University of Birmingham
Centre for Railway Research and Education
Contents

- Birmingham Centre for Railway Research and Education
- RRUK
- EURNEX
- Current projects in aerodynamics
- Climate Change and the Railway
University of Birmingham Centre for Railway Research and Education

- 12 academic staff
- 15 post doctoral researchers
- 20 doctoral students
- MSc in Railway Systems Engineering and Integration
- Research income from Research Councils, EU, UK and European railway industry
University of Birmingham Team

- Electrical, Electronic and Computer
  - Dr Stuart Hillmansen, Dr Clive Roberts, Dr C Goodman
- Civil Engineering
  - Dr Min An, Prof Chris Baker, Dr Michael Burrow, Dr Gurmel Ghatora, Prof Felix Schmid, Dr D Chapman, Dr A Quinn, Dr M Sterling
- Other Engineering Disciplines
  - Dr Claire Davis (Met & Mat)
  - Prof John Thornes (Geography)
  - Dr Andrew Tobias (Mech Eng)
Birmingham Areas of Research

- Aerodynamics and wind
- Asset management
- Environment and climate
- Geotechnical engineering
- Materials and Metallurgy
- Modelling and computation
- Network capacity
- Non-destructive testing
- Power and traction
- Remote condition monitoring
- Risk and safety
- Signalling and train control
- Systems engineering
Railway Research UK

- £7m EPSRC funded virtual research centre comprising of 8 universities
- Led by University of Birmingham and Southampton University
- Together with:
  - Loughborough University
  - University of Leeds
  - Imperial College London
  - Manchester Metropolitan University
  - University of Nottingham
  - University of Newcastle
Railway Research UK

- University of Birmingham – geotechnics, aerodynamics, systems, energy, metallurgy…
- University of Leeds – transport economics
- Imperial College London – metal fatigue, novel technologies
- Loughborough University - mechatronics
- Manchester Metropolitan University – vehicle dynamics
- University of Newcastle – metallurgy, safety, policy
- University of Nottingham – human factors
- University of Southampton – geotechnics, noise and vibration, policy and regulation
EURNEX: European Rail Research Network of Excellence

- FP6 Integration Activity
- Integrate Research from 36 Universities
- Birmingham leads the UK and Benelux Group and is involved in the following working groups
  - Operations and System Performance
  - Rolling Stock
  - Environment and Energy
  - Infrastructure and Signalling
Current Projects in Aerodynamics and Wind

- EPSRC - Aerodynamic/Train System Interactions (with MMU)
- RSSB - The behaviour of pantographs in cross winds (with Interfleet Technology)
- Met. Office - Impact of strong winds on transport systems
- PhD student - Train slipstream measurements using the rotating rail rig
- MSc student – The flight of ballast under Eurostar trains
Climate Change and the Railway
Climate Change and the Railway

- The nature of climate change
- Can railways help to alleviate climate change?
- The effect of climate change on the railway
- A specific example – “Quantifying the Effects of High Summer Temperatures due to Climate Change on Buckling, Broken Rails and Rail Related Delays in the UK.”
- The future - FUTURENET
The nature of climate change

“Most of the observed increase in global average temperature since the mid-20th century is very likely [more than 90%] due to the observed increase in anthropogenic greenhouse gas concentrations.” IPC 2007

**Mitigation** of climate change

Slow down global climate change by reducing greenhouse gas emissions.

**Adaption** to climate change

Respond to the predicted impacts of unavoidable global climate change.
The nature of climate change

- IPCC A1FI emissions
- A2 emissions
- B2 emissions
- B1 emissions

Global temperature rise, degrees (°C)

Start to diverge from mid-century
The nature of climate change

Temperature

Source: UKCP09 Climate Change Scenarios (funded by DEFRA, produced by Tyndall and Hadley Centres for UKCP)
The nature of climate change

Precipitation

Source: UKCIP02 Climate Change Scenarios (funded by DEFFRA, produced by Tyndall and Hadley Centres for UKCP02)
The nature of climate change

20 year wind speed

Source: UKCP02 Climate Change Scenarios (funded by DEFRA, produced by Tyndall and Hadley Centres for UKCP02)
The nature of climate change

20 year rainfall

Source: UKCIP02 Climate Change Scenarios (funded by DEFRA, produced by Tyndall and Hadley Centres for UKCIP)
The nature of climate change

<table>
<thead>
<tr>
<th>Projected Impacts of Climate Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global temperature change (relative to pre-industrial)</td>
</tr>
<tr>
<td>0°C</td>
</tr>
<tr>
<td>Food</td>
</tr>
<tr>
<td>Water</td>
</tr>
<tr>
<td>Ecosystems</td>
</tr>
<tr>
<td>Extreme Weather Events</td>
</tr>
<tr>
<td>Risk of Abrupt and Major Irreversible Changes</td>
</tr>
</tbody>
</table>
Can railways help to alleviate climate change?

- Arguments are often made that railways are more environmentally beneficial than other modes – particularly when investment decisions are being made.
- This is particularly the case for high speed rail (300kph or above)
- Is this argument sustainable?
## % of emissions by mode

<table>
<thead>
<tr>
<th>Mode</th>
<th>Percentage of UK CO2 emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger cars</td>
<td>12.8</td>
</tr>
<tr>
<td>Passenger rail</td>
<td>0.6</td>
</tr>
<tr>
<td>Domestic aviation</td>
<td>0.4</td>
</tr>
<tr>
<td>Buses and coaches</td>
<td>0.6</td>
</tr>
<tr>
<td>Motorcycles</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>Total Passenger</strong></td>
<td><strong>14.5</strong></td>
</tr>
<tr>
<td>International Aviation</td>
<td><strong>6%</strong></td>
</tr>
<tr>
<td>Road freight</td>
<td>7.9</td>
</tr>
<tr>
<td>Rail freight</td>
<td>0.2</td>
</tr>
<tr>
<td>Shipping</td>
<td>0.7</td>
</tr>
<tr>
<td><strong>Total freight</strong></td>
<td><strong>8.8</strong></td>
</tr>
</tbody>
</table>
## Emissions for different modes

<table>
<thead>
<tr>
<th>Mode</th>
<th>Emissions gCO₂/pkm</th>
<th>% change since 1995</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rail diesel</td>
<td>74</td>
<td>-16</td>
</tr>
<tr>
<td>Rail electric</td>
<td>54</td>
<td>-26</td>
</tr>
<tr>
<td>Rail overall</td>
<td>61</td>
<td>-22</td>
</tr>
<tr>
<td>Car and taxi</td>
<td>106</td>
<td>-8</td>
</tr>
<tr>
<td>Domestic air</td>
<td>231</td>
<td>+5</td>
</tr>
</tbody>
</table>
## Change in UK electricity mix

<table>
<thead>
<tr>
<th>Year</th>
<th>Coal</th>
<th>Oil</th>
<th>Gas</th>
<th>Nuclear</th>
<th>Ren.</th>
<th>Other</th>
<th>Carbon intensity gCO2/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>68</td>
<td>5</td>
<td>0</td>
<td>20</td>
<td>2</td>
<td>5</td>
<td>718</td>
</tr>
<tr>
<td>2005</td>
<td>34</td>
<td>1</td>
<td>37</td>
<td>20</td>
<td>5</td>
<td>4</td>
<td>489</td>
</tr>
</tbody>
</table>
# Emissions for different rail vehicles

<table>
<thead>
<tr>
<th>Train type</th>
<th>Emissions per passenger km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 220 Voyager (diesel 5 car multiple unit – 125mph)</td>
<td>105</td>
</tr>
<tr>
<td>Class 390 Pendolino (electric 9 car tilting train – 125 mph)</td>
<td>55</td>
</tr>
<tr>
<td>Class 43 HST (diesel 10 car – 110mph)</td>
<td>55</td>
</tr>
<tr>
<td>Class 91 electric loco + Mk3 coaches (110-mph)</td>
<td>45</td>
</tr>
<tr>
<td>Class 373 Eurostar – 18 coach 225mph</td>
<td>12</td>
</tr>
</tbody>
</table>
## Rail and air emissions for different journeys

<table>
<thead>
<tr>
<th>Journey</th>
<th>Out &amp; back by plane...</th>
<th>Out &amp; back by train...</th>
</tr>
</thead>
<tbody>
<tr>
<td>London to Paris</td>
<td>3.5 hours, 244 Kg/CO2</td>
<td>2.75 hours, 22 Kg/CO2</td>
</tr>
<tr>
<td>London to Edinburgh</td>
<td>3.5 hours, 193 Kg/CO2</td>
<td>4.5 hours, 24 Kg/CO2</td>
</tr>
<tr>
<td>London to Nice</td>
<td>4 hours, 250 Kg/CO2</td>
<td>8 hours by Eurostar+TGV, 36 Kg/CO2</td>
</tr>
<tr>
<td>London to Barcelona</td>
<td>4.5 hours, 277 Kg/CO2</td>
<td>Eurostar then overnight sleeper, 40 Kg/CO2</td>
</tr>
<tr>
<td>London to Tangier</td>
<td>5 hours, 435 Kg/CO2</td>
<td>48 hours by Eurostar, sleeper trains &amp; ferry, 63 Kg/CO2</td>
</tr>
</tbody>
</table>
Emissions for different pollutants

Air versus High speed rail
Can railways help to alleviate climate change?

Source: World Resources Institute, Climate Analysis Indicators Tool (CAIT). See: http://cait.wri.org
Can railways help to alleviate climate change?

- Rail has significantly lower carbon emissions than cars or domestic air
- All modes are reducing CO2 emissions – but rail more than most
- A modal shift to rail could reduce emissions significantly
Can railways help to alleviate climate change?

- Can railways help to alleviate climate change?
- Maybe – but many caveats
  - Overall % emissions produced by trains is small
  - Long life of trains mitigates against rapid adaptation of rolling stock
  - Emissions from different train types vary significantly
  - Energy mix for electric trains is crucial
- Decreased emissions are likely to be a useful by-product of new high speed rail links – but the primary reasons for construction will be economic and a need for increased capacity
The effect of climate change on the railway

**Warm, wet winters**
- Higher wind - effects on OH lines, Pansway, tree fall onto track and overhead
- Higher rainfall – damage to bridges, earthworks
- Longer vegetation growth periods – leaf fall
- Drainage problems
The effect of climate change on the railway

Hot, dry summers
Rail buckling, subsidence
Thunderstorms (lightening),
Thermal comfort problems
Equipment overheating and line side fires
OH lines stretching
The effect of climate change on the railway

**Extreme events**
Higher extreme storms resulting in problems due to

- Driven rain
- Extreme winds
- River flooding
- Storm surge – coastal flooding
- Tree fall
- Bridge pier scour
The effect of climate change on the railway

Positive effects and complacency
  Modal shift,
  Reduced low temperature effects
    (less ice, icicles, freezing, snow)
  Reduced winter delays
Quantifying the Effects of High Summer Temperatures due to Climate Change on Buckling, Broken Rails and Rail Related Delays in the UK.

Kay Dobney, Professor Chris Baker, Dr Andrew Quinn, Dr Lee Chapman.
Methodology

1. Map the rail network (GIS)
2. Impact of baseline weather on buckling and rail related delays. (Network Rail’s Alterations Database, Met Office data)
3. How climate change may alter temperature patterns (UKCIP, EARWIG)
4. Use 1 to 3 to assess the possible impact that temperature changes due to climate change may have on buckles and rail related delays.

To test the methodology the South East region in the UK has been used.
The Science of Rail Buckles

<table>
<thead>
<tr>
<th>Track condition</th>
<th>On standby</th>
<th>Impose 30/60mph speed restriction</th>
<th>Impose 20mph speed restriction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good condition</td>
<td>SFT + 32</td>
<td>SFT + 37</td>
<td>SFT + 42</td>
</tr>
<tr>
<td>Inadequate ballast</td>
<td>SFT + 10</td>
<td>SFT + 13</td>
<td>SFT + 15</td>
</tr>
</tbody>
</table>

[SFT = stress free temperature (normally 27 °C in UK)]

Table 1: UK Critical Rail Temperature (CRT) values for standard track in good and poor states of repair.

Formula showing the “rule of thumb conversion between ambient air temperatures and rail temperature.

\[ T_{air} \approx \frac{2}{3} T_{rail} \]
How heat affects railway operations in the South East: rail related delays

Average delay minutes per day for maximum daily temperatures in the range 1°C to 38°C, showing variability bars for each 1°C interval.
How heat affects railway operations in the South East: Buckles

Maximum daily temperature on days when a buckle occurred compared with the severity of the buckle.
Costing Delays in the South East

The trend between maximum daily temperature and the number of delay minutes.

\[ m = 42t - 923 \]

Where:
- \( m \) is the estimated delay minutes
- \( t \) is the maximum daily temperature.
EARWIG’s Future Weather Predictions for the South East

Number of days occurring per year that fall within 1°C intervals.
## Costing Delays (SE)

Cumulative cost of rail related delays caused by heat (US$m)

<table>
<thead>
<tr>
<th>Time series and cause of delay</th>
<th>BL MH av delay mins</th>
<th>2020 MH av delay mins</th>
<th>2050 MH av delay mins</th>
<th>2080 MH av delay mins</th>
</tr>
</thead>
<tbody>
<tr>
<td>C’lative cost US$m</td>
<td>2.2</td>
<td>4.4</td>
<td>8.4</td>
<td>16.4</td>
</tr>
</tbody>
</table>
Future Work

The focus of the rest of this project will continue to be temperature related.

1. **Hot summers:**
   Rail buckling, Rail related delays, Thermal comfort.

2. **Warm winters:**
   Low temperatures (ice, icicles, freezing) Snow, Reduced winter delays, Modal shift, Complacency.

Work from other groups include:

- Sea level rise
- Earthworks failure
- Flooding
- Urban heat island
The future – the FUTURENET project

- Project Partners
  - Universities of Birmingham, Nottingham and Loughborough
  - Hydraulics Research, British Geological Survey, Transport Research Lab
  - Network Rail, Highways Agency, WSP, IMechE

- Aims
  - What will be the nature of the UK transport system in 2050 (taken as the mid-point of the UKCIP scenarios), both in terms of its physical characteristics and its usage?
  - What will be the shape of the transport network in 2050 that will be most resilient to climate change?
The future – the FUTURENET project

- Objectives
  - The development of a number of possible UK transport scenarios for 2050
  - The identification of a route corridor for the study together with an inventory of infrastructure assets for that route corridor
  - The development of conceptual models of weather / climate induced failure mechanisms of transport systems, together with meteorological and climatic trigger levels
The future – the FUTURENET project

- Objectives
  - The development of a modelling methodology that will integrate the work of the first three objectives, and allow the effect of climate change on the resilience of transport networks to be systematically studied
  - The development of generic tools that can be applied to other transport corridors and the wide dissemination of the results amongst stakeholders