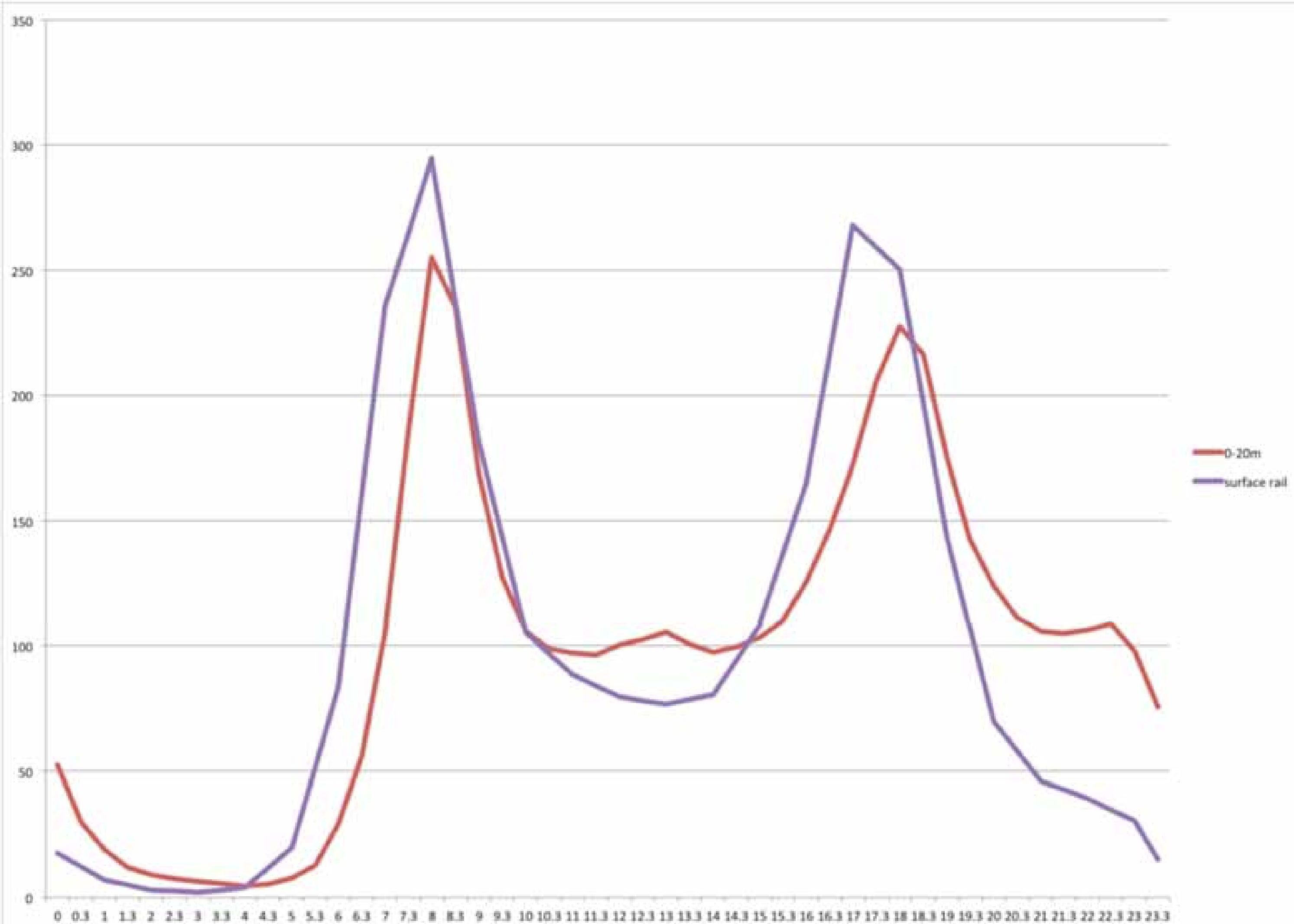
- Oldest station in London – First built in 1836
- Five Year Improvement Programme, while running its regular service
- 6.5 billion pounds
- Started in 2013
- For longer trains and more frequent services
- 50% increase in passenger
- 66% more space
- 24 trains per hour by 2018
- The largest concourse in the UK

Sinan Acikgoz

Loizos Pelecanos


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

Temporal concentration of twitter presence 20m from Rail compared to rail trips in progress from NTS2012



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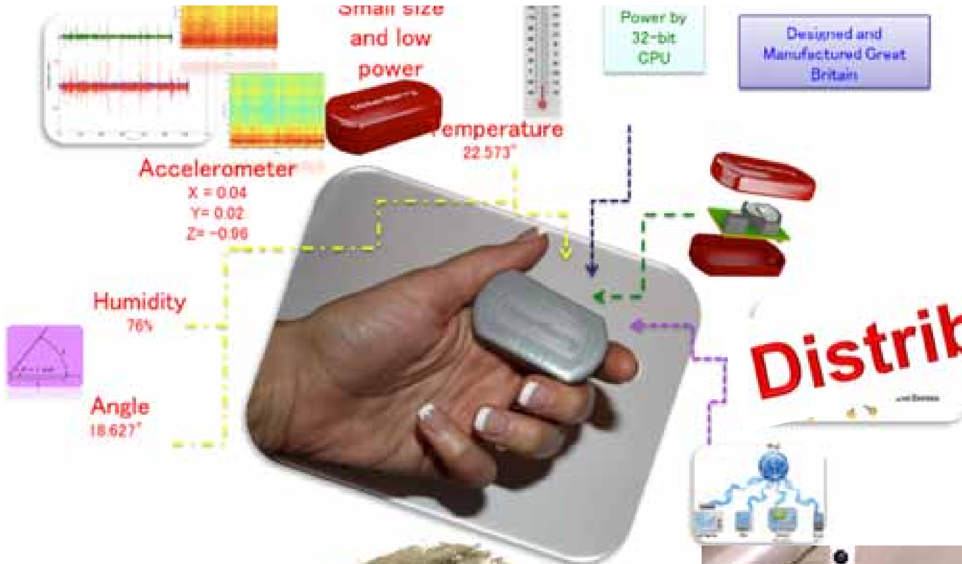
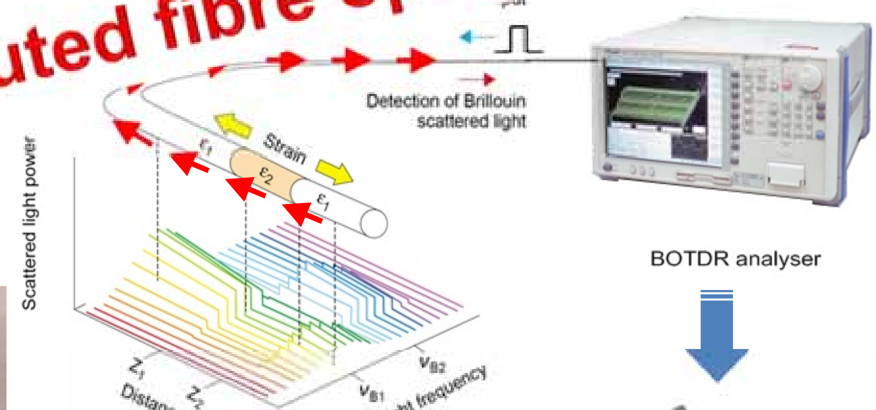
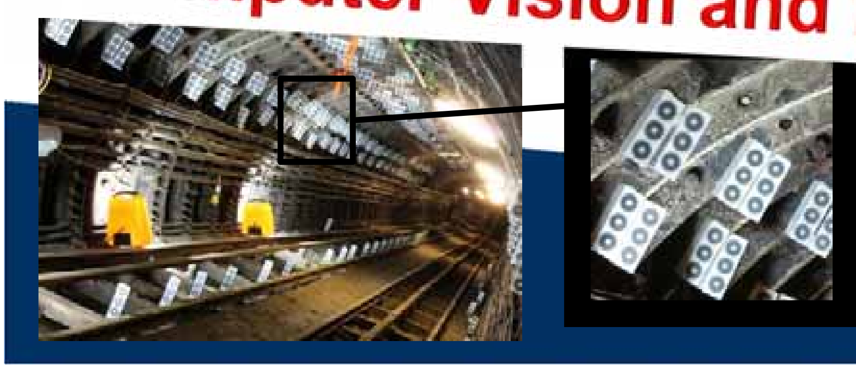
Ultra low power wireless sensor network

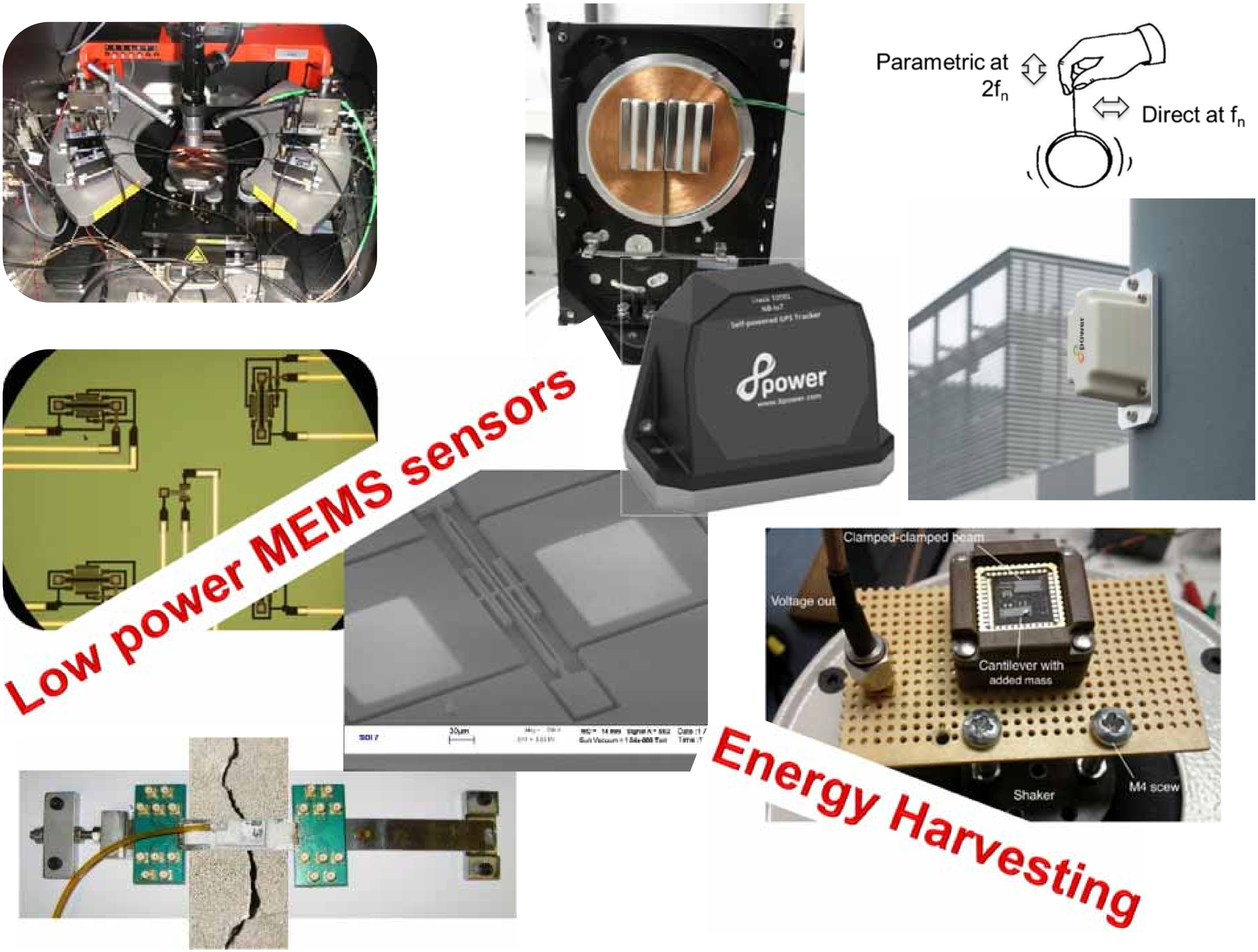


Distributed fibre optic sensing



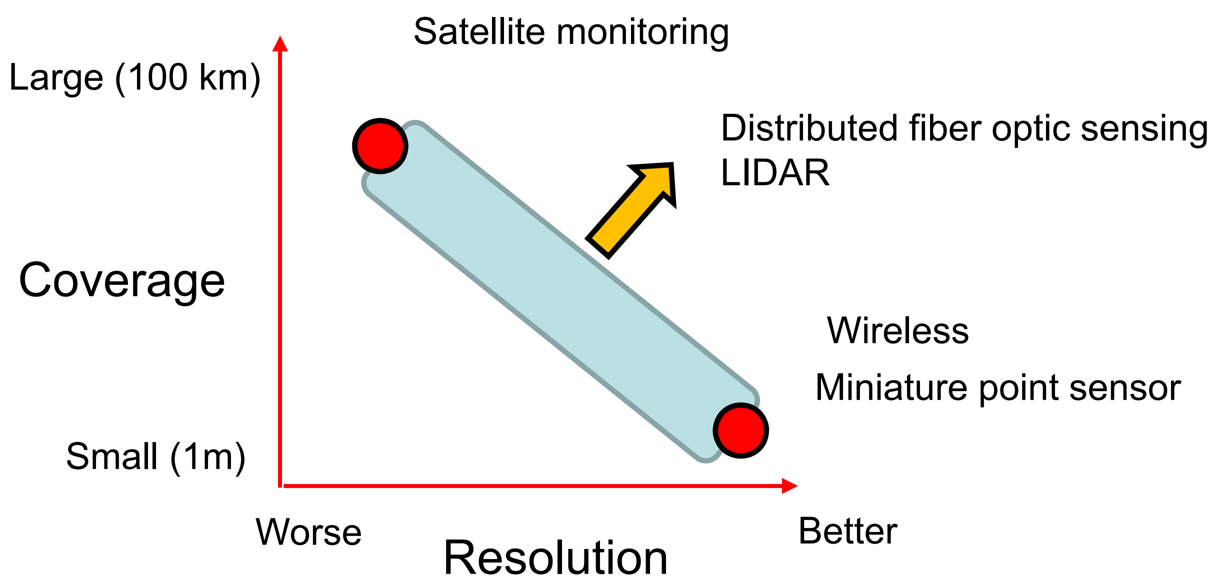
Computer Vision and Robotics



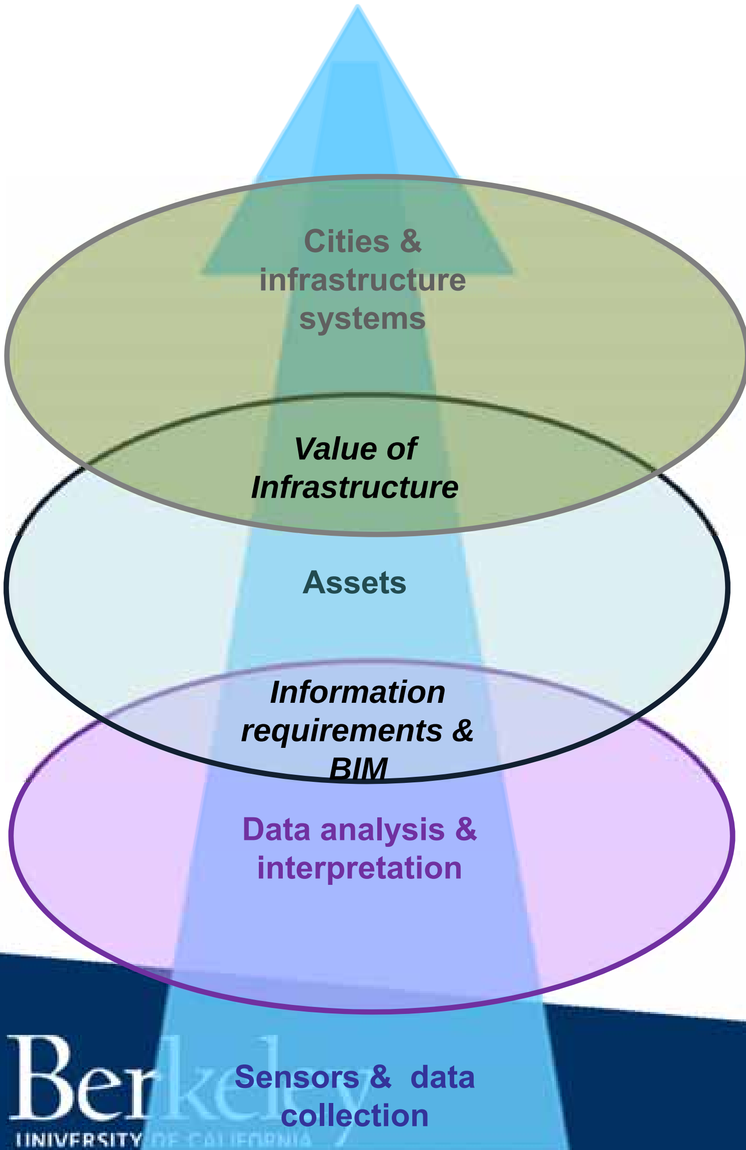

Parametric at $2f_n$
Direct at f_n
power
Clamped-clamped beam
Voltage out
Cantilever with added mass
Shaker
M4 scew
30µm
Low power MEMS sensors
Energy Harvesting

Sensor development - Trend

- Better accuracy, resolution and precision
- “Point” sensors to “Distributed” sensors
- Wider coverage
- Smaller and low power
- More dynamic (faster data acquisition)
- More robust
- Better communication (wireless)
- **Long performance**



A Bigger Picture….
The Value of Sensing needs to be evaluated.



CITY-SCALE SYSTEM OF SYSTEMS
- *What economic value does our infrastructure create?*
- *How does our infrastructure best serve our communities?*
- *What form should our infrastructure take?*

LIFETIME VALUE OF INFRASTRUCTURE
- *How do we operate, manage & maintain our assets to deliver best whole life value?*
- *How do we futureproof our assets against changing requirements & against shocks?*
- *What decisions? what information?*

EFFICIENT ANALYSIS AND INTERPRETATION IN REAL TIME
- *How do we best design, construct & monitor our structures to deliver the performance we need?*
- *What data do we need to do this, & how do we interpret it?*

ROBUST SENSOR SYSTEMS
- *What sensors do we need?*
- *How can we make them robust?*
- *Reliable, robust systems for data collection*
- *Standards to enable interoperability*

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Goal: Moving from *single bridge* fragility to *corridor* fragility

Multiple bridges

Embankment fills

Liquefaction

Slope failure

Consider impact of alternative routing

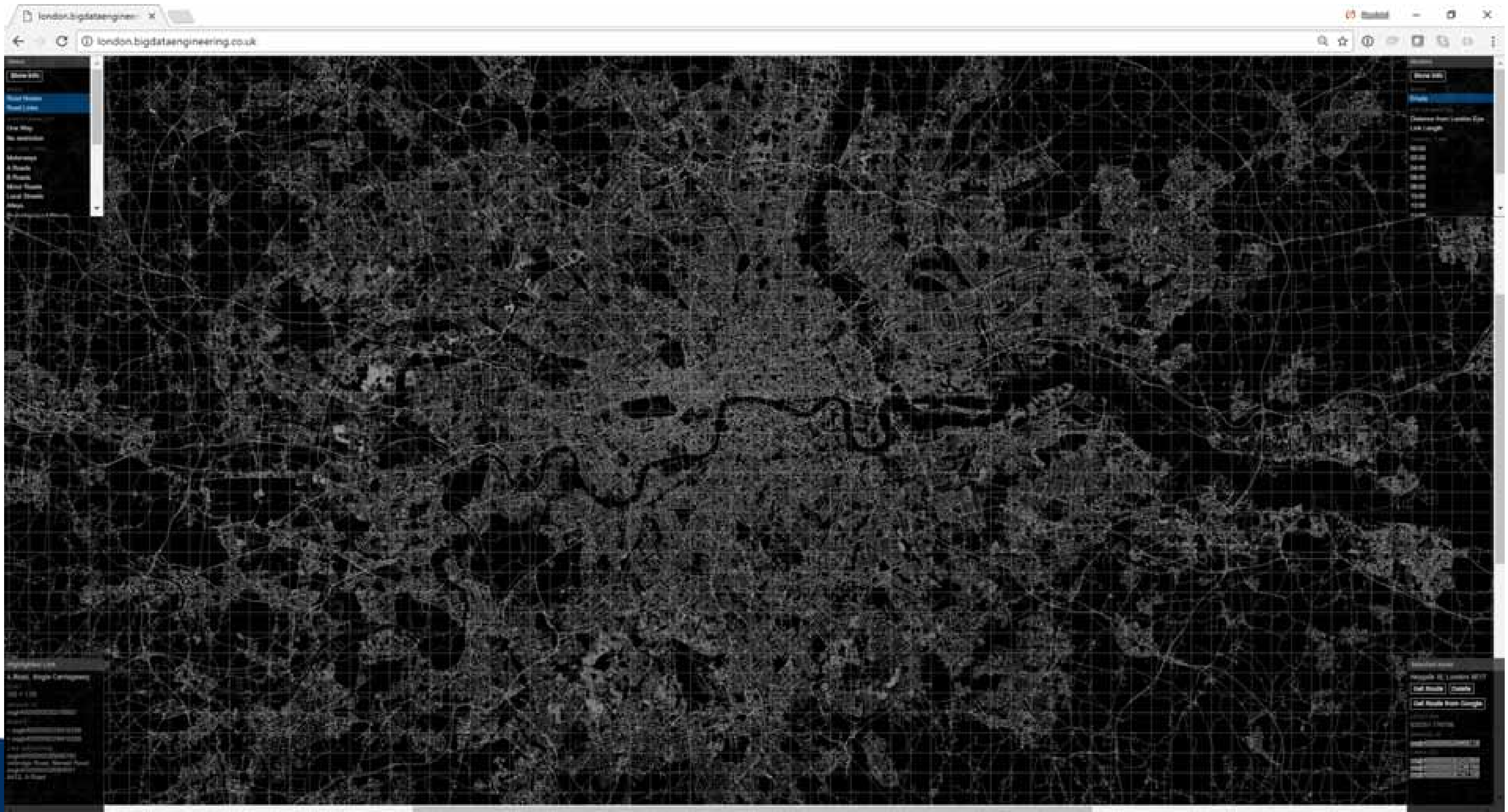
How do we prioritize which corridors to strengthen?

Scenario Planning will be a critical tool in reaching consensus

Caltrans

Tom Shantz

Macro View



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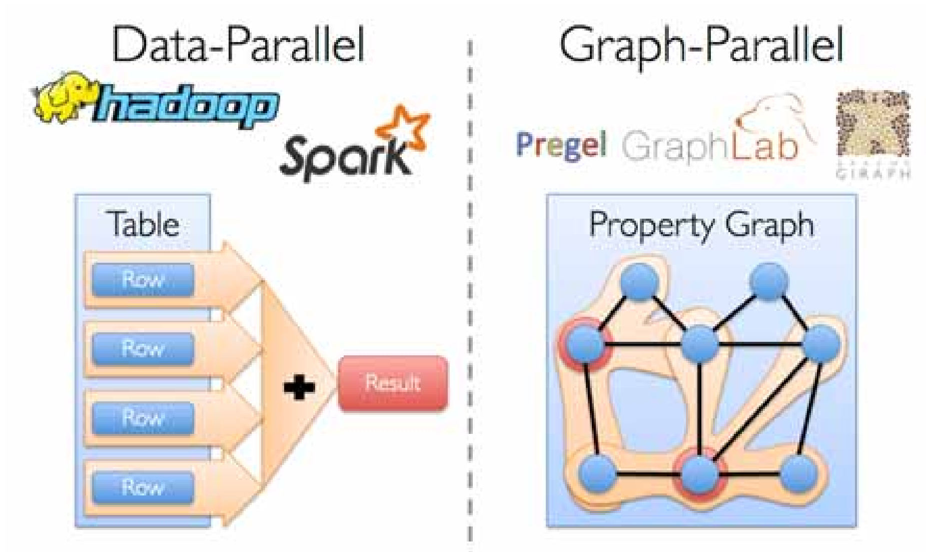
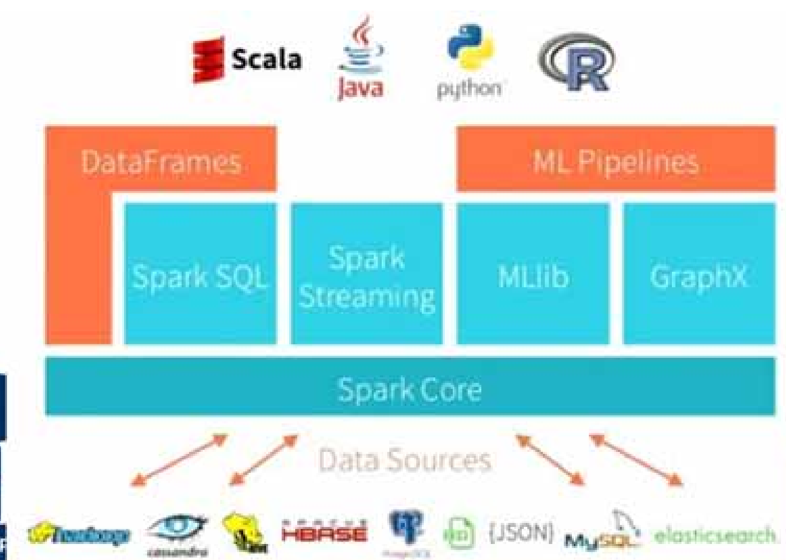
High Performance Computing and Graph Database





- Graph MapReduce
- In-memory cluster computing
- Decentralised data structures

- Graph size
  - ~250k nodes
  - ~800k edges

- ~1.5GB .gml to 43MB .json.gz

Micro View

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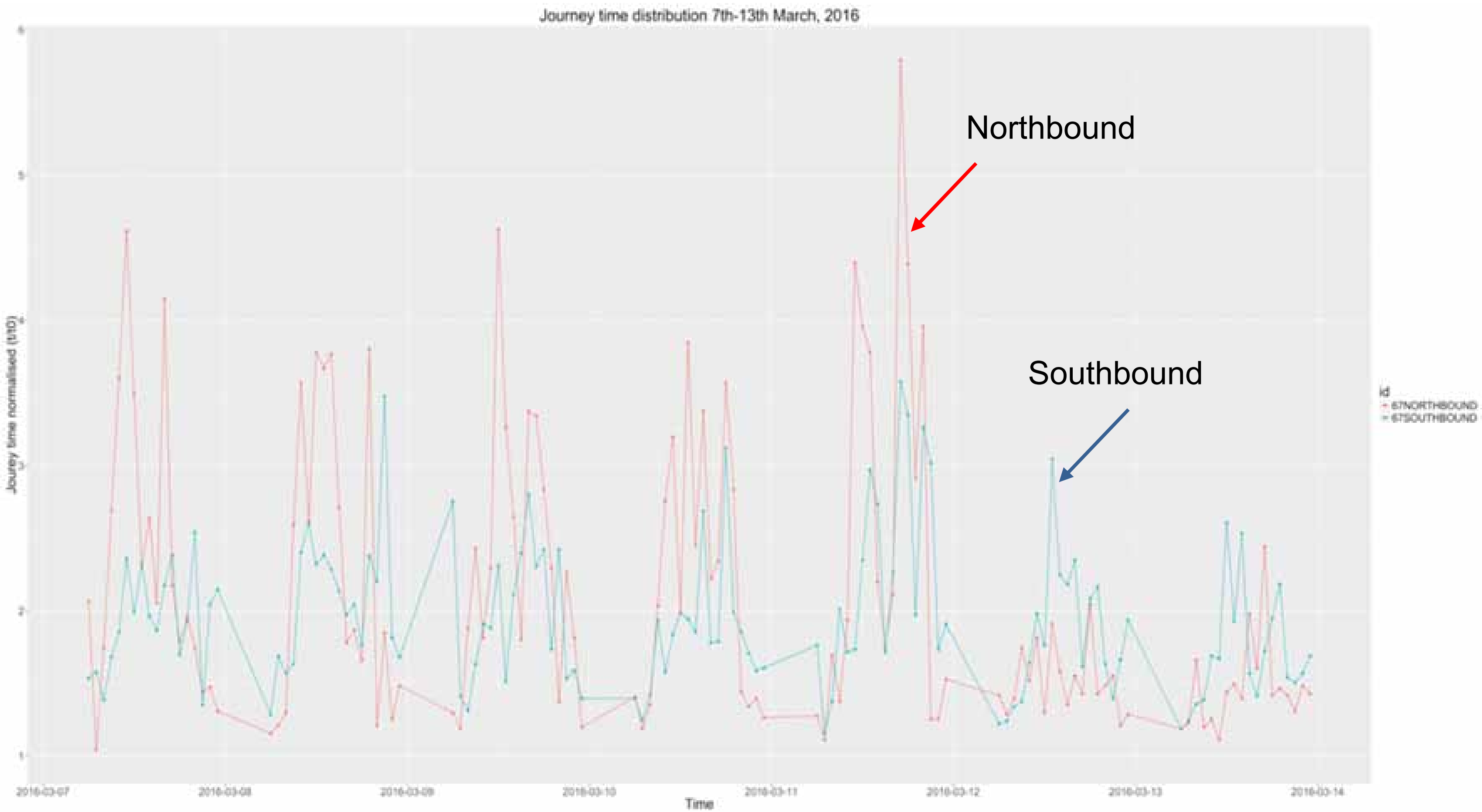
Crowd sourced data
Google Travel time distributions



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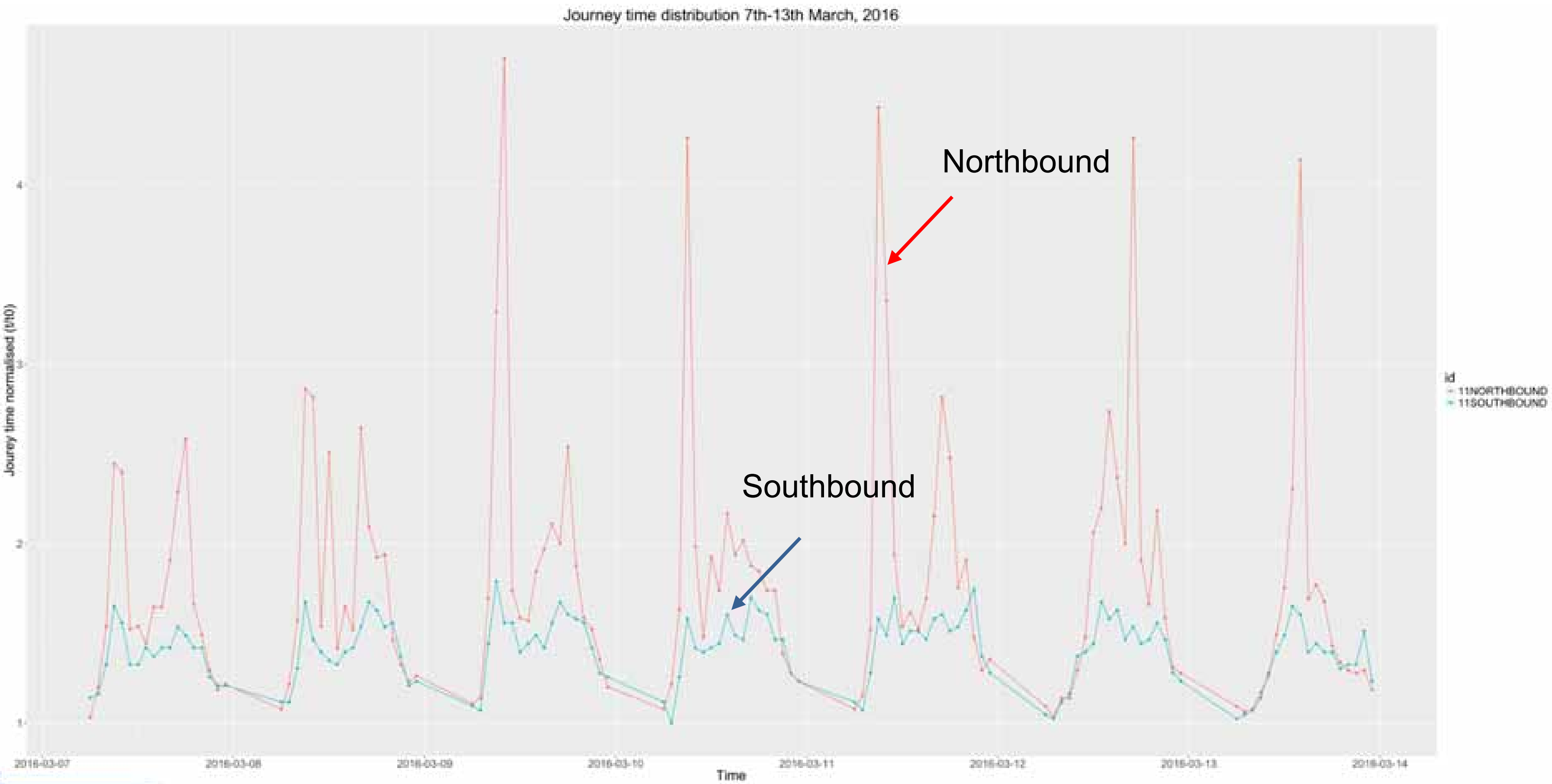
Travel time distributions



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Travel time distributions

A208, Chiselhurst. Newshopper.co.uk, 2016

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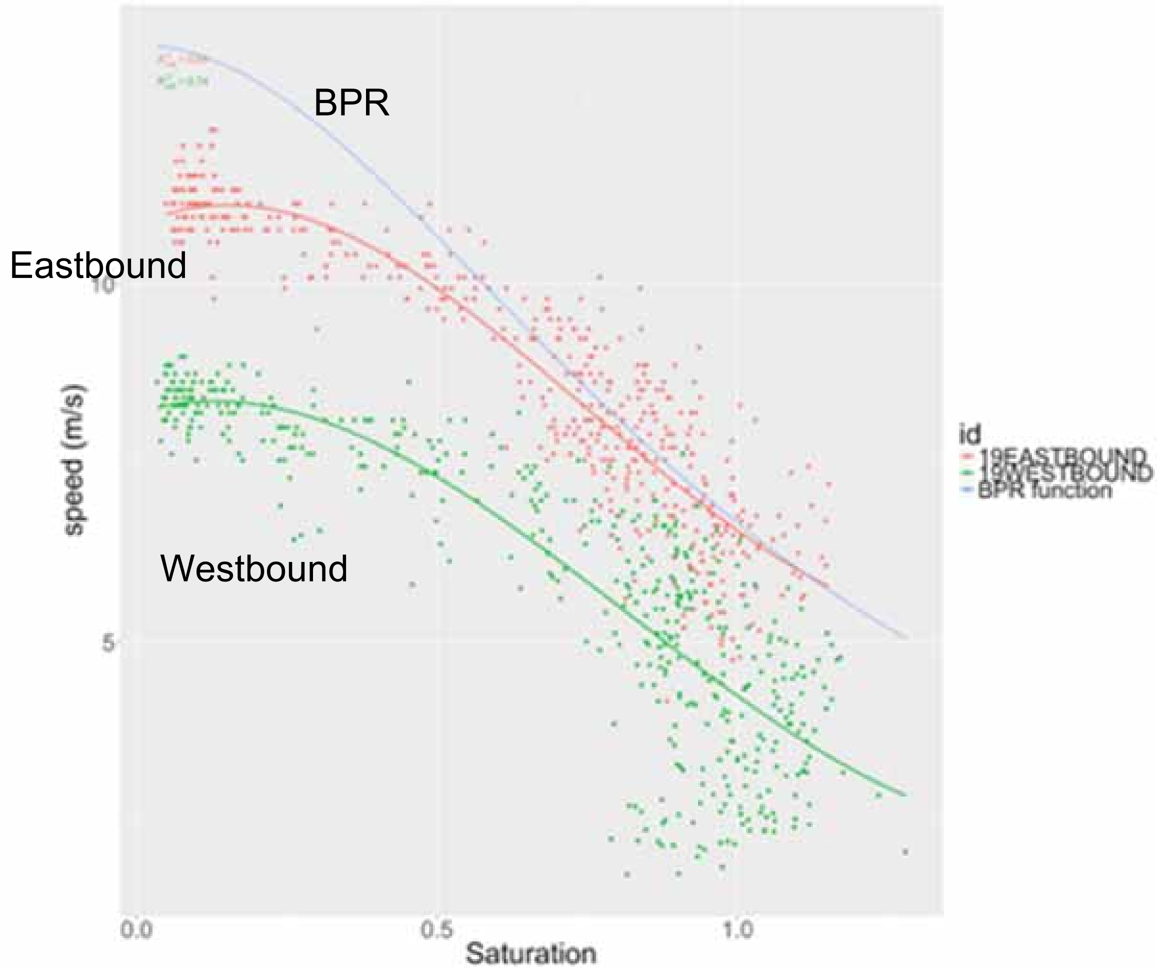
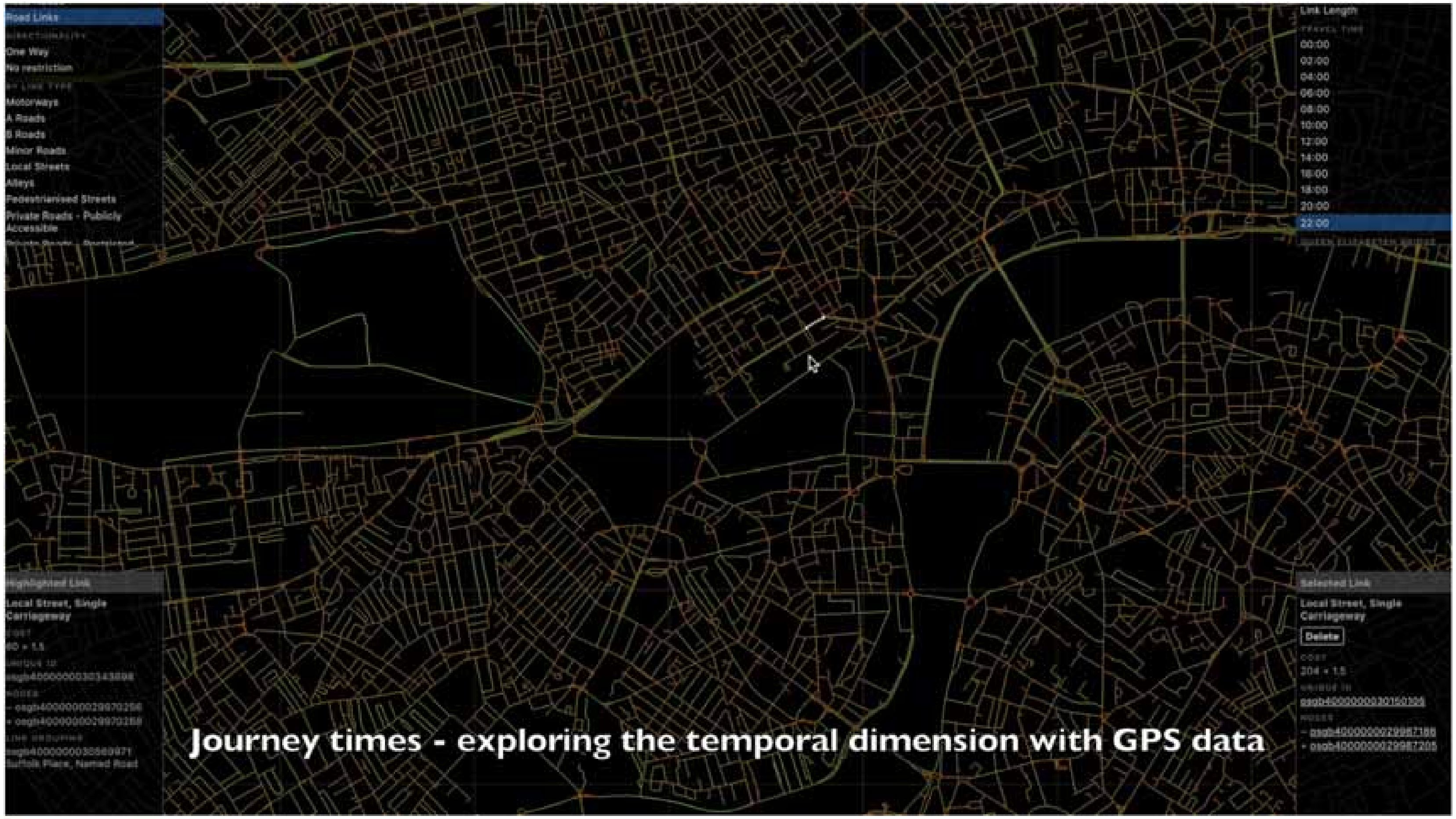
Context specific volume-delay functions



Agent Based Model – Scenario testing
30 min interval movement of 300,000 agents (5% of London population)



Emerging behaviour, cascading behaviour, reactive & adaptive agents….

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ABM Model Capability and Performance

The London ABM:

1. 250,000 nodes and 800,000 links

2. 300,000 agents with personal attributes;

3. An agent searches for (weighted) shortest routes based on traffic condition simulation results from the last time step. The graph (the link-level weight created by traffic) is updated at 30 minutes interval.

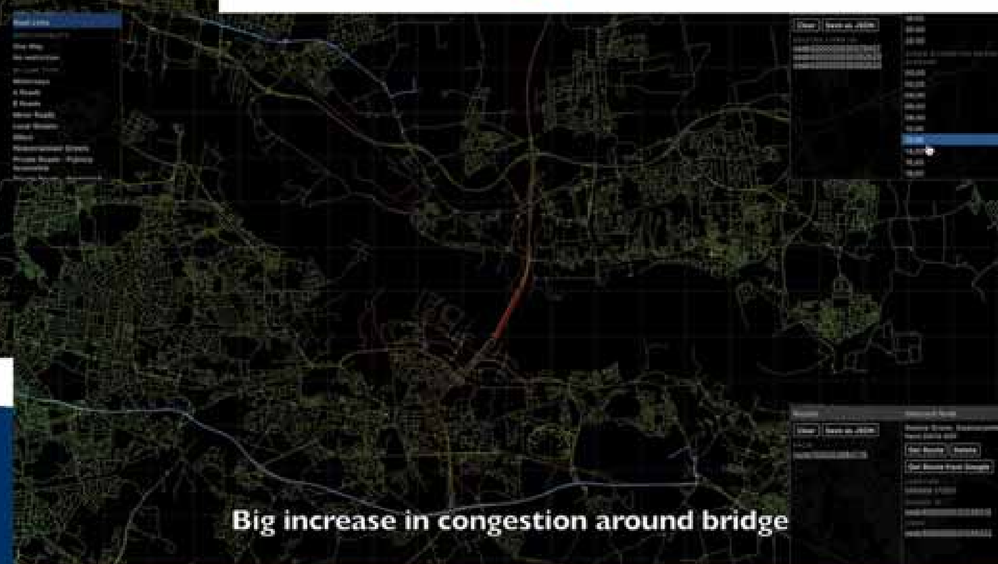
4. Using 6-node Microsoft Azure HD Insight (Apache Spark) cluster (2 master nodes and 4 compute nodes)

ABM Model Outcomes

1. Modeling traveler behaviors
2. Simulating traffic congestions due to the excessive travel demand in the urban road network;
3. Modeling dynamic traffic distributions under emergencies such as infrastructure failure.

No bridge closure

Bridge closure



Iterative decision making models

Decision making Model

Data

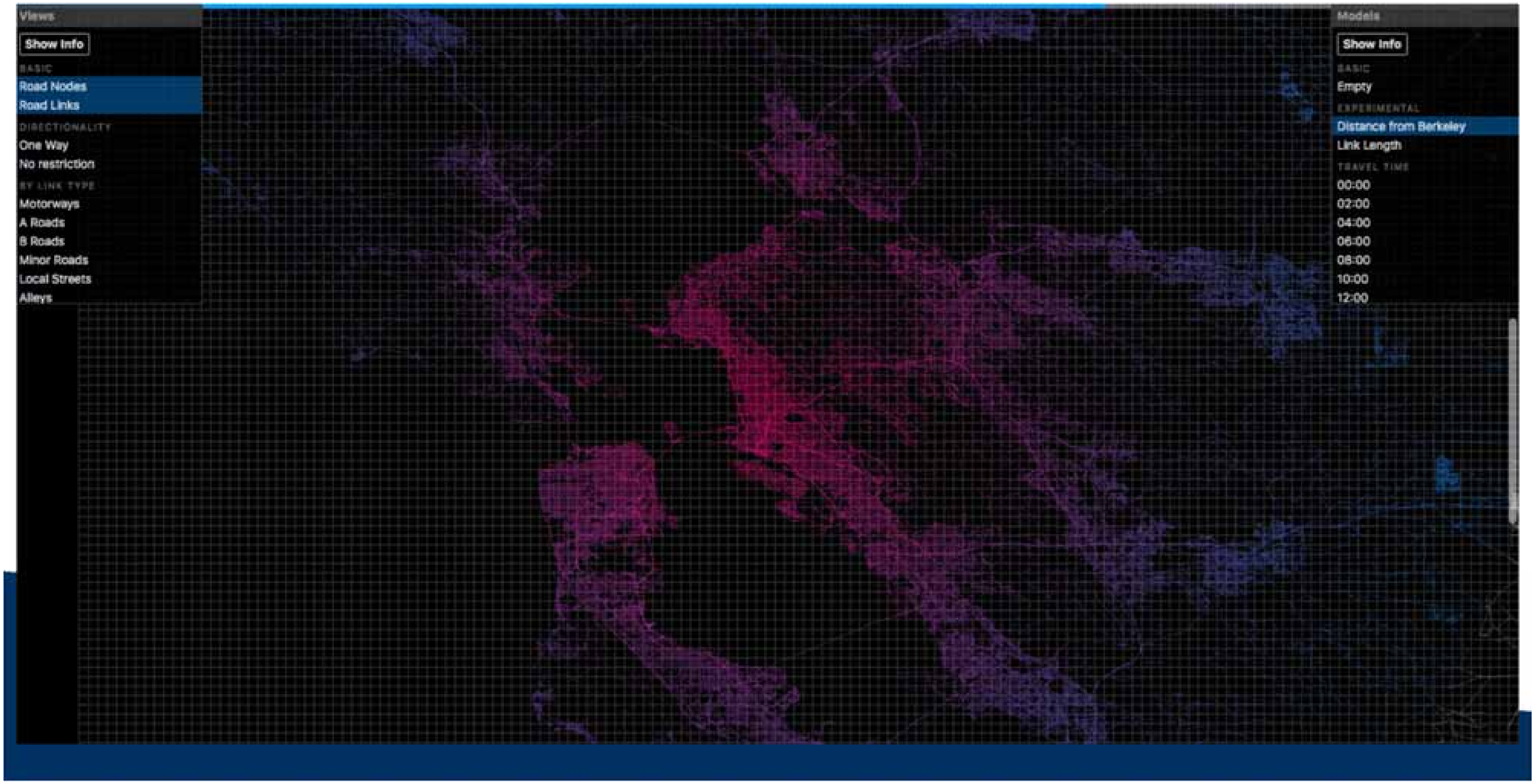
+ disruptive event {sudden precipitation}

In Real-time

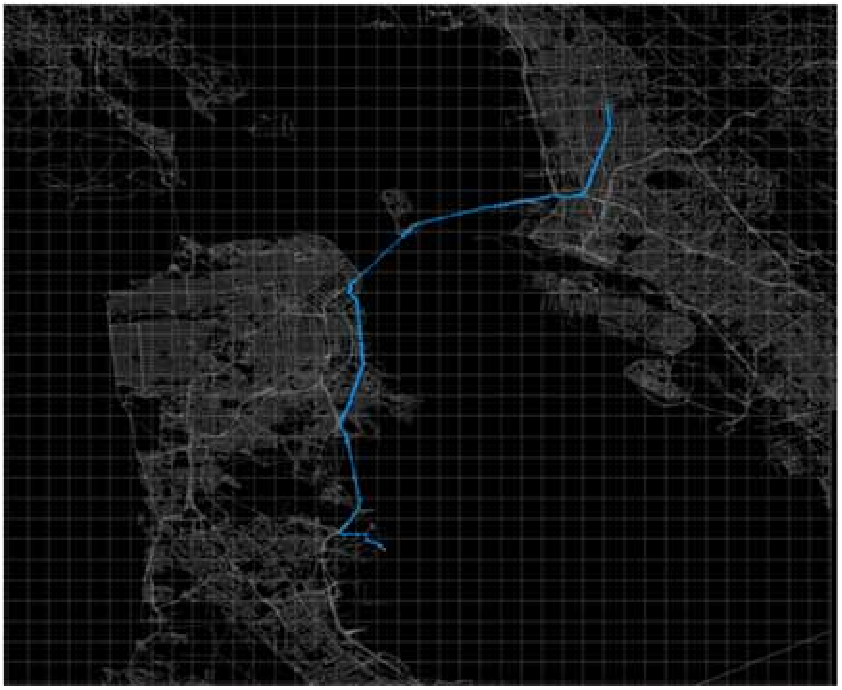
- How should transit operators respond locally and globally?
- How should traffic lights respond?

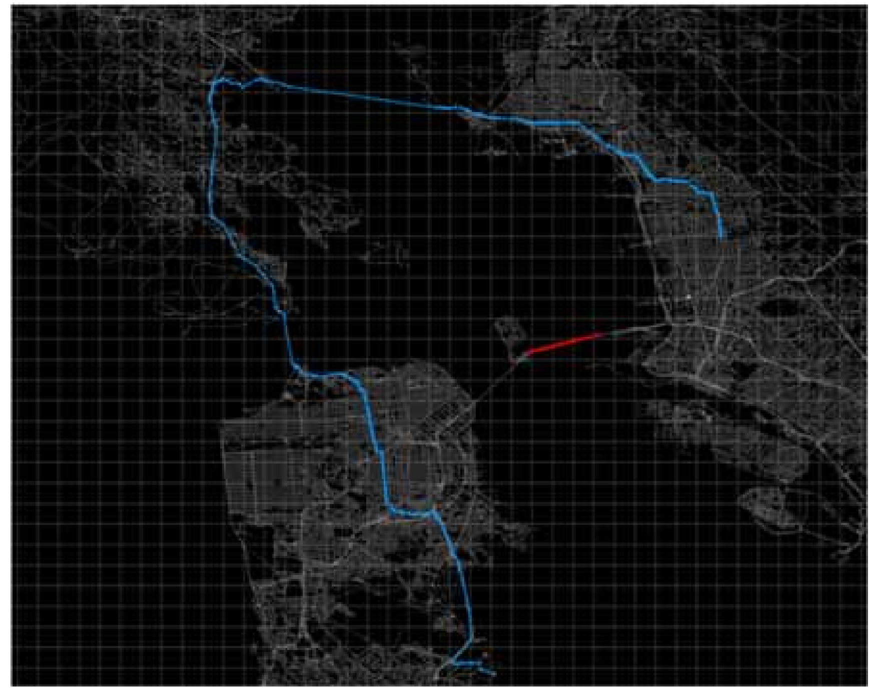
Bay Area Road Network

1. Data from OpenStreetMap
2. 380,000 nodes and 500,000 links
3. Interactive demonstration at http://sf.cb-geo.com:3000/

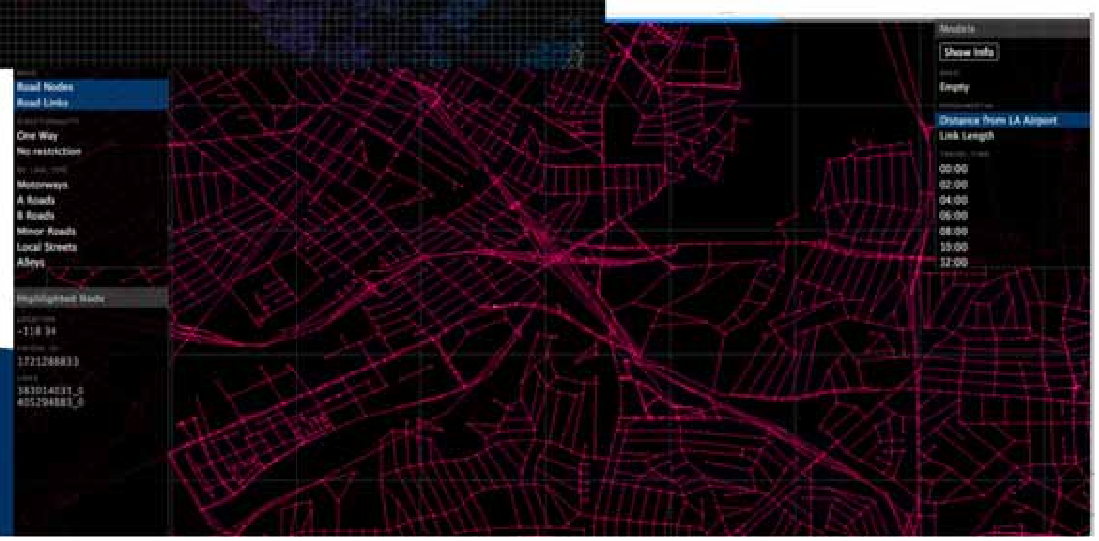


Routing before and after Bay Bridge Closure





LA Road Network
381,000 nodes, 491,000 links



City-scale interaction simulation between Water Pipeline Network and Traffic network

1. Water pipeline network:
   - EBMUD 108,676 pipes
   - LADWP 300,000 nodes
2. Hydraulic Analysis (Head loss) simulations:
   - 300,000 nodes
   - 4 GPUs Pascal P100
   - Matrix Assembly 2 sec, Solver 1 sec.
   - 1000 scenarios → 40 minutes
3. But better Visualization is needed to make decisions by different stake holders

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Joan Walker
Alex Bayen
Jack Baker

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Summary

- Innovation in sensors as part of Internet of Things
- Need to quantify the value of sensing for smart infrastructure
- Micro-simulations at the city scale is becoming possible
  - Agent based model for traffic modeling
  - Dynamic water flow modelling
- Thanks to recent developments in high performance computing and graph database.
- Opportunity to model large scale systems in real time
  - Rapid recovery scenario testing after an event (e.g. pipeline bursts after EQ)

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Thank you