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UK COLLABORIUM
FOR RESEARCH ON
INFRASTRUCTURE & CITIES
**Inspired infrastructure
for better living**

Transport and mobility

17 May 2022

William Powrie, University of Southampton

Transport and mobility: Key facilities



**National Infrastructure Laboratory,
Southampton**



**National Buried Infrastructure
Facility, Birmingham**



**Person-Environment-
Activity Research
Laboratory, University
College London**

Supported by Materials and Sensing Laboratories, Observatories etc

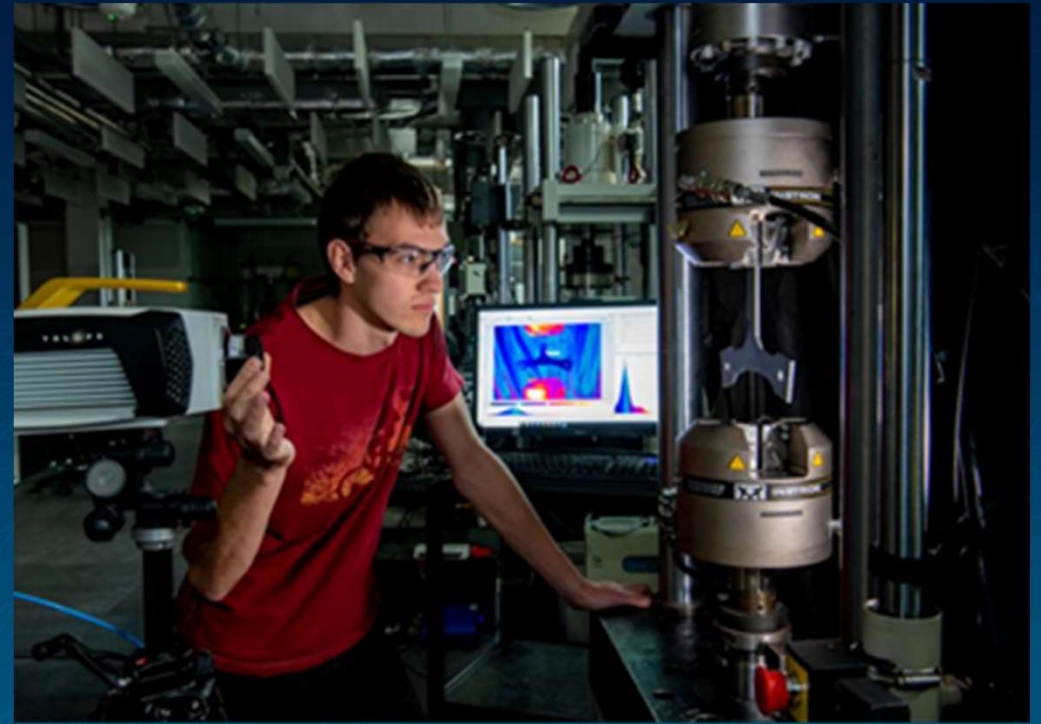
National Infrastructure Laboratory



Large Structures Testing Laboratory



Testing and Structures Research Laboratory



National Infrastructure Laboratory



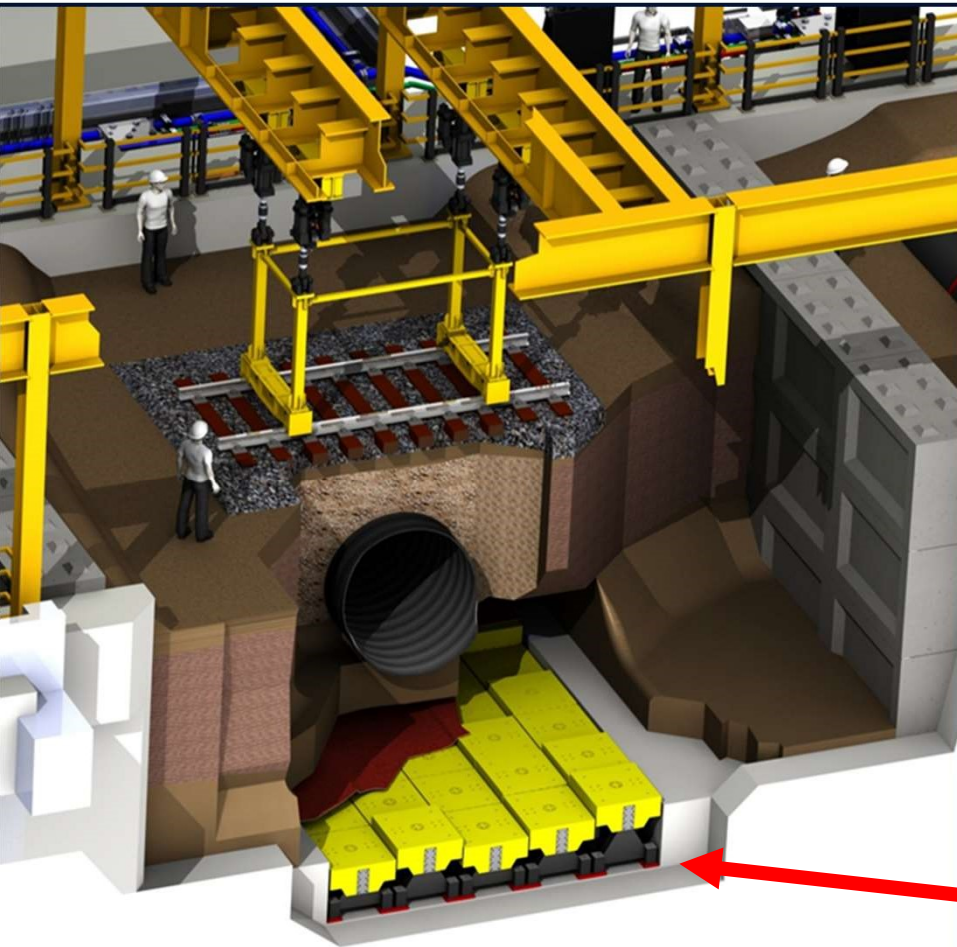
Geomechanics Laboratory



Geotechnical Centrifuge Facility



National Buried Infrastructure Facility



Full-scale trials of infrastructure systems that facilitate the urban metabolism – people and resource flows:

- Tunnels, pipelines and culverts sensed and monitored
- Geophysical testing – seeing through the ground
- Road and construction traffic loading
- Trenching and trenchless technologies, robotics

50 independent plates to simulate ground movement

Why do we innovate?



- New market demands
- New problems or priorities
- Develop new products, or improve the performance of existing ones
- Reduce costs and maintain viability

in order to

- Increase market share
- Grow existing markets
- Enter new markets

Future mobility: concerns



- Sources of energy
- Sources of raw materials
- Climate change
- Environmental pollution
- Biodiversity
- Health and wellbeing

Averting the climate catastrophe



Future mobility: sources of energy



- Biomass, (bio)ethanol, methane from AD of waste
- Electricity: national grid, regional/local grid, battery?
- Glycerol (waste from biodiesel production)
- Human (walking, wheeling and cycling)
- Hybrid energy storage technology for decoupling EV supply from grid. No need for grid connection could make marginal renewable schemes

Future mobility: availability of biofuels

Data: Dave Smith



	Source	Amount (Mt)
1 st generation	Crops	90
2 nd generation	Hydro-processed esters and fatty acids (HEFA)	85
	Municipal solid waste	115
	Wood processing	35
	Forestry	65
	Agricultural	70
	Cellulosic cover	120
3 rd generation / future	Algae	25
	Semi-arable land	20
	TOTAL	625

Future mobility: availability of biofuels



- Total available fuel from biomass: say 600 Mt / year
- Energy density of biofuel: say 40 GJ/tonne (1 GJ = 10^9 J)
- Total biofuel energy available $\approx 600 \text{ Mt} \times 40 \text{ GJ/t} = 24 \text{ EJ}$
per year (an EJ is an ExaJoule = 10^{18} J $\approx 2.8 \times 10^5$ GWh)

Future mobility: current world energy demand (EJ / year)



24 EJ / year from biofuels is all used by aviation

Data: Dave Smith

Industry	Steel	45
	Cement	14
	Aluminium	7
Transport	Light duty	123
	Heavy duty	60
	Shipping	19
	Aviation	24
Power and heating	Space and water heating	79
	Power	243
TOTAL		614

Uber's drivers in London must go electric by 2020

Adam Vaughan

Uber says its drivers will be banned from using vehicles that are not a hybrid or fully electric in London from 2020, as part of a plan to help tackle illegal levels of air pollution in the capital.

While hybrids such as the Toyota Prius have become synonymous with the ride-hailing service, less than half of its London UberX drivers currently have an electrified vehicle. The taxi hailing firm said that must rise to 100% by 2020.

Diesel-powered cars on the app's other London services, such as UberXL for larger cars, will also be banned from 2020.

For other British cities blighted by dirty air, where fewer UberX cars are electrified already, the 100% hybrid and electric deadline will be 2022.

In the longer term, the US company said that by 2025 all of its cars in London must be fully electric or a plug-in hybrid, on which the battery typically lasts about 40 miles before switching to petrol.

Jaguar Land Rover followed Volvo this week by promising to no longer launch new models that are not electrified to some degree. However, it will continue selling existing petrol and diesel models.

Uber said it was prioritising London, where dirty air causes nearly 9,500 deaths a year, because the city had a particular

35p

Surcharge to be imposed by Uber on all fares in London from October to help fund its switch to electrified vehicles intended to improve air quality

severe problem with particulate pollution and toxic gases from vehicles.

Fred Jones, Uber's head of UK cities, said: "Air pollution is a growing problem and we're determined to play our part in tackling it with this bold plan."

Uber's 40,000 drivers in London will also be given financial assistance to switch

to a new car, with grants of up to £5,000 towards a hybrid or fully electric car.

The grants will be funded with £2m from the company but users of the

will also a 35p surcharge on trips from

Camp initiative city charging speed of away from action to

Uber new river booking launch began offering similar to

But T demand not have ment Tf accept p



All Volvo cars to be electric or hybrid from 2019



The Guardian, 9/9/17 and 25/7/17

Future mobility: renewable electricity



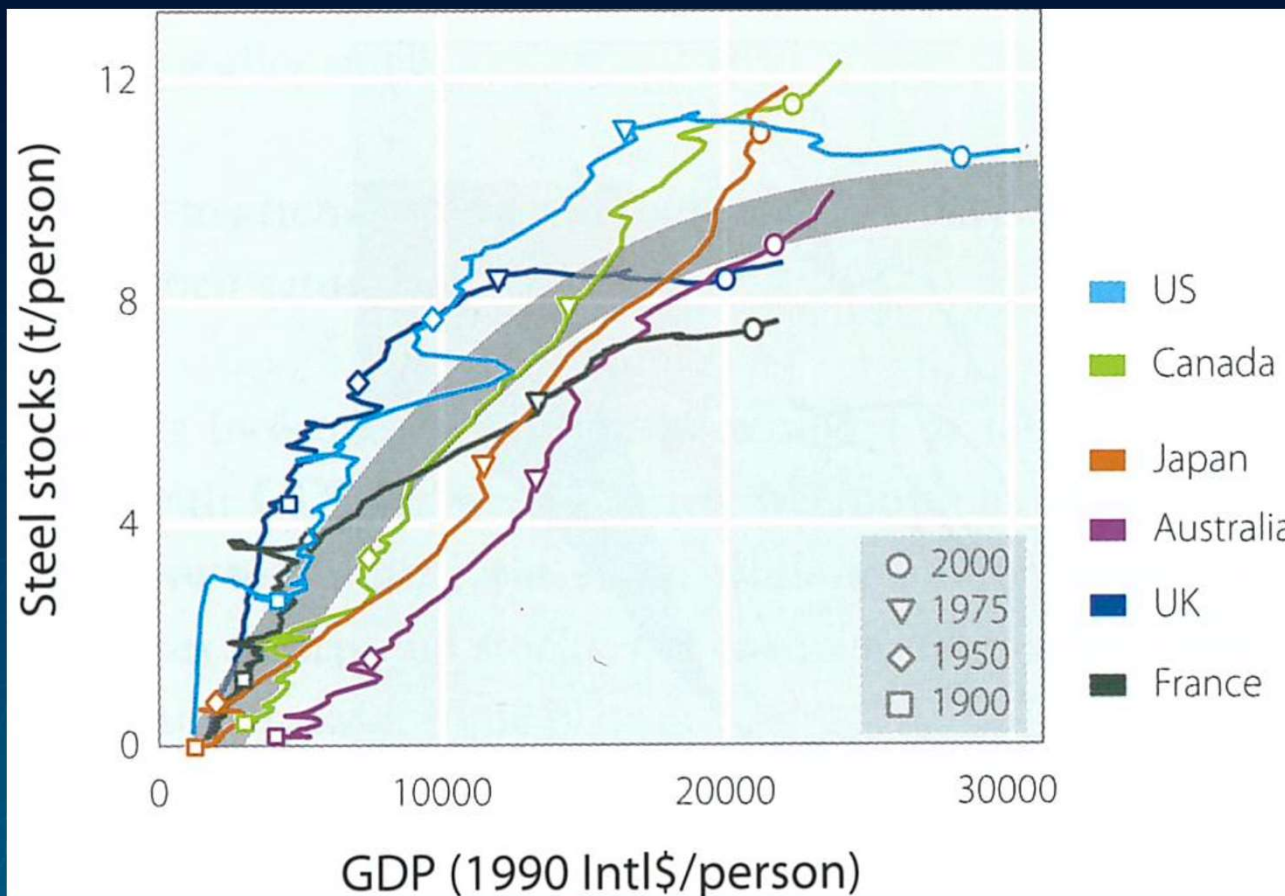
- The largest wind turbine, the prototype Siemens SG 14-222 DD, has 3 no. 108 m long blades and 15 MW maximum power output
- At an average of just over 50% of maximum capacity it would produce 70 GWh / year ($\sim 2.3 \times 10^{-4}$ EJ/year)
- Would need $\sim 4\,000$ of these to produce 1 EJ over a year (an EJ is an ExaJoule = 10^{18} J $\approx 2.8 \times 10^5$ GWh)

Future mobility: materials for batteries, vehicles or electrification infrastructure



- Lithium
- Cobalt
- Copper
- Steel
- Aluminium

Iron and steel



- World iron reserves ~80 billion tonnes (Statista)
- World population 2018 ~7.7 billion people (UN)
- Average per capita steel in circulation in a developed country ~10 tonnes (Allwood and Cullen, 2015)

Allwood and Cullen (2015) *Sustainable materials without the hot air*. UIT

Future mobility: the role of rail



- Currently the only mode offering zero CO₂ emissions at point of use
- Inherent efficiency in terms of operational energy
 - Pendolino average 23 Wh / seat/km @ ≤200 km/h
 - Electric car average 45 Wh / seat/km @ ≤112 km/h

But it is not just about CO₂

FIGHTING FOR AIR

ENGINEERS MUST ACT TO TACKLE AIR POLLUTION FROM TRANSPORT

BY ALEXANDRA WYNNE

Healthy Transport

The headlines have said it all since the beginning of the year – the UK's transport is responsible for people dying too early. The country that is often so ready to tell the rest of the world how it should be keeping people safe and healthy is facing record fines for air pollution breaches.

The UK is on a final warning from the European Union and reports suggest it is facing potential heavy fines if it is unable to quickly demonstrate a plan to comply. The government now finds itself under even greater pressure to show how it will reduce nitrogen dioxide (NO₂) with an improved air quality plan.

And the pressure to come up with a big plan to fix the NO₂ and CO₂ problems is only likely to become more pronounced – an ageing, and potentially more physically and mentally fragile, growing population and continued migration into towns and cities are all key drivers for change.

And this is far bigger than just a UK

KEY FACT

9M
Projected number of premature deaths caused by air pollution globally in 2060

problem. Globally, the number of premature deaths due to outdoor air pollution is projected to increase from 3M in 2010 to as many as 9M in 2060, according to a recent report from the Organisation for Economic Co-operation and Development (OECD).

So why should civil engineers care? Because transport is one of the prime causes of airborne pollution. And that, many will tell you, is the domain of civil engineers. So if civil engineering is the go-to profession for all matters related to transport-centred development and placemaking, this should surely be the profession taking responsibility for tackling air pollution.

Problem-solving is certainly in the engineering mindset, says Institution of Mechanical Engineers head of transport and manufacturing Philippa Oildham, who takes an active interest in this area.

"Engineers work by having challenges, and problems to fix. That's what we strive for, to improve things," she says.

But she accepts it is a tough challenge to take on.

"The challenge is huge. Part of the reason why it's such a big area is that it's not just about building



GLOBALLY THE NUMBER OF PREMATURE DEATHS DUE TO OUTDOOR AIR POLLUTION IS PROJECTED TO INCREASE FROM 3M IN 2010 TO AS MANY AS 9M IN 2060

new infrastructure. We have a huge amount of existing infrastructure, a lot that hasn't been updated since Victorian times, and we need to look at how we retrofit or replace that or work with what we've got.

"Not only how do we do that for now but also how do we future proof it for the next 100, 200, 300 years?"

Atkins former head of innovation Elspeth Finch, now chief executive of start-up Indigo&, says that more must be done to begin making the economic case for making transport healthier – connecting the improved tourism potential and fewer hospital beds taken up by those suffering the effects of air pollution.

There has to be a move away from just patching up and adding to what we already have.

"We need to look more at scenario planning, and what cities are going to look like in the future in terms, not so much of the physical infrastructure, but of how people are going to behave, how they want to work, how they're going to live and therefore how technology and how transport is a part of that," suggests Finch, also chair of the Enterprise Hub's Innovators Network.

"There's a big amount to do around consumer behaviour, which sometimes engineers don't spend enough time on as, say, advertisers and people who really care about consumer trends and what drives behaviours."

She elaborates, saying that while transport influences over the past 10 years, such as Uber's taxi revolution, could not have been fully predicted, there is more that can be done to anticipate trends – for instance, perhaps car ownership will diminish, with Millennials reaping the rewards of a shared economy instead.

All of which does make putting air pollution reduction in the "too difficult" box a tempting option and can lead to accusations of engineers, on occasion, not caring enough, or more frequently, being disorganised in their attempts to tackle the problem.

Anecdotal evidence came last month when engineers showed such little interest in signing up to attend the launch of ICE London's *Engineering Cleaner Air* report that the event had to be cancelled.

It is a complex issue, and the industry should not really be waiting for the people who ultimately pay the bills to demand change.

But that demand for change is coming.

“There's a big amount to do around consumer behaviour, which sometimes we as engineers don't spend enough time on”

Right now a tidal wave of government inquiries, initiatives and policies on the subject is waiting to hit.

The House of Commons transport select committee is currently running an urban congestion inquiry; the Commons business, energy and industrial strategy committee has an inquiry into developing the market for electric vehicles; and four select committees are coming together for the first time to examine air quality.

And then there is the Department for Environment, Food and Rural Affairs' latest shot at the government's Air Quality plan.

Its last efforts were thrown out by the UK's High Court for not going far enough, and the 24 April publication deadline was imminent as this issue of *New Civil Engineer* went to press.

The result of that legal battle is testament to how difficult the issue of air quality is proving for the government.

Policies in recent years have displayed a naivety and lack of understanding about the consequences of road use, and in particular the 1990s, push for the use of diesel vehicles to combat CO₂ emissions growth. Now, with the increased understanding of air pollution, that maybe seems unwise in hindsight, although it is worth noting that the problems do not all stem from the uptake in diesel vehicles.

So where do we go from here? When looking for the next radical transformation of our transport systems it is tempting to seek help from futuristic ideas. Airbus' plan to fill the skies with "flying cars"; China's plans for drone taxis in Dubai; Elon Musk's visionary Hyperloop; and, of course, autonomous vehicles (AVs) to name just a few.

But are these the red herrings? It is not always clear what problems they are seeking to solve. As far as the more tangible AVs go, there has to

New Civil Engineer, May 2017

AIR POLLUTION: THE FACTS

“Road transport is estimated to be responsible for about 50% of total nitrogen oxide emissions”

One of the hoped for fixes for air pollution is greater uptake of electric vehicles



Air pollution is the release of particles and noxious gases into the atmosphere.

Natural emissions of particles come from the sea, the soil and from plants. Particle pollution from human activity is largely the result of the combustion of fossil fuels such as coal, oil, petrol or diesel.

The principal concerns centre on carbon monoxide, nitrogen dioxide, ground level ozone, particulates, sulphur dioxide, hydrocarbons and lead.

Road transport is estimated to be responsible for about 50% of total nitrogen oxides emissions, with nitrogen dioxide levels highest close to busy roads and in large urban areas. Gas boilers in

buildings are also a source of nitrogen oxides.

Nitrogen dioxide also reacts with hydrocarbons in the presence of sunlight to create ozone, contributing to the formation of particles.

Larger particles are generally filtered in the nose and throat and do not cause problems. Particles smaller than about 10 micrometers, referred to as PM10, and particles smaller than 2.5 micrometres (PM2.5), can settle in the airways and deep in the lungs and cause health problems.

The health effects of particle air pollution have been widely studied. They include premature death and the worsening of heart and lung disease.

Source: London Air Quality Network, King's College London



AIR QUALITY



Just as the A556 development began gaining momentum, a nationwide shake-up of road schemes looked set to throw it off course.

In November 2013 the Highways Agency had to scale back plans for hard shoulder running between junctions 8 and 15 of the M60 because the resulting increased flow of traffic was expected to cause unacceptable air quality breaches (New Civil

Engineer 19 November 2013).

Specifically, nitrogen dioxide (NO₂) emissions close to roadsides in Greater Manchester and other major cities were already too high and the Agency became fearful of the detrimental effect that adding hard shoulder running between junctions 8 and 15 of the M60 would have to human health.

The A556 plan also came under review. As a result of a consultation in the ensuing

months, the 70mph designed road, is actually now only allowed to open with a speed limit of 60mph – purely because the enhanced speed with which the road can feed traffic into the city centre would exacerbate air quality concerns.

Limits will be reviewed in five years' time and are also likely to be heavily influenced by the imminent arrival of the new draft plan for Air Quality (see feature p22).

Future mobility: the challenge for rail



- Currently the modal split for inland surface transport in the UK is about 90% road : 10% rail
 - Thus a shift of 10% from road would double current rail journeys
 - When the number of passenger km (64.1bn in 2015/16) is already greater than at any time in the last 60 years, on a network that has roughly halved in size
 - Post-pandemic opportunities for rail freight
- ⇒ **Generate and accommodate modal shift**

Rail Analysis

EMILY ASHWELL

Lessons must be learned from electrification débâcle

The electrification of the Great Western route has been a "stark example of how not to run a major project", according to the chair of the influential Commons public accounts committee (PAC). The PAC published its report on the scheme in March. It says the electrification project was flawed from the start in terms of planning, design and cost estimates.

The ability of the Department for Transport (DfT) and Network Rail to manage the planned electrification schemes on the Midland Main Line and TransPennine routes is a concern, it adds.

The cross party committee's report describes the £1.2bn estimated cost increase on the Great Western route in the space of a year as "staggering and unacceptable". Network Rail admits that it is unable to say for sure that it will be on budget at £2.8bn by December 2018 and that "significant risks" have still to be managed.

The report comes at a crucial time for the rail industry as the rail regulator's latest review of Network Rail's spending performance starts to shape the next regulated period, CP6. The government is already indicating that further electrification is out of favour and the way to get faster journey times on higher capacity lines is by improving signalling to increase train frequency, longer trains; and new hybrid trains that

Electrification: Work went ahead despite poor planning and incomplete designs

can switch between diesel and electricity depending on the section of line they are running on.

The PAC report says poor infrastructure works planning is one of the main reasons for delays and cost overruns. Designs were incomplete, cost-estimates were poor, and construction started before the 1,800 separate local authority consents were in place.

Scrutiny of the job was also criticised. The DfT left much of this to the Office of Rail and Road (ORR). "The Department accepts that this system was too complex, 'much weaker and less reliable than [it] thought', though it believes that it has since put in place a "very clear structure of accountability", says the report.

It goes on to recommend that DfT and Network Rail get independent opinions on whether their plans are deliverable and the PAC said it expected to see this on future major programmes, such as the Midland Main Line and TransPennine upgrades.

"This is a stark example of how not to run a major project, from flawed planning at the earliest stage to weak accountability and what remain serious questions about the reasons for embarking on the work in the first place," said PAC chair Meg Hillier.

"The Department failed to adequately challenge Network Rail's plans to carry out the infrastructure work and, even now, casts doubt on whether electrification work on this



“ This is a stark example of how not to run a major project

and other lines is even necessary. Government accepts it got this project badly wrong and must now demonstrate it has learned the lessons. Network Rail admits there are still very significant risks in the Great Western scheme and it is vital these are fully identified and carefully managed."

The Department for Transport and Network Rail both said they had already learnt lessons and implemented change, including the way work is commissioned and overseen.



GWEP, Reading

Active travel: walking, wheeling and cycling



Jason Gill and Carlos Celis-Morales, Institute of Cardiovascular and Medical Sciences, University of Glasgow: *The Conversation*, April 2017

Study based on 250,000 people over 5 years found that cycling to work was associated with

- 41% lower risk of dying
- 46% lower risk of developing heart disease
- 45% lower risk of developing cancer

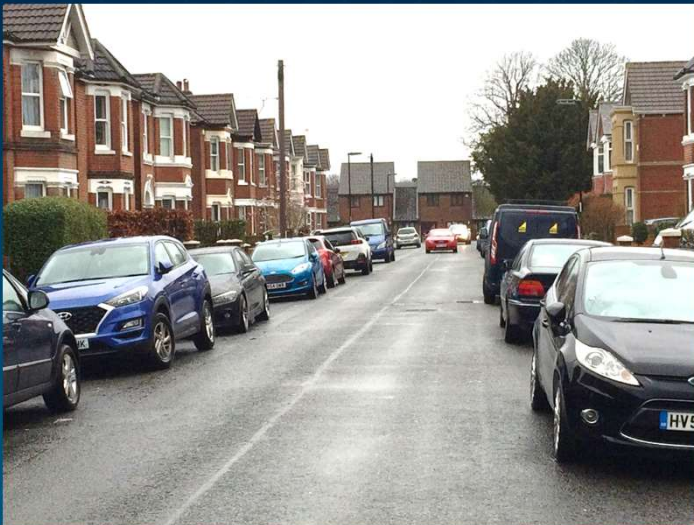
<https://theconversation.com/cycling-to-work-major-new-study-suggests-health-benefits-are-staggering-76292>

Active travel: infrastructure requirements



Photo: Auto Express

- Make space for walkers and cyclists, who have been squeezed off roads in past 40 years by more traffic and 30% increase in size of motor vehicles



- Reducing private vehicle ownership will reduce the number of vehicles in circulation and reduce the amount of dead space in towns and cities used for car parking (dedicated and on-street)

But what about White Van Person?

**Parcel delivery: 2 companies,
18 vehicles, 3 depots, 1 day**



Squares: GPS tracker on vehicle

Circles: GPS tracker on driver

Intensity of trace represents overlap of activity by road

Tom Cherrett, University of Southampton



Per working day, the average courier is.....



- Delivering 127 parcels...
-to 72 different consignees
- Making 37 vehicle stops
- Walking 7.9 km (28% of total journey distance)...
- ...leaving the vehicle stationary on the street for 4.6 hours

Sustainable transport: a way forward - 1



- Provide good infrastructure to encourage active transport (walking, wheeling and cycling) [direct health benefits + clean air]
- Accommodate micromobility (e-scooters and e-bikes)
- Invest in rail to provide capacity for modal shift
- Go electric: in cities, have only electric buses, trams, trains, bikes, scooters, delivery vehicles and personal mobility pods for those who need them
- Make public transport affordable [reduce bus/train fares not fuel duty]

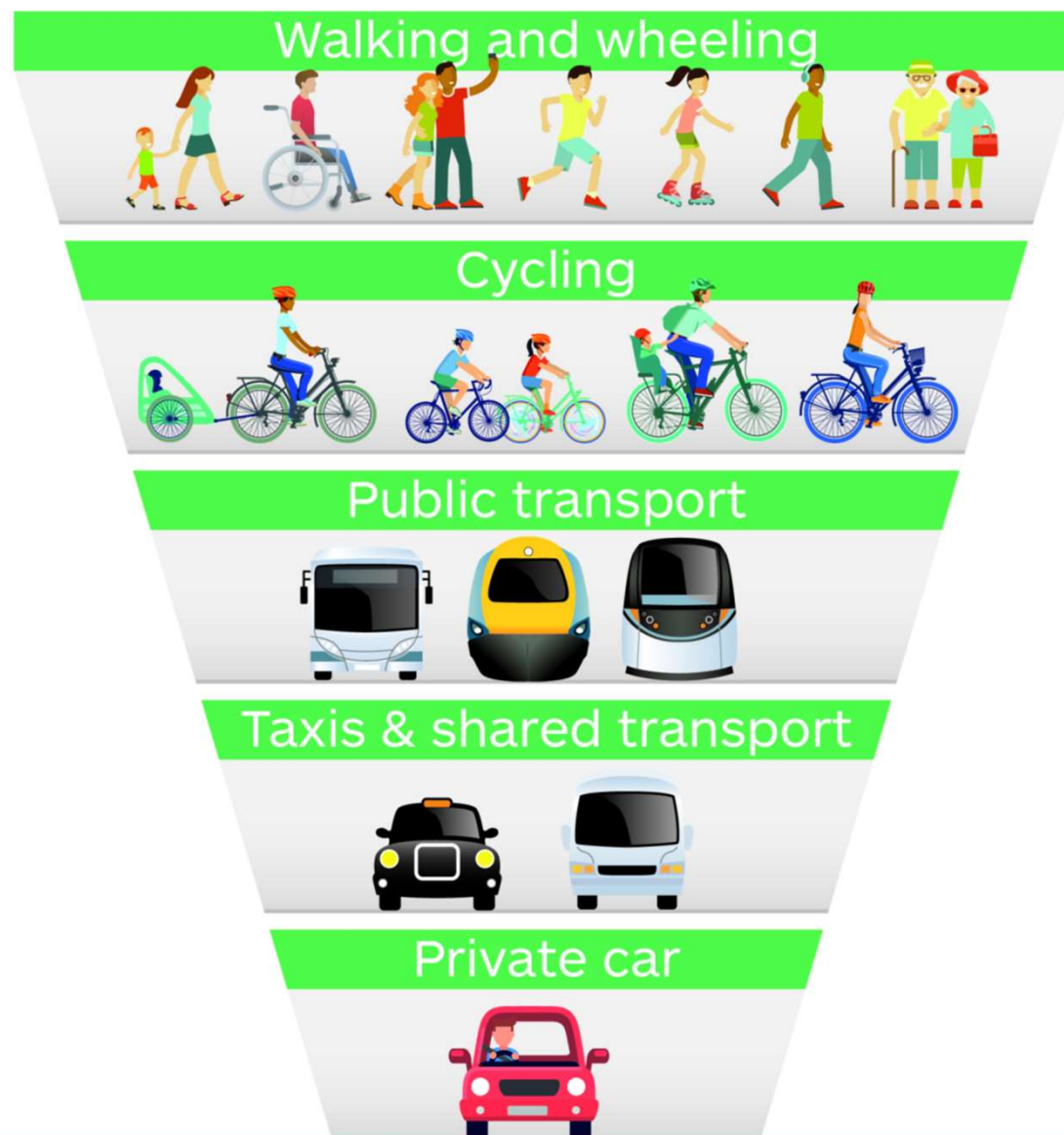
Sustainable transport: a way forward - 2



- Retain benefits of home working to avoid having to size infrastructure for peak flows [even out demand through the day]
- Coordinate deliveries at out of town distribution hubs
- Discourage individual car ownership, especially in towns and cities [good public transport options, free space for recreational use, dial-up pods]
- Prioritise scarce biofuel resources for use where there is no reasonable alternative [aviation, road freight not displaced to rail?]
- Batteries for remaining lightweight road vehicles
- Decongest, decarbonise, depollute, declutter: make space for people

Transport Hierarchy

Transport Scotland
National Transport
Strategy





Beijing, Sunday 27 October 201



Picture: South China Morning Post International Edition



Picture: BBC

© Stuart Doo/Getty

Perspectives on the past, present and future



Yogi Berra

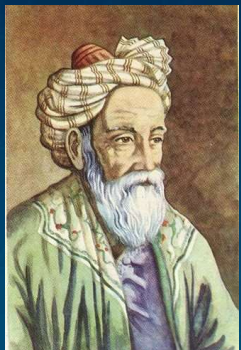


(a) "It's tough to make predictions, especially about the future"

(b) "I can cope with the present and plan for the future, but the past will always haunt me"



Chris Brown



Omar Khayyám

(c) "The moving finger writes; and, having writ, moves on: nor all thy piety nor wit shall lure it back to cancel half a line, nor all thy tears wash out a single word of it"



William Gibson

(d) "The future is already here, it's just not very evenly distributed"

(e) "It is often easier to shape the future than to predict it"



William Powrie



Picture: *The Conversation*

Innovation: universities as partners and a resource



- Capability: the UK has world class researchers and facilities
- Location: networks of local, regional and national facilities
- Capacity: access to what you need for as long as you need
- Multi-disciplinary
- Problem solving based on understanding the underlying science
- Technology transfer from other industries
- New ideas looking for applications

Case study – making electrification affordable



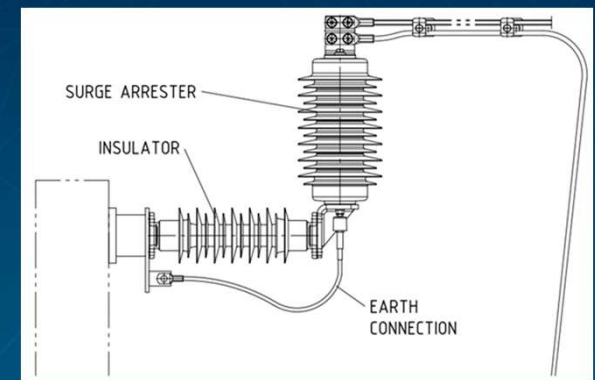
- Strategic government priority – decarbonising transport
- Traction decarbonisation: electrification of 13,000 stkm by 2050
- Minimise embedded carbon in the electrification infrastructure
- Make the infrastructure affordable

Three areas for research, development and innovation:

- Reduce the need for new work (avoidance of bridge reconstruction)
- Reduce the cost and embedded carbon in what you do build
- Improve the performance and life of components (whole life and early cost both important)

Reducing the need for new work (avoidance of bridge reconstruction)

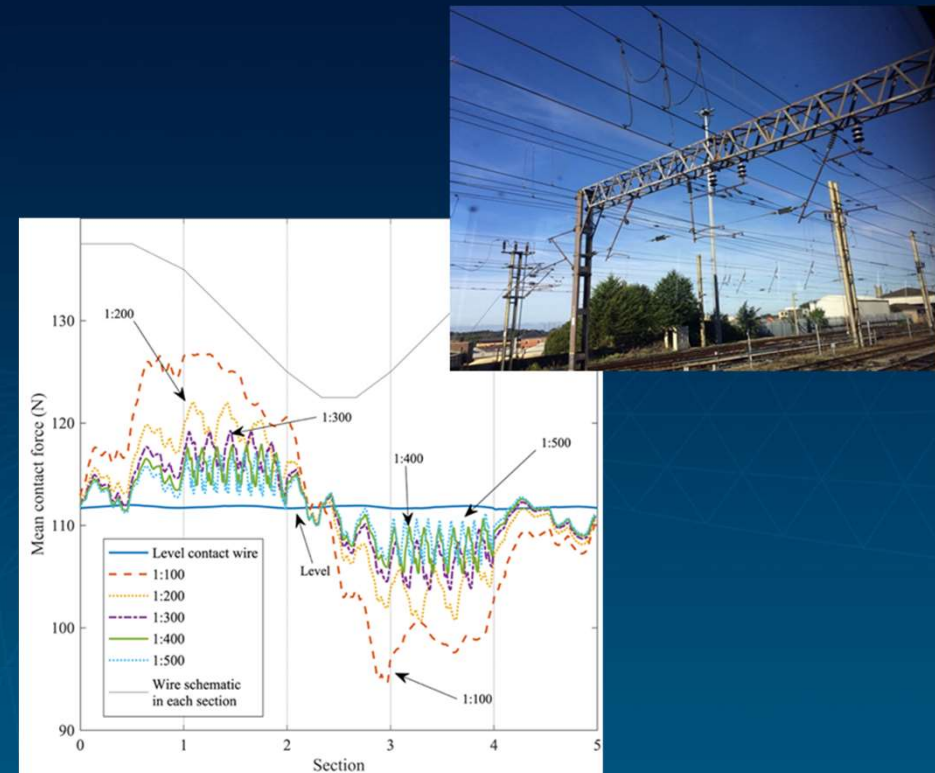
- Cardiff Intersection Skew Bridge. £40M reconstruction avoided by safely reducing electrical clearances, using surge arresters and insulating coatings. Led by Network Rail, partners Siemens and GLS Coatings; solutions tested in the high voltage lab at Southampton.
- Follow-on projects to generalise the results are being carried out at Southampton. Results of Phase 2 are the subject of an E&P Technical Advice Note issued by NR for consultation. Phase 3 has started in the high voltage lab.



Reducing the need for new work (avoidance of bridge reconstruction)



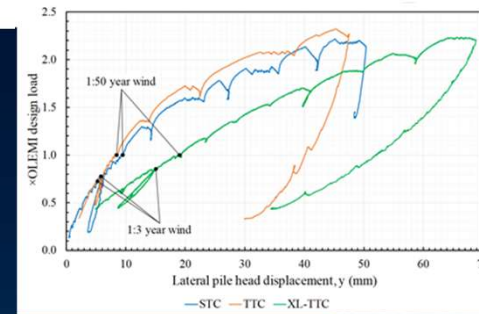
- Effect of contact wire gradient on the dynamic performance of the catenary pantograph system. When electrifying an existing railway the height of the contact wire is often forced to vary to avoid rebuilding structures.
- Results show that exceeding the standard maximum gradient of 1:500 leads to only a 5.6% increase in the peak force even when the gradient is increased to 1:200. Project partners University of Sheffield, Network Rail and Furrer and Frey.



Reducing the cost and embedded carbon of new work



- The design of OLE mast foundations. Numerical analysis and full-scale site trials demonstrated that the design approach was over-cautious and also justified a more realistic design method, which was adopted as a Network Rail standard.
- Independent estimates put the saving at £600M over three years and this contributed to restarting the electrification programme. Research by the University of Southampton, partners Network Rail and In Situ Site Investigation.



Ref:	NRL3ICV/074
Issue:	03
Date:	02 December 2017
Compliance date:	03 March 2018

Level 2
Specification

Design and Installation of Overhead Line Foundations

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Reducing the cost and embedded carbon of new work



- Feasibility study on composite masts for OLE. The first lightweight composite masts have been created and tested at St Bride's feeder station, just outside Newport in Wales. A DfT / Innovate UK-funded project led by Furrer and Frey with partner universities Cranfield, Southampton and Newcastle composite materials manufacturer Prodrive, and rail technology developer TruckTrain.
- A follow-on proposal to develop a viable product from TRL4 to TRL7 has been submitted, with direct support from NR.



Improving the performance and life of components



- Mechanical testing of Bridge Approach Droppers. Network Rail frequently requires low height (or uplift) droppers to be installed between the catenary and the contact wire. The type test requirements for droppers focuses on standard dropper lengths. NR has asked Southampton to develop a more evidence-based approach to type testing requirements, starting in July 2022.
- As well as reviewing 1,000 measured in service traces, the University will undertake millions of fatigue test cycles on 22 combinations of dropper design and length, totalling 4,600 machine days.

Types of engagement



- Long term strategic relationship
- Collaborative research
- Consultancy
- Sponsoring a doctoral student – longer term results and potential to nurture new technical leaders
- Government schemes supporting knowledge transfer
- Secondments - inward and outward

Good value but not free. Understand costs and benefits

How to identify and access the support you need



- If you know who you want, approach them
- If you are not sure who has the capabilities you want, or you want help to understand what might be possible, approach the Centre of Excellence contact listed on the UKRRIN website www.ukrrin.org.uk
- If your challenge doesn't seem to fit one Centre, contact any of the Centre leads or ukrrin@rssb.co.uk
- Take independent advice from RIA or RSSB

Questions and Discussion

I have drafted the attached news item for the website and newsletter and included quotes from you and Tim Chapman. Please can you let me know if you require any amends?



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