Smart Infrastructure

Kenichi Soga

UNIVERSITY OF CAMBRIDGE

CSIC Cambridge Centre for Smart Infrastructure and Construction
Establishment of “Infrastructure UK” in 2010
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%
Industrial Strategy (2013)

Innovation and Productivity

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 new build 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

Construction 2025

CSIC
Cambridge Centre for Smart Infrastructure and Construction

EPSRC
Engineering and Physical Sciences Research Council

Innovate UK
Technology Strategy Board

University of Cambridge
Mission:

“Transform the future of infrastructure through smarter information”

Vision:

• Enable step changes in construction practice
• Establish a world-leading sensing and monitoring industry
• Extend asset life & reduce management costs
Ultra low power wireless sensor network

Distributed fibre optic sensing

Computer Vision and Robotics
Low power MEMS sensors

Energy Harvesting
The smart infrastructure and construction industry

Owners & Operators
- Public Sector
- Private Sector

Consultants & Contractors
- Design, construction, operation
- Instrumentation and monitoring

Technology & Information Suppliers
- Large companies
- SMEs
Field demonstrations & case studies
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
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”
London Bridge station, one of the oldest train stations in the UK, is currently being redeveloped to increase its capacity.
FO Monitoring

Real time 3D model construction

Real time people monitoring

Real time people movement prediction

Social Media tracking

Movements from LIDAR

Analysis

Wireless Noise monitoring
Sensor deployment and live counting data

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

Stent, Martani, Jing
Simulating people flows for temporary station layouts

Zachariadis, Martani, Jing

Hoarding line shown with
Sensor location shown with
Wireless sensing and identification of noise
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

Can we link all this information to:
1) Retrieve a better understanding of response
2) Improve communication between agents

Jennifer Schooling
Krishna Kumar

BSI - Smart cities standard (PAS 182)
Westminster City, London
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)
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)
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
Elisabete Silva
Bingyu Zhao
Krishna Kumar

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Crowd sourced traffic congestion

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

Google Maps, 2015

<table>
<thead>
<tr>
<th>Data</th>
<th>Example</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrastructure</td>
<td>Nodes &amp; links (including directions)</td>
<td>OS, Google</td>
</tr>
<tr>
<td>Junction</td>
<td>Turn restrictions, lane locations &amp; junction costs</td>
<td>OS, Google</td>
</tr>
<tr>
<td>Traffic</td>
<td>Traffic congestion</td>
<td>Google</td>
</tr>
<tr>
<td>Real-time incidents</td>
<td>Accidents or road works</td>
<td>Waze, TFL</td>
</tr>
<tr>
<td>Financial</td>
<td>Fare costs</td>
<td>DfT, Operators (TfL, Eurostar etc)</td>
</tr>
</tbody>
</table>
Downe to St Pancras International journey times

Journey time (seconds)

- 50 mins
- 110 mins

Time

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

06:30

08:00

10:00

11:00
Transit to St Pancras - 08:00

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

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!
From traffic to infrastructure

Traffic load

Traffic

Infrastructure condition

Traveller user cost

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

Degradation models for individual infrastructures

Similarities in degradation modelling, e.g., model structures, degradation measures, condition influencing factors

Highly interconnected transportation network

Network interactions

System wide transport infrastructure condition analysis model

Bingyu Zhao
## Summary of transport infrastructure degradation models in the literature

<table>
<thead>
<tr>
<th></th>
<th>Road</th>
<th>Railway (including tram)</th>
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</thead>
<tbody>
<tr>
<td><strong>Empirical models</strong></td>
<td>ASSHTO guide for design of pavement</td>
<td>INNOTRACK (INNOTRACK programme, 2009)</td>
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<td></td>
<td>structures (ASSHTO, 1993)</td>
<td>TCDD (Jovanovic et al, 2012)</td>
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<td>PARIS (European Commission, 1999)</td>
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<td>HDM-4 (Kerali, 2000)</td>
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<tr>
<td><strong>Mechanistic-empirical (M-E) models</strong></td>
<td>MEPDG (ARA, Inc., 2004)</td>
<td>TU Graz (Veit, 2007)</td>
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<td></td>
<td>WLPPM/LTPPM (Collop &amp; Cebon, 1995)</td>
<td>MAINLINE (MAINLINE consortium, 2012)</td>
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<tr>
<td><strong>Stochastic models</strong></td>
<td>ADOT (Golabi, Kulkarni, &amp; Way, 1982)</td>
<td>Melbourne Tram (Yousefikia, 2014)</td>
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<td></td>
<td>HIPS (Busch, Holst, &amp; Christiansen, 2010)</td>
<td>Markov (Prestcott et al., 2013)</td>
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<td></td>
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<td>SNCF exponential (Quiroga et al., 2012)</td>
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<td>SNCF gamma (Meier-Hirmer et al., 2009)</td>
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</tbody>
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Cellular Automata (CA) + Agent Based Modelling

(x,y) type condition climate geology maintenance...

Year 0
Year N
Year N+1

Bingyu Zhao
Case study: London railway network degradation simulation

<table>
<thead>
<tr>
<th>Time step</th>
<th>1</th>
<th>2</th>
<th>3</th>
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<tbody>
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<td><img src="image2" alt="Image" /></td>
<td><img src="image3" alt="Image" /></td>
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<tr>
<td>Overall condition: 0.13</td>
<td>Overall condition: 0.03</td>
<td>Overall condition: 0</td>
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<tr>
<td>(0.5, 0.5)</td>
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<td><img src="image5" alt="Image" /></td>
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<td>Overall condition: 0.79</td>
<td>Overall condition: 0.63</td>
<td>Overall condition: 0.52</td>
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<tr>
<td>(-0.5, -0.5)</td>
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<td><img src="image11" alt="Image" /></td>
<td><img src="image12" alt="Image" /></td>
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<tr>
<td>Overall condition: 1</td>
<td>Overall condition: 1</td>
<td>Overall condition: 1</td>
<td></td>
</tr>
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</table>
CSIC - Open source city scale simulator - Prototype
Sensors
Asset
City

Thank you