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Assessing the resilience of transport networks to climate change: Selecting a study corridor
FUTURENET WP2 Progress Report 1: The study corridor

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<table>
<thead>
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<th>Date</th>
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<th>Editor</th>
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</tr>
</thead>
<tbody>
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Executive Summary
This progress report relates to Work Package 2 of the project FUTURENET- Future resilient transport networks, an Engineering and Physical Science Research Council (EPSRC) funded project under the Adaptation and Resilience to Climate Change (ARCC) programme. TRL was a partner in FUTURENET together with the University of Birmingham, who led the project, the Universities of Loughborough and Nottingham, HR Wallingford and the British Geological Survey. The project ran from June 2009 to March 2013.
FUTURENET aims to develop methods of quantitatively assessing the resilience of transport networks to climate change impacts. This was carried out through the following work packages:

- WP1 – Development of possible socio-economic scenarios for the UK transport system in 2050
- WP2 – Identification of a transport corridor and collection of baseline data for this corridor
- WP3 – Development of conceptual models of transport failures due to climate effects
- WP4 – Development of a modelling methodology to enable the impacts of climate change on the network to be modelled
- WP5 – Development of generic models and dissemination
TRL led the second work package, and produced two reports describing the progress on this work package up to March 2012. This report describes the identification of a suitable transport corridor, to be utilised in the development of models and methodologies to evaluate resilience. The aim was not to assess the resilience of this corridor, but develop a methodology that would enable this. Data and information on the use and infrastructure within this corridor was collected to use in the development and validation of the models. This element of WP2 is described in a second progress report PPR644 (Reeves et al, 2013).
Although the models were developed using a particular corridor, the project aims to produce generic methodologies which can be applied throughout the UK. In order to achieve this, the study corridor should encompass as many different situations, geologies, topographies, climates and infrastructure types as possible in order that the models produced are relevant to all parts of the UK. At the same time, the modelling complexity needs to be at a level that it is achievable within the project timescale and budget. To do this, the study corridor has to meet a number of criteria. It has to include different modes of transport with sufficient users to make them a viable mode of travel. The corridor must experience a range of climates, and be projected to face different types and magnitudes of climate change impacts. It also has to include a variety of topography and geology, and to include a range of different types of transport infrastructure. However, it has to be limited in geographical size so that the level of modelling is practical.
Discussions within the project team led to a short list of corridors. Information on the usage, climate etc. for these corridors was gathered to compare against the identified criteria. This resulted in London to Glasgow along the west coast being selected as the study corridor. It is as strategically important route to the UK, with use via road, rail and air for both passenger and freight. The south-east to north-west direction provides a range of
The Study Corridor

temperature and precipitation and climate change impacts, and limiting the corridor to the west coast helps to reduce the modelling complexity. The principle study network, within this corridor, consists of the trunk roads (including both the M1 and M40), the west coast mainline railway line and Heathrow and Glasgow International airports.
Contents

1 Introduction
   1.1 FUTURENET
   1.2 Work package two

2 Criteria for selecting a transport corridor
   2.1 Proposed criteria
   2.2 Corridor options

3 Evaluating the corridor options
   3.1 Traffic volumes
      3.1.1 Air
      3.1.2 Rail
      3.1.3 Road
   3.2 Climate data
      3.2.1 Current climate
      3.2.2 Projected climate changes
   3.3 Summary

4 Corridor selection

5 Transport assets within the corridor
   5.1 Road assets
   5.2 Rail
   5.3 Air

6 Future actions

7 Conclusions

Appendix A: Climate projections for the 2050s (© UK Climate Projections, 2009)
1 Introduction

1.1 FUTURENET

FUTURENET (Future Resilient Transport Networks) is a research project investigating the characteristics required for a climate resilient UK transport system (in terms of both infrastructure and usage) in 2050. The project is funded under the UK Research Councils’ “Adaptation and Resilience to Climate Change” programme (ARCC) and runs from 2009 to 2013. ARCC is part of “Living With Environment Change” (LWEC) - a ten-year programme to provide decision makers with information to manage and protect vital ecosystem services. ARCC projects are supported by the Engineering and Physical Science Research Council (EPSRC), The Economic and Social Research Council, the UK Climate Impacts Programme and LWEC. The FUTURENET project is being undertaken by researchers from the University of Birmingham, the University of Nottingham, The University of Loughborough, TRL, HR Wallingford and the British Geological Society.

FUTURENET is examining how transport in the UK will change from the current day to 2050 by exploring different socio-economic scenarios and then exploring how these changes will impact on the resilience of the UK’s transport system to climate change. The project will produce generic models and methodologies to help stakeholders assess the resilience of the transport network they are responsible for. These will provide information on the future resilience of their network under different scenarios, helping to inform their decision making.

The aim of the project is to determine:

- What will be the nature of the UK transport system in 2050, 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?

FUTURENET is divided into the following work packages:

WP1 – Development of possible scenarios for the UK transport system in 2050

Work Package 1 develops a number of different possible socio-economic scenarios for the UK transport network in 2050 based on a literature review of foresight work in all relevant areas; a series of workshops with stakeholders; and data from the travel behaviour studies to be carried out in Work Package 4.

WP2 – Identification of a transport corridor and the collection of baseline data for this corridor

A suitable transport corridor needs to be selected to utilise in the development of the methodologies and models. Work Package 2 involves the identification of this transport corridor and the collection of baseline data on the corridor including an asset inventory, hydrological and geological data and topography.
WP3 – Development of conceptual models of transport failures due to climate effects

Work Package 3 collates and, where required develops, models of transport failures, in a form that can be used in Work Package 4. This includes both damage and disruption from extreme events and also changes in deterioration rates. It identifies the meteorological and climate failure triggers and/or thresholds that affect transport infrastructure, travelling conditions or ground conditions. Models will be developed for specific areas of vulnerability within the corridor identified in Work Package 2.

WP4 – Development of a modelling methodology to enable the impacts of climate change on the network to be modelled

The outputs of WP 1-3 feeds into Work Package 4 which develops a modelling methodology for assessing the resilience of future transport networks. This analysis will be driven by a suite of scenarios (plausible narratives) that describe possible pathways of change in a wide range of model components. It includes developing current and future climate scenarios (using UKCP09) for the chosen corridor, and a travel behaviour scenario to ascertain how people react when transport is disrupted due to climate impacts. The models will look at how resilient the selected route is within the different future scenarios and what adaptation measures can be taken to increase resilience. The methodology will be developed using the transport corridor identified in Work Package 2 but will produce generic components that can be developed into models for the analysis of the wider transport network in the UK in WP5.

WP5 – Development of generic models and dissemination

Work Package 5 involves the development of generic models and methodologies that can be applied to other transport corridors to support decision making. WP5 also includes composing a description of the methodology and dissemination of the models and outcomes of the project.

More information can be found on the project website http://www.arcc-futurenet.org.uk.

1.2 Work package two

The aims of Work Package 2 are:

1. To identify a suitable transport corridor for the study;
2. To collect baseline data on this corridor;
3. To select a GIS system to manage all of the spatial data, and populating it with the data collected.

This report summarises how the first of these aims was achieved: the identification of the transport corridor on which the Futurenet models and methodologies are based. It describes the selection methodology, the criteria used, the characteristics of the corridor selected and the principle assets within it that were included in the models. A second report (Reeves et al, 2013) describes the data collected on the corridor.
2 Criteria for selecting a transport corridor

It was decided to utilise a specific transport corridor for the development of the modelling methodology. This corridor needs to be carefully chosen to allow the aims of the project to be fulfilled and a robust model developed, but also be practical to model. No single corridor can encompass all situations, geologies, topographies, climate and infrastructure that a transport operator will come up against. However the selected corridor needs to cover the widest range of typical situations possible in order that generic models applicable to all of the UK can be developed. In order to achieve this, the study corridor needs to fulfil a number of criteria identified by the project team.

2.1 Proposed criteria

The criteria for the selection were discussed at the project meeting held on the 6th July 2009 at TRL Offices. The identified criteria were divided into essential and desirable characteristics for the corridor to possess:

The essential characteristics were:

- Containing road, rail and air travel modes
- Significant passenger (leisure and business) and freight usage
- Variations in climate
  - temperature
  - precipitation
  - sheltered/exposed
- A range in the projected change in climate
- A range of geology
- A range of flood risk
- Areas of high winds
- Narrow corridor / reduced travel options to reduce complexity of modelling

In addition, desirable characteristics were:

- Probable future transport infrastructure changes
- Includes a port and maritime freight (water was considered to be a less utilised mode of travel, and therefore its inclusion is desirable rather than essential).
- Transport hubs along the route corridor
- Cross-border to include a number of national governments
2.2 Corridor options

Based on the identified criteria the initial suggestions of suitable corridors were:

- London to Newcastle
- London to Cardiff
- Folkestone to Manchester
- London to Manchester
- London to Edinburgh
- London to Glasgow
- Folkestone to Newcastle

After further discussion it was felt that London was an essential area to include in the model due its importance to the UK and the high volume of transport movements around this area. Therefore the following options were selected for further consideration:

- London to Glasgow
- London to Edinburgh
- London to Newcastle
- London to Manchester
- London to Cardiff
3 Evaluating the corridor options

In order to select the most appropriate corridor, data was collected on the ‘Essential’ and ‘Desirable’ characteristics for the short-listed routes. This included information on the projected climate of 2050 of the start and end cities (using UKCP09) and traffic flow data for road, rail and air. Discussions were also held with the key asset operators to seek their insights into the benefits and disadvantages of different corridors.

3.1 Traffic volumes

One of the necessary criteria for route selection was that there is a viable route for each mode, with sufficient passenger and freight traffic volumes. Traffic volumes for the short listed routes were investigated to determine if this was the case. These are discussed in the following sections.

3.1.1 Air

The Civil Aviation Authority (CAA) collects passenger data from the main UK airports on domestic air passenger traffic. The 2008 data for the selected options is given in Figure 1.

![Bar chart showing passenger traffic in 2008 for London to various cities.](chart.png)

**Figure 1. Domestic Air Passenger Traffic for 2008 (CAA, 2008)**

From this data it can be seen that the longer routes, London to Edinburgh and London to Glasgow, are the busiest routes. Air passenger numbers from London to Cardiff are insignificant, with only 116 passengers recorded for 2008 – all of these were on non-scheduled charter flights.
3.1.2 Rail

Comprehensive data on passenger numbers on the selected corridors is more difficult to obtain. However, the number of rail journeys for a number of local authority areas was obtained and is shown in Figure 2. However, these numbers merely represent the throughput of the stations in the area and do not include data regarding passenger destinations or route selection.

![Figure 2. Station Usage 2007/2008 (Network Rail, 2007)](image)

Glasgow Central is reported to be the busiest station outside of London and the numbers using this station are growing rapidly, with a 50% increase in passenger numbers in the last ten years (Network Rail, 2007). Rail use in Manchester is also reported to have nearly doubled in the last ten years.

Broad estimates of passenger journeys from the cities at the ends of the suggested corridors into London for 2005/6 are shown in Figure 3 (Network Rail, 2007).

![Figure 3. Trips to London (passenger journeys in 2005/6) (Network Rail, 2007)](image)
This data shows that Manchester to London is the busiest route and journeys to London from Edinburgh, Cardiff and Newcastle are similar in number.

In terms of passenger kilometres travelled the top 30% of the busiest rail routes in the UK are shown in Figure 4 (DfT, 2007).

![Busiest Rail Routes](image)

**Figure 4. Busiest rail routes (DfT, 2007)**

3.1.3 Road

Precise road usage route data is particularly difficult to obtain at this scale as there is no way of knowing the origin and destination of every journey and there are numerous route options open to users of the road network. However data is available as traffic flow data usually expressed as Annual Average Daily Flows (AADT). These are based on data from automatic traffic counters installed on the trunk network, which allow average traffic flows for different sections of the route to be monitored. Maps showing Annual Average Daily Flows for the trunk road network is shown below for Scotland (Figure 5) and England (Figure 6).
Figure 5. Scotland Annual Average Daily Flows 2006 (Transport Scotland, 2009)
The maps show that the London to Manchester is the busiest corridor, with the most traffic travelling along the western side of England. Annual Average Daily Flows (AADFs) range from around 125,000 for much of the route from Birmingham to Manchester, to 25,000 and below from the Scottish border to Glasgow.
3.2 Climate data

Current and projected climate data was obtained for each of the shortlisted corridors. The corridor needs to traverse areas representative of as much of the range of UK climate as possible. It should also pass through regions of the country which are projected (by UKCP09, in the 2050s) to experience different changes in key climate variables.

3.2.1 Current climate

Figure 7 shows the current variation of temperature and rainfall across the UK. The climate maps from the Met Office are derived from weather station readings over the period 1961 to 1990. The annual mean temperature ranges from 10°C in southern England to less than 4°C in the Pennines and Scottish Highlands. The average annual precipitation varies from less than 600mm in the south east to over 3000mm in the Scottish Highlands. The east of the country receives less rainfall than the west.

![Mean Temperature and Rainfall Maps](image)

**Figure 7. Annual Mean Temperature and Rainfall (1961 to 1990) (Met Office, 2009)**

3.2.2 Projected climate changes

UKCP09 projections (UKCIP, 2009) were obtained for the 2050s for London and the possible destination cities using the UKCP09 User Interface (http://ukclimateprojections-ui.defra.gov.uk/ui/admin/login.php). The outputs for temperature and precipitation for the 2050s under the low, medium and high emission scenarios are given in Appendix A. These show that the more northern corridor destinations are projected to experience a smaller
increase in annual mean temperature than those in the south and that the destinations to the south are projected to experience a substantially greater percentage decrease in summer rainfall than those in the north and a slightly greater percentage increase in winter rainfall. The east of the country currently receives less precipitation than the west and this is expected to continue.

Therefore greatest variation in current climate and projected change in climate is obtained from a corridor following a south-east to north-west direction.

3.3 Summary

A summary of the information collected on the corridor options is given in Table 1.

The general findings for each corridor are:

London to Cardiff: This corridor has very little air traffic and limited temperature variation across the route. However, it is the least complex corridor to model.

London to Newcastle: This corridor has little air traffic and does not have a large range in precipitation. The roads along the east coast are also less busy than the west.

London to Manchester: This corridor is a busy route for all modes, but has a limited climate variation compared with that which occurs when extending the corridor further north.

London to Edinburgh: This is a busy route for all modes, but does not give as large a change in precipitation as the London to Glasgow corridor. The roads are also less busy along the East Coast.

London to Glasgow: This corridor is relatively busy for all modes. It gives the widest climate variation of the options being considered. Although extending further north and towards the south east coast would give greater variations, the traffic flow is not as large. The modelling for this corridor could be complex.
<table>
<thead>
<tr>
<th></th>
<th>London to Glasgow</th>
<th>London to Edinburgh</th>
<th>London to Newcastle</th>
<th>London to Manchester</th>
<th>London to Cardiff</th>
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<tr>
<td>Air traffic</td>
<td>High</td>
<td>Highest</td>
<td>Lowest</td>
<td>Medium</td>
<td>Practically none</td>
</tr>
<tr>
<td>Rail traffic</td>
<td>V. busy station, but relatively low rail passenger numbers travelling to London.</td>
<td>A less busy station than Glasgow or Manchester, but large passenger numbers travelling to London.</td>
<td>Least busy station, but large passenger number travelling to London.</td>
<td>Busy station. Largest number of passengers to London.</td>
<td>Less busy station. Large passenger numbers travelling to London.</td>
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<tr>
<td>Road traffic</td>
<td>Busy roads around Glasgow and London to Manchester, less busy Manchester to Glasgow (&gt;150,000 in places).</td>
<td>Less busy (&lt;75,000 AADF).</td>
<td>Less busy (&lt;75,000 AADF).</td>
<td>Very busy route. (&gt;150,000 in places)</td>
<td>Less busy (&lt;75,000).</td>
</tr>
<tr>
<td>Temperature variation across corridor</td>
<td>5 to 7°C.</td>
<td>5 to 7°C.</td>
<td>1 to 3°C.</td>
<td>4 to 5°C.</td>
<td>0 to 2°C.</td>
</tr>
<tr>
<td>Rainfall variation across corridor</td>
<td>1400mm.</td>
<td>400mm.</td>
<td>200mm.</td>
<td>650mm.</td>
<td>650mm.</td>
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<tr>
<td>Projected change in annual mean temperature(^1)</td>
<td>London +2.5°C, Glasgow +2.1°C</td>
<td>London +2.5°C, Edinburgh +2°C</td>
<td>London +2.5°C, Newcastle +2.2°C</td>
<td>London +2.5°C, Manchester +2.3°C</td>
<td>London +2.5°C, Cardiff +2.4°C</td>
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<tr>
<td>Change in winter and summer mean daily precipitation(^1)</td>
<td>London DJF +15%, London JJA -21%, Glasgow DJF +12%, Glasgow JJA -15%</td>
<td>Edinburgh DJF +11%, Edinburgh JJA -13.5%</td>
<td>Newcastle DJF +12.5%, Newcastle JJA -16%</td>
<td>Manchester DJF +11%, Manchester JJA -15%</td>
<td>Cardiff DJF +14%, Cardiff JJA -23.5%</td>
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<td>Modelling complexity</td>
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<td>High</td>
<td>High</td>
<td>High</td>
<td>Low</td>
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- Entries in green fit with the requirements for a suitable transport corridor for this study.
- Entries in orange are borderline in fitting with the requirements for a suitable transport corridor for this study.
- Entries in red do not fit the requirements for a suitable the transport corridor for this study.

\(^1\) Taken from UKCP09 central estimate, 2050s, medium emissions as indicative of the magnitude of climate change. DJF – December, January, February. JJA – June, July, August.
4 Corridor selection

The project team met to discuss the options and information gathered on the short listed corridors. Aspects such as the complexity of modelling, the inclusion of alternative routes within the corridor, climate variations across the corridor, the importance of including air travel and the availability of data were explored.

The possibility of limiting the alternative routes related to the corridor to reduce the model complexity was discussed. It was suggested that this could restrict the flexibility of alternative routes, and hence provide a false indication of the resilience of the corridor. However it was agreed that some limiting was necessary in order to avoid the necessity of attempting to model the whole of the UK network which is outside the project remit. It is important to recall that the aim of the project is to produce a methodology by studying a particular corridor rather than evaluate the resilience of the entire UK transport network.

It is vital that the outputs produced at the end of the project are useful to practising transport professionals. As a result the usability of the final models and methodologies is an important consideration and it was suggested that if the modelling was too complex it may not be practical for others to use.

The conclusions were that a southeast to northwest corridor would provide the largest range of climatic conditions in terms of annual rainfall and mean annual temperature. If this corridor is extended as far as Scotland it would also provide a greater variety of terrain, e.g. passing over Shap Fell, Cumbria which is the highest point on any motorway in the UK. In terms of usage this is also a busy corridor for road, rail and air travel for both passengers and freight. There were concerns over the complexity of modelling that a longer corridor with more potential diversionary options would generate, however it was accepted that the London to Cardiff corridor did not have the characteristics required. It was suggested that extending the corridor from Manchester further north to Glasgow would not create significant additional complexity.

Therefore the transport corridor selected was London to Glasgow via the West Coast. It was felt that restricting the corridor to the West Coast would reduce complexity, but provide sufficient alternative routes. The selected corridor was discussed with key stakeholders to identify any potential problems obtaining data for the route.

Initial discussions were held with Network Rail, the Highways Agency, Transport Scotland and ADEPT (formerly the County Surveyors Society) to introduce the project and the corridor selected. The purpose of selecting a particular corridor for study and the data availability for the different corridor options was discussed. No problems specific to the selected corridor were identified; therefore the London to Glasgow via the west coast corridor was proposed to the FUTURENET Project Management group as the corridor for study.
5 Transport assets within the corridor

A corridor from London to Glasgow along the west coast, still provides numerous travel options particularly for road. It was decided to restrict the corridor further by:

- For air considering London Heathrow to Glasgow International only (the most used route)
- For rail using the West Coast Main Line – London Euston to Glasgow Central
- For road considering only trunk roads and including both the M1 and M40 routes to reach the M6 from the M25

The roads included in study network are highlighted in Figure 8.

![Map of the UK showing transport assets within the corridor.](image)

**Figure 8. Futurenet principle road network (©Crown copyright, 2010)**

The transport assets considered within the corridor consisted of:

- The trunk roads highlighted and their associated infrastructure such as bridges, embankments, drainage and adjacent vegetation.
- The West Coast Mainline railway and associated infrastructure, e.g. signalling, tunnels and overhead lines.
- London Heathrow and Glasgow International airports and access routes to these.

In the event of an incident, travellers would have the option of taking alternative routes off the principle network, particularly in the case of road travel. This capability has to be included in the model to make it realistic. However, the large number of alternative options needed to be restricted, so it was decided to utilise the official Emergency Diversionary Routes agreed by the HA and TS with the Local Authorities (LAs). See the
Database and Route Parameter Report (RPN 2129) for more detail on this. There are also a number of relevant assets which are located outside the corridor, but which are essential to the running of the transport assets within it such as air traffic control centres, train depots, control centres etc. These were not included in the modelling.

5.1 Road assets

The Futurenet principle road network consists mainly of trunk roads. The trunk roads in England are maintained and managed by the Highways Agency. The HA network is divided into 14 maintenance areas, which are managed by different managing agent contractors or operating companies. The Futurenet corridor passes through seven different areas (maintenance areas 3, 5, 7, 8, 9, 10 and 13).

In Scotland the trunk roads are maintained and managed by Transport Scotland and the network is divided into four maintenance areas. The Futurenet corridor passes though the south west area.

In addition there are a number DBFO’s in the study corridor managed by private companies; the M25 DBFO which includes the start of the M1, the M6 toll road, the M40 DBFO and a large section of the A74(M)/M74 maintained by Autolink. At the two ends of the corridor are roads managed by Transport for London and London Boroughs, and Glasgow City Council.

5.2 Rail

The principal rail route is the west coast mainline which runs from Euston London to Glasgow Central Station. Network Rail manages both these stations in addition to the track and associated infrastructure. Smaller stations en route are managed by Train Operating Companies (TOCs), who also operate train services. The west coast mainland route (Network Rail route 18) is the busiest mixed traffic route in the UK and a priority Trans-European Network route (Network Rail, 2009). It is one of the busiest freight routes in Europe, 43% of UK rail freight uses the route at some stage of its journey. Virgin Trains runs the fast intercity passenger trains along this route and uses primarily Class 390 EMUs (Pendolino), and Class 221 DEMUs (Super Voyager) rolling stock. There are also regional services and CrossCountry services (e.g. Birmingham to Manchester) along the route.

5.3 Air

The principle air route is from Heathrow London to Glasgow International, both airports are owned by BAA. Heathrow is 14 miles from central London and Glasgow international is 7 miles from Glasgow City Centre. There is an average of 69 flights to London per day from Glasgow International. The numbers travelling to Glasgow from the London airports in 2008 are given in Figure 9.
The other key infrastructure relating to air travel is the air traffic control centres. The National Air Traffic Services (NATS) provides airport air traffic control services at Heathrow and en-route air traffic management from its centres at Swanwick in Hampshire, West Drayton in Middlesex, Manchester and Prestwick in Ayrshire. The Area Control Centre at Prestwick, near Glasgow deals with flights in Scottish airspace and parts of the North Atlantic. A new control centre at Swanwick has taken over control of airspace in England and Wales.
6 Future actions

The task of identifying the study network is complete, so there are no future actions required.

7 Conclusions

The selection of a suitable study corridor is key to achieving the aims of FutureNet, as it needs to balance the coverage of a wide range of situations with an achievable level of modelling complexity. The criteria for the corridor selection were that it should include:

- A range of climate and projected climate change;
- A range of geology and topography;
- Allow viable air, rail and road options with a reasonable amount of traffic flow for each mode, and passenger and freight; and
- Be practical to model within the time and budget available.

After further discussions it was agreed that the route should commence in London, due to its significance to the UK economy and large traffic volumes. Based on these criteria the following short list was drawn up:

- London to Glasgow
- London to Edinburgh
- London to Newcastle
- London to Manchester
- London to Cardiff

Information on traffic volumes and climate was used to evaluate the short listed routes further. The following conclusions were drawn:

London to Cardiff: This route has very little air traffic and limited temperature variation across the route. However, it is the least complex route to model.

London to Newcastle: This route has little air traffic and does not have a large range in precipitation. The roads along the east coast are also less busy than the west.

London to Manchester: This route is a busy route for all modes, but does not give the climate variation extending the route further north does.

London to Edinburgh: This is a busy route for all modes, but does not give as large a variation in precipitation as the London to Glasgow route does. The roads are also less busy along the east coast.

London to Glasgow: This route is relatively busy for all modes. It gives the widest climate variation of the options being considered. The modelling for this route could be complex.

It was decided that the route that best met the criteria was the London to Glasgow route with the provision that it went through the west coast route to reduce model complexity and obtain the maximum variation in climate. This route was agreed with the key stakeholders and submitted to the rest of the team. The principle study network within
this corridor consists of the trunk roads (including the M1 and M40), the west coast mainline, and Heathrow and Glasgow International airports.
References

CAA, 2008. Airport data, Table 12.2
http://www.caac.org.uk/docs/80/airport_data/2008Annual/Table_12_2_Dom_Air_Pax_Route_Analysis_2008.pdf

http://www.dft.gov.uk/about/strategy/transportstrategy/dasts/annex1.pdf


http://www.transportscotland.gov.uk/road/traffic-count

Appendix A: Climate projections for the 2050s (© UK Climate Projections, 2009)

(a) London – Annual mean temperature

![Image of temperature distribution]

(b) London – Annual daily mean precipitation

![Image of precipitation distribution]
(c) Cardiff – Annual mean temperature

(d) Cardiff – Annual mean daily precipitation
(e) Newcastle – Annual mean temperature

![Graph showing probability distribution of mean temperature with categories Low, Medium, High]

Digital Information:
- Time Period: 2040-2069
- Emission Scenario: Low, Medium, High
- Spatial Average: Grid Box 25km
- Variables: Temp, Precip
- Probability Data Type: pdf
- Data Source: UK Climate Projections
- Location: Grid Box No. 1034
- Temporal Average: ANN
- Future Absolute Climate: True

(f) Newcastle – Annual mean daily precipitation

![Graph showing probability distribution of precipitation with categories Low, Medium, High]

Digital Information:
- Time Period: 2040-2069
- Emission Scenario: Low, Medium, High
- Spatial Average: Grid Box 25km
- Variables: Precip
- Probability Data Type: pdf
- Data Source: UK Climate Projections
- Location: Grid Box No. 1034
- Temporal Average: ANN
- Future Absolute Climate: True
(g) Manchester – Annual mean temperature

(h) Manchester – Annual mean daily precipitation
(i) Glasgow – Annual mean temperature

Plot Details:
- Time Period: 2040-2069
- Emissions Scenario: Low, Medium, High
- Spatial Average: Grid Box 25km
- Variables: Temp_Jan, Feb, Mar, Apr, May, Jun
- Probability Data Type: pdf

(j) Glasgow – Annual mean daily precipitation

Plot Details:
- Time Period: 2040-2069
- Emissions Scenario: Low, Medium, High
- Spatial Average: Grid Box 25km
- Variables: Precip_Jan, Feb, Mar, Apr, May, Jun
- Probability Data Type: pdf
(m) Newcastle – Winter mean daily precipitation

(n) Cardiff – Winter mean daily precipitation