



ENGINEERING, INFRASTRUCTURE & CLIMATE CHANGE ADAPTATION STUDY

Report of the Transport Sector workshop 14 July 2010

The summary findings of the Transport Sector workshop, presentations and separate submissions are as follows:

- All transport sectors (national roads, local roads, rail, air, maritime) are aware of the potential implications of climate change on their businesses, are in general well advanced with their thinking on mitigation and adaptation, and are keen both to share their knowledge and to learn from others' efforts. However there is little organised cross-mode knowledge transfer to support their work.
- Little work is being done on the "soft" issues of the impacts of climate change on culture and behaviour.
- Transport investment is subject to cost–benefit appraisal formulae that do not yet recognise climate change issues. In particular there is a need to invest in the short- or medium-term with the expectation of a very long-term benefit – something that may be inconsistent with, for example, the franchise cycle of the railways.
- A catalogue of the key standards and some sort of central Information and coordination office would be beneficial in supporting research and investment more effectively.
- A lot of research is being done and done thoroughly but with almost no intra-or inter-mode coordination and information dissemination. Consequently there is probably duplication and inefficiency in the use of resources. We identified three key gaps in the current research:
 - the effect of climate change on aviation
 - the effect of climate change on wind strength and direction (potentially a key issue for ports and airports)
 - interdependency of transport with other elements of the infrastructure
- There is a very strong case for some central funding to bring together the existing knowledge and present it as common standards, treatment protocols and techniques for addressing bridge scour, drainage, embankment and cutting stability, and subsidence which are common to many areas of road and rail engineering.
- There has been a lot of work on risk analysis but for the most part it has been simple *ie* addressing just one risk element. There is a need for more work on complex risk assessment when two or more different classes of risk coincide
- There has been some innovative research on transport as a complex system but more needs to be done to look at transport and climate change as a multi-mode complex system with links to energy, ICT, and water infrastructure systems.
- The ten effects posing the biggest risks to Local Authority highway networks are:
 - Pavement failure from prolonged high temperatures
 - Increased length of the growing season leading to prolonged and/or more rapid growth of the soft estate;
 - Lack of capacity in the drainage system and flooding of the network;
 - Surface damage to structures from hotter and drier summers;
 - Scour to structures from more intense rainfall;
 - Damage to pavement surface layers from more intense rainfall;
 - Subsidence and heave on the highway from more intense rainfall;
 - Scour and damage to structures as a result of stronger winds and more storminess;
 - Severe damage to light-weight structures from stronger winds
 - Less disruption by snow and ice due to warmer winters

Introduction

This report summarises the processes and outputs of the workshop held on 14 July 2010 under the chairmanship of Professor Eric Sampson. The 36 participants at the workshop considered the likely impacts of climate change on transport infrastructure. Discussion was stimulated by a series of presentations covering Integrated Transport, the Strategic Road Network, the Rail Network, Airports and Ports while CIRIA considered the impact of natural hazards across a broader front. Written material was also taken into account from discussions with Leicestershire County Council who were unable to be present.

Each of the presentations forms an appendix to this document and contains fuller detail. This report meanwhile focuses on the principal discussions and findings as follows:

- Not enough work is being done on 'soft' issues:
 - behavioural response to climate change (especially temperature)
 - the DfT guidelines on cost–benefit measurement and the Treasury Green Book (Appraisal and Evaluation in Central Government) need to be developed to recognise climate change issues especially the long time frame involved
 - hidden or unintended consequences of adaptation activity:
 - eg possible increases in cycling fatalities linked to temperature-induced behaviour change
- Adaptation, interdependencies and risk assessments need to be considered as total systems and in at least three ways:
 - within a sector (eg vulnerability of roads networks where local authorities (LAs) and the Highways Agency have different approaches and standards)
 - within transport (ie the linking of the different modes)
 - interdependencies of transport with energy, ICT, water etc.
- Internal transport interdependencies can be systemically fatal
 - the rail network might be resilient and virtually fully available but if local roads and bus services collapse then railway workers might not be able to get to work to provide the rail service.
- Not enough work being done on instrumenting infrastructure to enable autonomous reporting of condition and availability. Work is also needed to ensure maintenance of monitoring capability during electrical power and telecoms disruption.
- Most sectors have considerable records of data and information that might potentially benefit adaptation studies but until very recently this material was not collected and stored with climate change in mind. Some exploratory work on data recovery and data mining looks like a sound investment.
- Buildings seem not to be considered a part of infrastructure but they are a key element for sea and air ports and public transport network interchanges.
- Not enough research is being done on the effect of climate change on aviation.
- Not enough research is being done on the effect of climate change on wind strength and direction (potentially a key issue for ports and airports)
- Climate change work so far has assumed no radical change in the UK's economic make-up.
 - there seems to be a strong case for exploring whether there would be significantly different issues and interdependencies if major change happened eg, doubling or halving the UK manufacturing base, rail moved to a predominantly electric or a predominantly diesel energy regime or the importation of substantial proportion of electrical energy.
- Funding adaptation work could be impeded if some Regulator powers and responsibilities are not amended to reflect the new operating regime.
- There is no coordination of the various adaptation investments, research and other activities – much of which is believed to be happening somewhere. Some are proceeding too slowly because of inadequate funding. Adaptation research work needs a central

'clearing house' logging all initiatives by the numerous bodies in this area to help reduce overlap of activity and duplication.

- There has been a lot of work on risk analysis but for the most part it has been simple *ie* addressing just one risk element. There is a need for more work on complex risk assessment when two or more different classes of risk coincide. Local Authority Emergency Planning scenarios might be a usable base for this.
- It was recognised that funding for adaptation work will be in short supply. It would be useful to compile an initial list of the top 25 or so items of 'most critical' transport infrastructure, assume that they will be protected and the necessary work funded; then examine infrastructure items 'below the line' to see how failure in these areas might impact on water, energy, ICT.
- Concern was expressed about the pricing of data and research work by the Meteorological Office. There was a strong feeling that the Office was lagging behind other Departments in opening up data and information collected at public expense (the Cabinet Office 'Berners-Lee' liberalisation initiative) which was inhibiting experimental work and creating a near-monopoly for research in this area.

The next five sections of this report address the key questions posed by DfT's Chief Scientific Adviser, Professor. Brian Collins that underpin the whole of this research. These questions are:

1. What are the issues/technical and operational impacts from climate change (focusing on the medium-term [to 2030] and long-term [to 2100] impacts) on the sector?
2. What are the potential adaptation options to address these issues/impacts? This should include consideration of engineering/design standards – do they need to change and if so why and how? For example should we allow regulators to operate beyond pure economic regulation; or incentivise cooperation between regulators? Or encourage investments outside the core business that are vital to improve resilience. Allow more resilient premium services?
3. What are the potential barriers to implementing these options (including consideration of the wider context within which engineering operates)?
4. What are the opportunities (*eg* skills, economic, innovation) from adapting our infrastructure, in particular to the engineering profession and engineering organisations? Whether opportunities could be brought out more, *ie* the potential for the ICT sector to provide technology to help the country / industry adapt.
5. What interdependencies does the sector have with the other three sectors and will climate change impacts exacerbate these (not to be examined in-depth but a list of issues will be useful to the interdependency group)? What about potential cascades of failure across the national infrastructure?

1. Issues and Operational Challenges Arising from Climate Change

A number of likely impacts of climate change on transport infrastructure have been drawn from Annex C of the Engineering, Infrastructure and Climate Change Adaptation Conference Report, December 2009 (Defra) reproduced here as Appendix 8.5. The summary list below shows transport related infrastructure marked with high potential for damage by severe weather conditions and medium or high likelihood of occurring.

1. Roads: storm surge; prolonged rainfall; flood; drought; snow; extreme wind; frost; fog; soil shrinkage
2. Pedestrian route: snow
3. Cycle paths: flood
4. Surface rail: storm surge; prolonged rainfall; flood; snow; extreme wind
5. Underground rail: prolonged rainfall
6. Airport: electric storm; flood; drought; snow; extreme wind; fog
7. Airways: electric storm; extreme wind
8. Terminals: drought
9. Coastal infrastructure: sea level rise; storm surge; flood; fog
10. Seaports: sea level rise; storm surge; flood; drought; fog
11. Inland waterways: storm surge; prolonged rainfall; flood; drought; frost; soil shrinkage
12. Embankments: water table rise; storm surge; prolonged rainfall; flood
13. Tunnels: flood
14. Bridges: storm surge; prolonged rainfall; flood
15. Pipelines: prolonged rainfall; flood
16. Control systems: storm surge; prolonged rainfall
17. SatNav: electric storm
18. Oil Distribution: sea level rise; storm surge; flood
19. Gas Distribution: sea level rise; storm surge; flood
20. Electric car recharge network: electric storm; prolonged rainfall; flood
21. CO₂ transport: flood

2. Adaptation Options to Meet Issues and Challenges

- 3.1 A number of adaptation concerns and available options were identified across the sector. Principal ideas included:
- Systematic risk assessment
 - dependent on up-to-date, accurate asset registers
 - using information systems developed for other purposes to assess risk from climate change
 - Amendments to design standards and operating practices will be required:
 - incorporate adaptation into business-as-usual maintenance routines
 - drainage systems
 - earthworks
 - some simple measures can be cheap and effective
 - new buildings, especially stations, are making increased use of reflective and/or shaded glass
 - quick wins are possible eg redesigning culverts in embankments can help to prevent landslips, painting bus roofs white can reduce the risk of overheating. Degrading service frequency and quality might be a useful adaptation technique in some circumstances
 - adapt to changing climate over the life-time and replacement cycle of assets eg road surfaces, rail tracks
 - learn from
 - each other
 - other systems – the types of UK weather expected to result from climate change are found elsewhere in the world now
 - Some major infrastructure may require significant investment to meet adaptation requirements
 - eg coastal rail tracks cannot be moved, and so may need significant and costly adaptation

- New infrastructure will need to be built consistently with adaptation requirements eg ports. This approach will 'future proof' current investment.
- It is important not to reduce specifications of new build due to financial pressures. Infrastructure procurement needs to take future climate and weather conditions into account (possibly even those of currently unlikely weather conditions as mitigation measures appear to be lagging behind).
- Communication with passengers/consumers and other transport agencies will be a key adaptation strategy. There is a need to understand how passenger and/or consumer behaviour might change in relation to climate change
- Some disruption to transport may be unavoidable – as now (eg floods of 2007):
 - A risk/reward profile will be needed to assess an “acceptable” level of disruption and it may be necessary to accept slower journeys (increases in journey times) in order to increase reliability.
 - It may be that reducing service frequency on the railway might be appropriate; (this has already been considered for the London Underground to cope with higher tunnel temperatures). Customer expectations would need to be carefully managed
 - Contingency planning will be required to manage extreme weather events and emergencies
 - Local authority emergency planning may need to be extended.
- A major assumption is that vehicles using the infrastructure are separate from it:
 - vehicles have shorter lifespan than the infrastructure on which they travel (eg average age of UK train rolling stock in 2006/07 was c.16 years¹)
 - It is assumed that vehicle operators will ensure their vehicles are adapted to changing climate as they are replaced but this may need to be enforced through regulation and/or legislation.

3.2: Sector Summaries:

Each organisation presenting has taken its own approach to these challenges and so, although brought together here, each section will emphasise those matters perceived as important by the host organisation.

3.2.1: Transport for London

Transport for London has the challenge of operating and sustaining an integrated transport system (bus, underground, tram, DLR, overground, river, traffic management), and has responsibility for promoting both cycling and walking. TfL operations are vulnerable to a range of hazards including flooding, drought, over-heating, air quality (a legal requirement), subsidence and ground heave and wind storms

TfL has developed a number of adaptation mechanisms including detailed risk assessments and adaptation costing, securing road drainage, changing infrastructure specifications (bus design, tube, Crossrail), and installing ground water pumping. It has integrated adaptation into its business continuity planning and the ongoing maintenance and replacement of assets. TfL recognises communication with customers, employers and employees and between transport services is essential.

3.2.2: The Highways Agency

The Highways Agency is responsible for the Strategic Road Network in England. While only 2% of road network is regarded as national infrastructure it carries 25% of all traffic and almost 50% of HGV traffic so there are nonetheless significant risks. These include the reduction in asset

¹ DfT, “Transport Trends 2009 Edition: Section 3 Public Transport”
<http://www.dft.gov.uk/pgr/statistics/datatablespublications/trends/current/section3pubtran.pdf>

condition and safety from climate change and reduced network availability and/or functionality. The cost of maintaining a safe and serviceable network is likely to increase and there is increased safety risk to road workers with increased programme and quality risks due to required changes in construction activities. Not all of the current Agency internal operational procedures are appropriate to the future and dealing with climate change will incur increased business management costs.

The primary impacts of climate change are through the increase in average and maximum temperatures, increased winter and decreased summer rainfall with an increase in extreme rainfall events – giving particular challenges in relation to drainage capacity and flooding.

Secondary impacts are likely to be felt through a longer growing season coupled to reduction in soil moisture and changes in groundwater level. Flooding is expected to be an increasing problem. Winter is expected to see reductions in the numbers of days with fog or ice but a potential increase in the frequency of storm surges.

A particular concern raised was the issue of wind effect on road signs. It was felt that wind change effect is not sufficiently covered in CP09 and that road signs which are vulnerable to this may be heavily impacted.

The HA is undertaking risk assessments and considering the future challenges. Adaptations are likely to include future-proofing new designs such that they are able to deal with the range of conditions expected, retrofitting necessary solutions to the existing road network and developing contingency plans. The HA recognises the need to update its operating procedures, to monitor what is happening and to continue appropriate research.

Changes to standards and specifications are already being considered or applied and these include thermal action, thermal range and wind action (loads) applied to superstructures. The HA has already adopted French temperature standards for road surfaces and these are performing well. There is however an issue with standing water if present for more than a week. Design requirements are being changed through modifying temperature and wind maps (National annex Eurocode) as is the design of structure drainage, the use of temperature sensitive components or materials in construction and rehabilitation and the design of bearings and expansion joints.

Business processes are being changed to incorporate risk assessment of and adaptation to climate change. The whole is recognised as an iterative process of assessment and adaptation to risks.

The road network must be recognised and managed as a single network of assets. While it is not totally dependent on energy, in the sense that the network continues to function without signage, emergency signals *etc* the capacity of the system will be greatly reduced and traffic may be unable to enter or leave if traffic signals on local feeder roads lose power.

The renewal cycle for major routes is 30 years, with a third of the network resurfaced every 10 years. Bridge structures are designed for 120 year life (although some structures are significantly older) and it may be that some design expectations will need to be revisited in the light of changes to wind patterns and forces, and potentially changes in scour patterns from altered water flow.

Road user behaviour is also expected to change and generate new challenges. Not enough is known about the possible impact of changes in weather on driver behaviour. It is possible that both hot and cold extremes will increase road traffic while driver responses to the changing situations may lead to increase in accidents and delays.

Vehicles are, in this context, assumed to be relatively short-lived artefacts (5-10 years typically) and it is considered that they will be adapted by manufacturers. However, little is understood of the impact of electric, hybrid and fuel cell vehicles and the infrastructure changes that may be required to enable them, eg recharging points and/or hydrogen fuelling stations.

3.2.3: Construction Industry Research and Information Association

Prompted by recent flood events CIRIA has undertaken research to consider the resilience of transport infrastructure to flooding which has benchmarked UK critical infrastructure. The objectives of the research were to collect and collate information on currently available flood resilience and resistance measures, to identify approaches to improve the adaptation to flood risk and promote cross-sector collaboration and consensus. The project recognises the complex of both the regulatory context and the public / private sector mix and that it has complex interdependencies. A framework has been proposed for the development of standards based on risk and criticality based priority.

The study recommended that flood resilience measures should be implemented as an integral part of 'organisations' business continuity management processes, whole life asset management plans and climate change adaptation strategies'. It also noted that smarter investment planning would be required together with 'joined-up thinking' and a greater emphasis on whole of life project costing.

The ensuing discussion highlighted a number of requirements:

- to understand the behavioural impacts of climate change
- to consider what people will do differently following climate change, for example how work patterns might change and the consequences for usage of infrastructure
- to assess how increased homeworking and/or telecommuting may reduce the need to travel to work and that dependency on infrastructure
- to research how technology may enable both internal migration and changes in immigration patterns.
- to elevate awareness of economic aspects for adaptation to drive investment.

It was also recognised that there is a huge dependence on electricity for transport, to power small but increasing numbers of electric vehicles, for trains, for fuelling pumps for vehicles, aircraft and ships and to operate the control systems that enable them all to operate safely.

It was felt that despite incorporating changes required for adaptation in future standards, pressure on funds means some elements of adaptation are likely to be put off until infrastructure fails. It was noted that there does not appear to be a catalogue of the key standards. While CIRIA are considered to have documents that nearly fit that description and the Highways Agency has extensive Design Manuals for infrastructure, these are not written from a weather resistance perspective and there has been no prior proposal that this should be done. It is suggested that this would have potential for significant improvements in efficiency and effectiveness for Local Authorities – and generate cost savings.

3.2.4: Network Rail

Network Rail operates with a fixed infrastructure, it cannot easily move rails away from coastal areas, flood plains or other impacted areas. Using the West Coast Mainline as a model Network Rail adopted new standards for adaptive resilience in May 2008 and December 2010. These standards affect new build projects not current infrastructure and include, for example, increases in drainage channel capacity to allow a 20% increased flow with a 20% added margin. Track is now replaced on a 10 year cycle and, with an enormous legacy infrastructure, a risk management approach is in use based on asset registers.

The workshop discussed a number of issues. There is additional risk to trackside equipment from increased humidity (a clear cross-reference to the ICT workshop here) and although track is pre-tensioned to match a 27° C ambient temperature it is vulnerable to sustained higher temperatures. Overhead line equipment is tensioned by weights and is considered safe up to around within 38°C but it might be necessary to increase the standard line tension to increase resilience to changing wind strengths. The Channel Tunnel and High-Speed One being relatively new build are assumed to be resilient.

Although rolling-stock has a 30 year life (approximately) it is assumed that the impact of climate change will be accommodated as 'business as usual' in future design and that existing rolling stock will be replaced before the effect of climate change impacts. The question of infrastructure failure as a result of current weather on rolling stock eg Channel Tunnel breakdowns of December 2009 was raised although it was recognised that these were failures of power/traction unit and not the permanent way.

It was suggested that the structure of the industry, particularly its Regulatory and economic model and short franchise periods, might act as inhibitors to adaptation – it is already recognised that the franchise periods inhibit normal investment by franchise holders

The table below shows the likely impacts of climate change and consequences for the UK rail network.

Climate Impact Group	Cluster	Consequence
Heat	Track	Management of track buckle risk
Heat	Track	Reduced window of opportunity to carry out maintenance/ renewals work due to heat
Heat	People	Passenger health and impact on freight from train failure in extreme temperatures, including heat and cold
Heat	People	Staff working conditions, eg: use of heat watchmen
Heat	Power/ Telecoms/ Signalling	Floating electrical earth leading to stray earth currents caused by dry ground/ low groundwater; heat (solar gain) affecting lineside equipment; sag in tethered overhead line systems at terminal stations
Rainfall	Fluvial flood	Track and lineside equipment Failure
Rainfall	Groundwater flood	Track and lineside equipment Failure
Rainfall	Pluvial flood	Track and lineside equipment Failure
Rainfall	Fluvial flood	Scour and water effects at bridges
Rainfall	Fluvial flood	Scour at embankments due to high river levels and culvert washout
Rainfall	Fluvial flood	Safety of workforce carrying out inspections during an extreme flood event
Rainfall	Pluvial flood	Landslips
Rainfall	Fluvial flood	Accessibility of fleet and of maintenance depots
Insolation/ heat/ rainfall/ wind	Vegetation	Change in type, falling trees causing obstructions, poor adhesion, and track-circuit non-activation
Sea level rise and storms	Coastal and estuarine defences	Wave overtopping and flooding at defended coastal and estuarine railways

Ongoing availability of electricity is clearly a key risk area but is not included in this table as it is outside the scope of management of Network Rail and will be picked up as one of the key interdependencies..

3.2.5: Airports

Turning now to airports, specifically Heathrow, it is recognised that there will be impacts on buildings, operations and passengers. Buildings will face increased cooling demand for both

terminals and aircraft and there are likely to be shortages of power, fuel and water. Flooding of terminals and the airfield under certain circumstances are considered possible.

From an operational perspective it is possible that exceptional climate change may lead to payload limitation and/or a need for longer runways – a practical impossibility at Heathrow, while slower climb rates may mean the need for airspace redesign. Sustained higher temperatures could lead to diversion of incoming aircraft if temperatures were to become too high for safe landings while, as yet unforecast, changes in prevailing wind conditions would affect optimal runway orientation.

Increased temperature might reduce the need for de-icing which would represent opportunity a cost saving, but might increase bird hazards while there may be seasonal changes to passenger demand and other shifts related to road, rail or tube disruption.

The workshop was unclear whether water was an essential item for safe airport operation, *ie* what would be the impact on Heathrow of the loss, failure or closure of adjacent reservoirs?

3.2.6: Ports

Ports have a reporting requirement only in relation to wetside infrastructure. There is no requirement for reporting dryside issues. However, in practice, strategic ports (those carrying more than 10M tonnes cargo *per annum*) report on all facilities for which they are responsible. Climate change is considered likely to affect road surfaces, rail lines, sewage treatment, power supply efficiency, and IT systems through higher temperatures. Drought and pressure on water supplies, especially in the south east, are likely to have an impact while flooding and sea level rise generate higher risks for transport, water treatment, electricity substations and power stations. Storms will affect power and telecommunications networks and operations at ports and airports. Sea-level rise *per se* is likely to be a benefit for most ports as it enables larger ships to be moved and reduces the need for dredging. It is suggested that sea level rise can be factored into port planning and harmonise with the 20-30 year investment cycle in this sector.

Adaptation is being commenced with revised operating practices to protect staff working outside while specifications for new build already exceed the range of conditions required for adaptation – although this is seen as a happy accident rather than good design. As with all things commercial, customer needs and demands are the strongest driver of adaptation *eg* refrigerated units.

The workshop also considered that while wind can interrupt functioning of a port and so is already a constraint upon operation and expansion it is not necessarily forecast to increase.

It was noted that most buildings at ports are owned by private companies and do not currently come under any obligations to be resilient to climate change nor to report on their ability to cope.

3.2.7: Local Authority roads

The position with regard to Local Authority roads is complex. In 2007 the Audit Commission issued a series of national performance indicators (NIs) for Local Authorities. NI 188, Planning to Adapt to Climate Change, states: "To ensure local authority preparedness to manage risks to service delivery, the public, local communities, local infrastructure, businesses and the natural environment from a changing climate, and to make the most of new opportunities. The indicator measures progress on assessing and managing climate risks and opportunities, and incorporating appropriate action into local authority and partners' strategic planning."

Leicestershire, Derbyshire and Nottinghamshire acting as the 3 Counties Alliance Partnership (3CAP) began work in 2008 to assess the effect of climate change on their highways policies and standards. The project took predictions by the UK Climate Impacts Programme 2002 (UKCIP02), and developed an adaptation plan using a risk and probability management approach based on predictions made for the year 2050. The results indicated significant impacts on the construction and maintenance of local authority highways.

The ten effects posing the biggest risks from climate change to the highway network are:

- Pavement failure from prolonged high temperatures
- Increased length of the growing season leading to prolonged and/or more rapid growth of the soft estate;
- Lack of capacity in the drainage system and flooding of the network;
- Surface damage to structures from hotter and drier summers;
- Scour to structures from more intense rainfall;
- Damage to pavement surface layers from more intense rainfall;
- Subsidence and heave on the highway from more intense rainfall;
- Scour and damage to structures as a result of stronger winds and more storminess;
- Severe damage to light-weight structures from stronger winds
- Less disruption by snow and ice due to warmer winters

The 3CAP region looks to be ahead of many others in terms of predicting changes and implementing plans to tackle both the causes and effects of climate change. This project has identified responses to achieve Level 2 of National Indicator 188 [Comprehensive Risk Assessment] and the adaptation action plan developed by 3CAP to address the biggest risks achieves Level 3 [Comprehensive action plan and prioritised action in priority areas]. An outline timescale has been agreed for implementation of this adaptation action plan which would move the 3CAP councils towards achieving Level 4 of NI188 [Implement an adaptation action plan and establish a process for monitoring and review to ensure progress].

Work is starting to see to what extent the work done so far needs to be modified to incorporate UKCIP09; there looks to be a strong case for seeing whether the 3CAP work is sufficiently generic to be adopted by a much wider range of LAs.

3. Barriers to Implementing Adaptation Options

Uncertainty is perceived as the biggest single barrier to change. Currently the ‘risk’ of over-investment in unnecessary resilience is seen as greater than the risk and consequences of failure. This situation is probably not helped by relatively short-term investment appraisals and high uncertainty in job security – and the rate of job turnover amongst Senior Executives. There need for a better understanding of traveller behaviour has already been flagged; both this and the impact of climate change on national demographics need to be studied from a base of “hard”, quantified climate data (which is in short supply).

There are a large number of climate effects which are not properly understood or are not yet quantified at a sufficient level of certainty to support any specific changes in infrastructure, eg wind direction. While there are forecasts and models provided by the Environment Agency and the Meteorological Office, there are computational limits on processing data for climate forecasts – particularly given the processor hungry nature of the models that are currently being constructed.

Availability of funding is as ever a challenge and the current and future economic circumstances in which infrastructure will exist is highly uncertain. From a regulatory perspective, it was suggested that standards need to be agile to remain relevant and that there is little support or sponsorship from Government to enable a standards setting process. This was contrasted with the evidence from France where it is reported that the Government sponsors travel costs for delegates to accredited standards bodies.

Businesses within the sector tend to be organised in silos with climate change expertise often in one specific business area and not seen as central to operations. Meanwhile the transport industry itself is highly segmented (eg 24 train operating companies, innumerable Bus and Coach operators) and only marginally profitable in many situations. It is not an industry generating surpluses which are available for investment in projects of uncertain value and or return.

Transport is highly dependent on the other industries – energy, water (eg flood prevention, water needed for operations), and ICT for its continued operation and may suffer unforeseen consequences from assumptions of linearity and independence.

A scoping study before the workshop involving a number of the participants identified a number of issues that are already inhibiting engineering work on infrastructure:

Legal, Administrative and Institutional

- Adapting a significant part of rail infrastructure will require Town and Country Planning Act consents or English Heritage approvals (or both) which are usually slow processes
- Rail has had a number of cases where remedial work has been subject to mutually contradictory constraints by the Environmental Agency and Natural England
- Some rail and road earthworks likely to need attention are adjacent to Sites of Special Scientific Interest or similar designation so an additional approvals will be required
- In most cases adapting rail infrastructure will have implications for the Regulatory framework
- Adaptation at a national level could require very wide-impact moves which would be socially unacceptable for example a ban on car air conditioning
- There is little experience of disaster recovery management techniques and no recognised corpus of knowledge and training based on documenting previous incidents
- Resilience teams are primarily focused on the very short term (the next 60 minutes rather than the next 60 years), however, their expertise is highly valuable in understanding how infrastructure can be made more resilient and how interdependent sectors are impacted by incidents
- There is not a generous funding allocation for adaptation work under current budgets, which are likely to be reduced in view of pressures at national level
- There is a significant risk of duplication or gaps (or both) in the absence of any one central reference and coordinating body responsible for maintaining a list of known or emerging engineering standards, research activities *etc*
- Addressing climate change issues is essentially meeting a long-term need; however benefit–cost appraisal models give inadequate weight to benefits so far in the future
- There is no central ‘clearing house’ logging all initiatives by the numerous bodies in this area with the result that there is overlap of activity and almost certainly duplication.

Technical

- In most areas there is no shortage of underpinning science to take forward adaptation projects. However it is likely that a significant amount of that scholarship is in archived reports, and the knowledge within them has not yet been used to write standards or design engineering products and processes, because of resource limitations.
- Adapting infrastructure while it is in service will either involve partial removal of capacity or full closures / blockades; all of which are most unpopular with travellers
- Dealing with significant adaptation projects is likely to require project and programme management experience, together with knowledge and skills in areas such as drainage techniques, geotechnical engineering, all of which are in short supply
- In many cases working on transport infrastructure requires compliance with the practices and standards of the owners of co-located services – for example most water supply companies have specified margins for closeness to their main supply pipes which limit the freedom of action to adapt the rail infrastructure

A final major barrier is that of information sharing and co-ordination. Whilst recognising that there may be issues of commercial confidentiality, it is suggested that an information co-ordinating body – a nexus that brings together people and information at a single point of contact would have significant benefits. OLEV was offered as a model for this. An example of where such knowledge sharing could be valuable is in the stocks of disaster mitigation equipment. There is no central repository of such information and apparently no organised sharing of this information at a national

level. It is considered that this inhibits sharing of plant and equipment and inhibits the response to emergencies and disasters.

4. Interdependencies

There are significant and major interdependencies within the transport sector. Transport workers and managers must themselves travel to and from work, while the vehicles depend on the provision of energy – most commonly liquid fuel, delivery of which typically relies on road vehicles. There are interdependencies between transport and ICT with management systems, control systems and communications systems all relying on provision of power and for electricity – to run transport infrastructure (eg electric trains) and management systems.

There appears to be very little joint working between modes of transport, although when the opportunity is created there is much enthusiasm for sharing information. However, the workshop identified five areas where rail and road have the same physical infrastructure issues but could see no organised information sharing taking place. These issues are: bridge scour, drainage, embankment and cutting stability, subsidence. Recent events have highlighted the scour issue.

	Telecoms		Water				Energy		
	landline	wireless	drinking	sewerage	surface	rivers	electricity	gas	oil
Roads	✓				✓	✓			
Pedestrian routes					✓				
Cycling paths					✓				
Surface rail					✓	✓	✓		
U/G rail	✓						✓		
Airport	✓					✓	✓		
Airways		✓							✓
Terminals			✓				✓		
Coastal infrastructure	✓	✓							
Seaports						✓			
Inland waterways					✓	✓			
Embankments					✓	✓			
Tunnels						✓	✓		
Bridges						✓			
Pipelines							✓		
Control systems	✓	✓					✓	✓	
SatNav		✓							
Oil Distribution					✓		✓		
Gas Distribution					✓		✓		
Electric car recharge network		✓					✓		
CO2 transport					✓		✓		

Derived from Annex C, Engineering, Infrastructure and Climate Change Adaptation Conference (Defra, 2009) – likely damage rated “high” and probability rated “medium “or “high”

5. Opportunities Arising from Climate Change

Given that the UK transport sector has taken a lead in responding to the emergent threat from Climate Change there are a number of potential business opportunities arising. These include inward tourism, refrigerated transport systems and, significantly, the export of intellectual property and consulting know-how in solving the problems identified.

Other developments might include internet-enabled maps indicating weather/climate and likelihood of weather events at specific locations (based on Met Office data to 25km²) over different time periods, integrating data from different systems and acting as a knowledge sharing nexus.

While increased use of remote monitoring would improve prioritisation this in turn increases dependency on ICT and raises the possibility that warning signals may be lost in the increasing noise resulting from increased monitoring. The tools and skills to discriminate useful and meaningful information will be key.

The workshop raised concerns over the number of engineers available and of bottlenecks in engineering skills available to meet the challenge of climate change (“A National Infrastructure for the 21st Century”. Council for Science and Technology, 2009). They recognise that the UK has world-leading capability in climate change, and that nearly all the technology required to meet challenges of climate change already exists, here or elsewhere in the world. It is suggested that commercialisation of the Meteorological Office has hindered knowledge sharing as it is charging for essential data and the government needs to free up that data. It was further noted that the Environment Agency charges for access to data on rivers. Chapter 8 of the CST Report: “A National Infrastructure for the 21st Century” considered the issue of skills in greater depth and an extract from that forms appendix 2 to this report.

6. Unsolved Problems

It was recognised that, going beyond previous discussions there is a need to consider :

- The potential for co-incident (or ‘cascade’) events, eg a “double whammy” of, say, flood and heat; snow followed by mist and so on. This should also extend to ‘cascade failure’ – for example loss of energy causes outage of ICT based remote site control systems which in turn will inhibit recovery of the energy supply, whilst also disabling control of water and gas supplies and the operation of other transport systems. Such an event would severely impact on the electrified railways as they depend on the availability of electricity for both the rolling stock AND the signalling system. Failure of either prevents the safe operation of the railway.
- It was suggested that not all parts of the country face similar risk levels or similar impacts. Regional maps of severe weather impacts mapped against critical infrastructure elements would be useful.
- Location of future flood risk is a matter of critical importance which is not as well understood as it needs to be.
- The impact on human behaviour of climate change overarches everything else, is not at all understood, and needs to be properly researched and studied.
- A better understanding of the current and future economic scenarios and their interactions with climate change and adaptation needs to be developed in order to provide more reliable information for the sector.
- Currently conventional modelling and simulation systems present significant and costly computational challenges. They may slow down modelling process and inhibit capacity.

8. Appendices

8.1. Participants

Surname	Firstname	Job title	Organisation
Baker	Chris	Professor of Environmental Fluid Mechanics	Birmingham University
Beckford	John	Rapporteur, Professor, Information Science, Loughborough University	Beckford Consulting
Blythe	Phil	Professor of Intelligent Transport Systems	Newcastle University
Brooke	Jan	Environmental Consultant	
Brown	Chris	Rail Research Programme Manager	DfT
Chiverrell	Chris	Associate	CIRIA
Dora	John	Principal Civil Engineer	Network Rail
Earl	Graham	Head of Climate Change	BAA
Ebbutt	Paul	Principal Client Engineer - Civils Track & Civils, Strategy & Service Development	London Underground
Flanagan Palan	Vladislava	Principal Structures Advisor	Highways Agency
Furlong	Andrew	Director Policy and Communications	IChemE
Glendinning	Stephanie	Reader in Environmental Geotechnics	Newcastle University
Hadfield	Patrick	Rapporteur	Beckford Consulting
Hardy	James	Head of Strategy Support	RSSB
Hemmings	Philippa	Head of Engineering for Sustainability	EPSRC
Huebner	Yvonne	Principal Policy Advisor	IET
Kerwick-Chrisp	Dean	Head of Sustainable Development & Climate Change	Highways Agency
Kidd	Ben	Project Manager	CIRIA
Liaghat	Davood	Director	Buro Happold
Low	Lit Ping	Manager	PriceWaterhouseCoopers
Marsden	Jan	Geotechnical Advisor	Highways Agency
Newman	Peter		Defra
Perry	Robin	Director	Capita Symonds
Robinson	Mark	Associate Dean Transport	Newcastle University
Sampson	Eric	Member	IET Transport Policy Panel
Santhalingham	Santi	Principal Drainage & Water Quality Specialist	Highways Agency
Subryan	Colin		TfL
Thompson	David	Senior Analyst	Committee on Climate Change

Wall	Alison	Associate Director Mission Programmes	EPSRC
Webb	Matthew	Climate Change Strategy Manager	London Underground
White	Carolyn	Head of Business Development, Standards & Compliance	IET
Whitehead	David	Director	British Ports Association
Wilson	Gary	Head of Marine & Port Services	Hutchison Ports UK
Witton-Smith	Michelle	Environment Policy and Delivery Division	DfT
Woolston	Helen	Group Environment & Climate Change Co-ordinator	TfL

8.2. Extract from CST Report

“The Sector Skills Councils and other bodies representing industry and professions, such as learned societies, professional associations, higher and further education institutes, need to continue working together to provide the Government and the devolved administrations with this essential information. But the lead must be with the employers themselves, and in a co-ordinated way.

Encouraging the supply of science, technology, engineering and mathematics graduates should continue to be a Government priority. Putting in place more high-level apprenticeships and training and development of technician engineers should be an important component of the skills mix needed. The development of multidisciplinary skills sets to design, install, operate and maintain the NI will be essential.

There is a question of whether a more focused approach to skills training is needed for strategically important sectors such as the low carbon economy, and major infrastructure projects such as nuclear build and retrofitting of low-carbon solutions. There are other skills bottlenecks needing urgent attention, for example in transport planning and operational research. The economic and Social Research Council will have an important role in ensuring that these skills and the relevant research is undertaken to support a modernised national infrastructure.

Social science skills will be essential at many stages of planning and implementing change in the NI. These include:

- *researching, and gathering together the findings from existing research, on the social*
- *dimensions of modernising the NI*
- *informing modelling and simulation on a more interconnected NI*
- *operational management of the NI systems in a way which takes the social dimensions fully into account*
- *managing public engagement” (p49)*

8.3. References and Bibliography

8.4. Presentations

8.4.1	Helen Woolston	Transport for London
8.4.2	D Kerwick-Chrisp	Highways Agency
8.4.3	B Kidd	CIRIA
8.4.4	John Dora	Network Rail
8.4.5	Graham Earl	Heathrow Airport
8.4.6	Gary Wilson	Port of Felixstowe

Appendix 8.5: Matrices from the Transport Breakout Group December 2009

(1) LIKELEY INTERACTIONS BETWEEN CLIMATE CHANGE POTENTIALLY IMPACTING TRANSPORT INFRASTRUCTURE

TRANSPORT INFRASTRUCTURE AFFECTED ↓	CLIMATE CHANGE POTENTIALLY IMPACTING TRANSPORT INFRASTRUCTURE																												
	High temp		Low temp		Water table rise		Sea level rise		Storm surge		Prolonged Rainfall		Flood		Drought		Snow		Extreme W/mnd		Electric storm		Frost		Fog		Soil shrinkage		
	D	P	D	P	D	P	D	P	D	P	D	P	D	P	D	P	D	P	D	P	D	P	D	P	D	P	D	P	D
Roads	M	H	M	L	M	L	M	L	H	H	H	H	H	H	H	H	H	H	H	M	L	L	H	M	H	M	H	H	
Pedestrian routes	L	L	M	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	
Cycling paths	L	L	M	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	
Surface rail	L	H	L	L	M	M	M	M	H	H	H	H	H	H	H	H	H	H	H	M	L	L	L	L	L	L	L	L	
U/G rail	L	M	L	L	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	
Airport	M	H	M	L	M	L	L	L	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	
Air ways	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	H	H	H	L	L	L	L	L	L	
Terminals	L	L	L	L	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	L	L	L	L	L	L	L	L	L	
Coastal infrastructure	L	L	L	L	M	H	H	H	H	H	H	H	H	H	H	H	H	H	H	M	L	L	L	L	L	L	L	L	
Seaports	L	L	L	L	M	M	M	M	H	H	H	H	H	H	H	H	H	H	H	L	L	L	L	L	L	L	L	L	
Inland waterways	L	L	M	L	M	M	M	M	H	H	H	H	H	H	H	H	H	H	H	L	L	L	L	L	L	L	L	L	
Embankments	L	L	L	L	M	M	M	M	H	H	H	H	H	H	H	H	H	H	H	L	L	L	L	L	L	L	L	L	
Tunnels	L	L	L	L	M	M	M	M	H	H	H	H	H	H	H	H	H	H	H	L	L	L	L	L	L	L	L	L	
Bridges	M	H	M	L	M	L	L	L	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	
Pipelines	L	L	L	L	M	M	M	M	H	H	H	H	H	H	H	H	H	H	H	L	L	L	L	L	L	L	L	L	
Control systems	M	M	L	L	M	M	M	M	H	H	H	H	H	H	H	H	H	H	H	M	M	M	M	M	M	M	M	M	
SatNav	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	
Oil Distribution	L	L	L	L	M	M	M	M	H	H	H	H	H	H	H	H	H	H	H	L	L	L	L	L	L	L	L	L	
Gas Distribution	L	L	L	L	M	M	M	M	H	H	H	H	H	H	H	H	H	H	H	L	L	L	L	L	L	L	L	L	
Electric car recharge network	L	L	L	L	L	L	L	L	M	M	M	M	M	M	M	M	M	M	M	L	L	L	L	L	L	L	L	L	
CO2 transport	M	M	L	L	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	L	L	L	L	L	L	L	L	L	

Likely Infrastructure Damage and Probability of a climate change-related impact are each scored as High Medium Low

Cross cutting points:

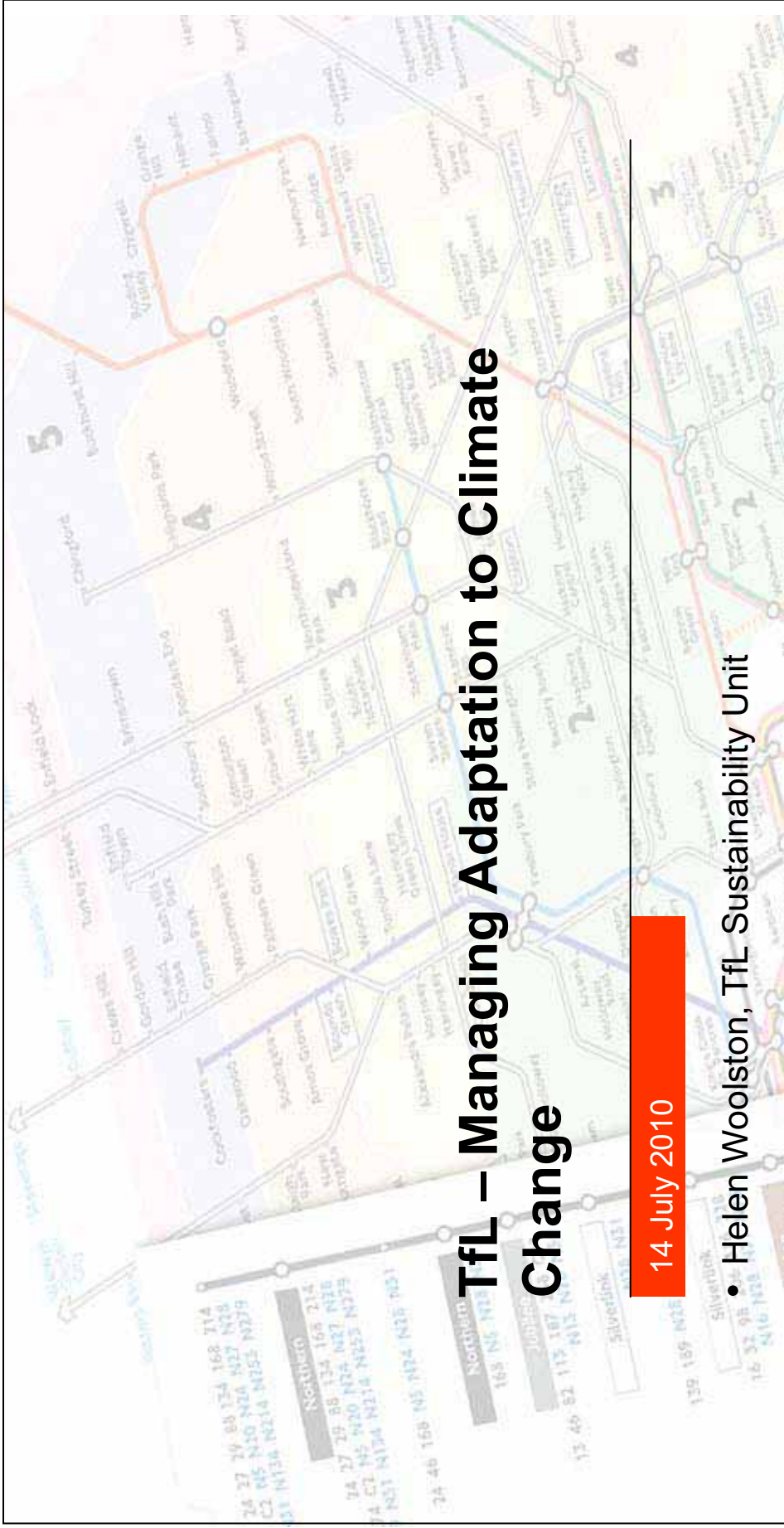
- The impact from repeated or cumulative events will be different from that of a one-off event.
- Consistent adverse conditions will support mitigating investment but sporadic events, even if more extreme, will not.

- Impact from climate change is different in different geographic areas.
- Different types of infrastructure have different intrinsic resilience eg diversion around a damaged road is far easier than around a damaged airport.
- Climate change might lead to changes in vegetation which in turn might impact on infrastructure, while seasonal demand on infrastructure might add to stress.
- Climate change might lead to changes in land use which in turn might require infrastructure changes

(2) TRANSPORT INTERDEPENDENCIES RELATIVE TO TELECOMS, WATER & ENERGY INFRASTRUCTURE

	Telecoms				Water						Energy							
	landline		wireless		drinking		sewerage		surface		rivers		electricity		gas		oil	
	D	P	D	P	D	P	D	P	D	P	D	P	D	P	D	P	D	P
Roads	H	M	L	L	L	L	M	M	H	H	H	H	M	L	L	L	L	M
Pedestrian routes	L	L	L	L	L	L	H	L	H	M	L	L	L	L	L	L	L	L
Cycling paths	L	L	L	L	L	L	L	L	H	M	H	H	H	L	L	L	L	L
Surface rail	L	L	L	L	L	L	L	L	L	M	M	M	H	L	L	L	L	M
U/G rail	H	M	M	L	L	L	M	L	M	M	M	M	H	L	L	L	L	M
Airport	H	M	M	H	M	M	H	L	M	M	M	M	H	L	L	L	L	H
Air ways	L	L	H	H	L	L	L	L	L	L	L	L	L	L	L	L	L	H
Terminals	M	M	M	M	H	M	H	L	M	M	M	M	H	L	L	L	L	M
Coastal infrastructure	H	M	M	M	M	M	M	M	L	L	L	L	H	L	L	L	L	L
Seaports	L	L	L	M	H	L	H	M	M	M	H	M	M	L	L	L	L	M
Inland waterways	L	L	L	M	L	L	L	L	H	M	H	M	L	L	L	L	L	M
Embankments	L	L	L	L	L	L	M	M	H	M	H	M	L	L	L	L	L	L
Tunnels	L	L	L	M	L	L	L	L	M	M	H	M	H	L	L	L	L	M
Bridges	L	L	L	L	L	L	L	L	L	L	H	M	L	L	L	L	L	M
Pipelines	H	L	H	L	L	L	L	L	L	M	L	M	H	L	L	L	L	M
Control systems	H	M	H	M	L	L	L	L	M	M	M	M	H	H	H	H	L	M
SatNav	M	M	H	H	L	L	L	L	L	L	L	L	H	L	L	L	L	L
Oil Distribution	M	M	H	L	L	L	L	L	H	M	L	L	H	L	L	L	L	L
Gas Distribution	M	M	H	L	L	L	L	L	H	M	L	L	H	L	L	L	L	L
Electric car recharge network	H	H	H	H	L	L	L	L	M	M	L	L	H	M	L	L	L	L
CO2 transport	M	M	M	M	L	L	L	L	H	M	L	L	H	M	L	L	L	L
Notes	<ul style="list-style-type: none"> • If oil distribution networks are damaged transport is severely impacted but the infrastructure remains intact • There are interdependencies within interdependencies eg loss of gas supplies leads to a high impact on the electricity infrastructure • Surface transport will be more electricity dependent and so more vulnerable in future years than now 																	

Likely Infrastructure Damage and Probability of an impact are each scored as High Medium Low



TfL – Managing Adaptation to Climate Change

14 July 2010

- Helen Woolston, TfL Sustainability Unit



Transport for London

River services

• 5.7m walk trips per day

Walking

• 2.2bn passenger

London Underground

• 3m trips per day
• 4bn passengers last year
• Traffic management services operated to
• 100% of major roads (including
• bridges and tunnels)

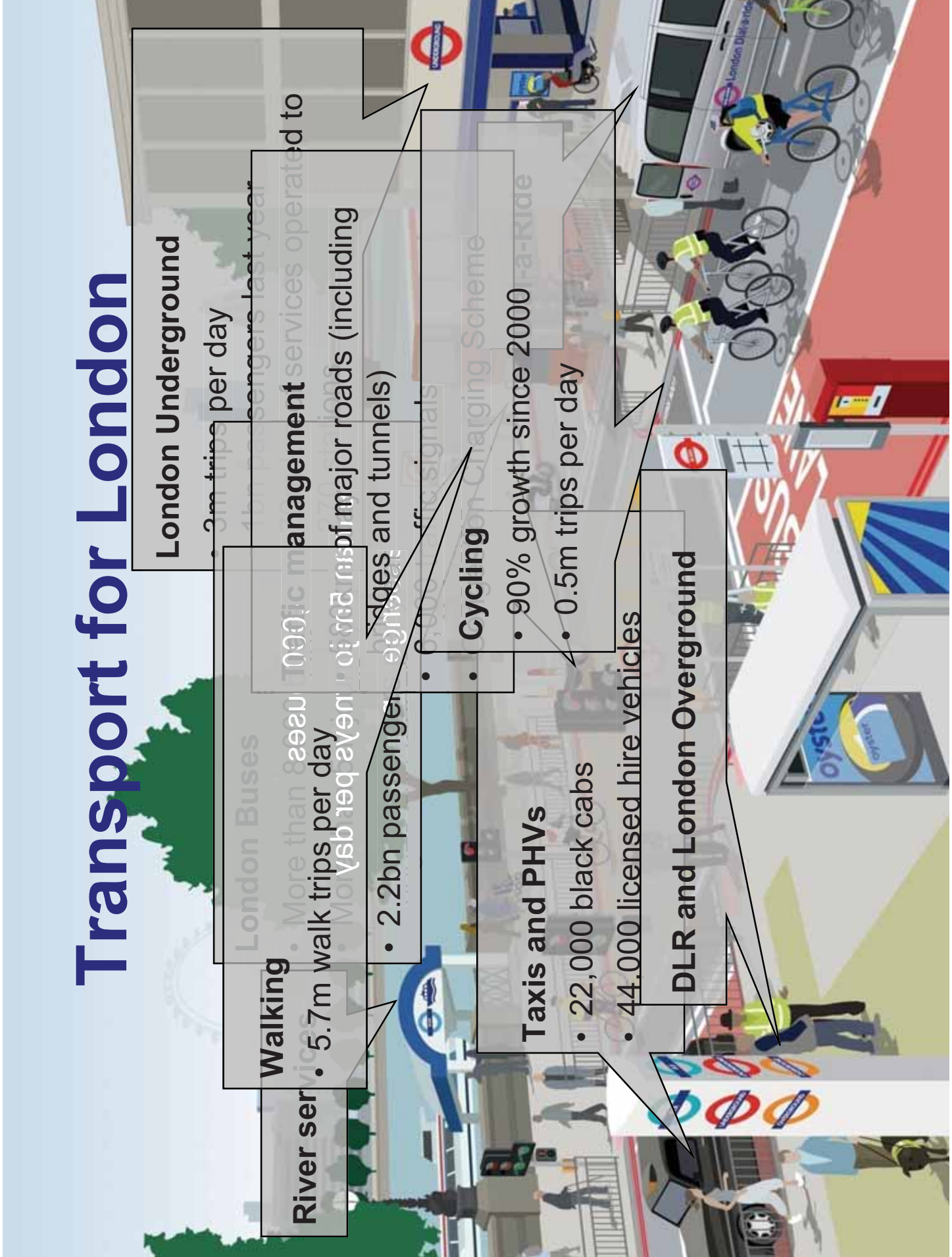
Cycling

• 90% growth since 2000
• 0.5m trips per day

Taxis and PHVs

• 22,000 black cabs
• 44,000 licensed hire vehicles

DLR and London Overground



Legal and Strategy Drivers



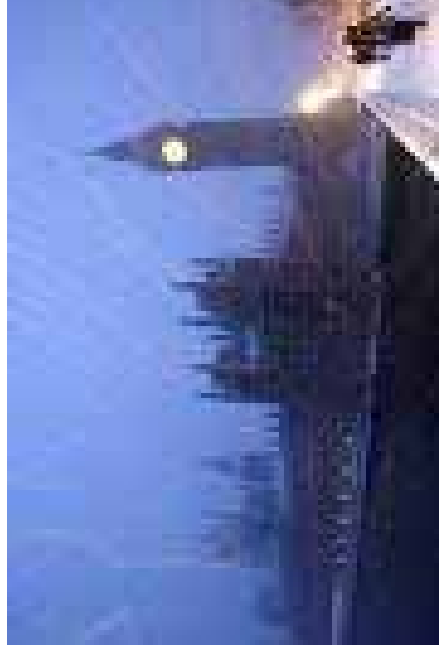
- Government Reporting Power
 - requires public bodies (including the GLA) to carry out risk assessments into the impacts of climate change and to publish these and plans to deal with the impacts
 - TfL reporting as part of GLA, due 31 December 2010



- Mayor's Climate Change Adaptation Strategy
- *The United Kingdom Climate Projections have helped to give us information on which to make our risk assessments and plans*

TfL's Analysis of the UK Climate Projections 09 show that there is likely to be:

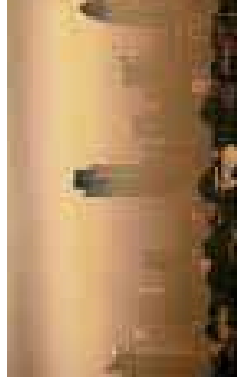
- Warmer wetter winters, rainfall becomes more seasonal
- Hotter drier summers
 - By the 2040s, European summers like 2003 could become normal; by the 2060s they would be cool
 - Increased number of summer deaths during heatwaves (ref 2003)
 - Exacerbated by Urban Heat Island effect
- Summer 2050's (high emissions)
 - +3°C
 - -30-40% rainfall
- Winter 2050's (high emissions)
 - +1.5 -2 3°C
 - + 25-30% rainfall
- More frequent extreme weather events
- Rising sea levels - increased risk of river flooding
- Increase in PM10 concentrations in hotter weather



How is London vulnerable to climate change?

- *Vulnerability is... 'the degree to which a system is susceptible to and unable to cope with adverse effects of climate change'*

- Flooding
- Water Resources
- Overheating
- Air Quality
- Subsidence and heave
- Wind Storms
- Global climate events



Identifying Climate Change Risks to TfL Assets

- Risk Identification Workshops Approach
- Current assets
 - Tracks
 - Drainage
 - Bridges
 - Embankments
 - Signals
 - Stations
 - Green estate
 - Surfaces – platforms, footways, pavements
 - Transport interchanges
- Planned build eg Crossrail, stations bridges



Examples of recent weather impacts

- Summer 2003 heatwave
- July 2007 rainfall
- February, December 2009 and January 2010 snow



Risks to TfL's Operational Services and Employees/Contractors

- Importance of communication, with customers, partners, businesses
- Employees' and contractors' skills, health and safety and quality of work
 - Currently no legal upper temperature limit for workers
- Services, timetables, frequency, emergency planning
- Customer comfort and information (eg Keep Cool LU campaign)



Existing TfL Activities

- Adaptation Programme – risk assessment workshops
- Flood Risk Assessments
- Drainage hotspots work
- Groundwater Pumping programme
- Bus specification
- Crossrail detailed design
- Cooling the Tube programme
- Resilience, Business Continuity, Emergency Planning, Risk Assessments and management
- With GLA:
 - Drain London
 - Environment Agency Thames Estuary 2100



Safe roads, Reliable journeys, Informed travellers



ENGINEERING, INFRASTRUCTURE & CLIMATE CHANGE ADAPTATION STUDY

Dean Kerwick-Chrisp
Head of Sustainable Development and Climate Change

sustainability@highways.gsi.gov.uk

Climate Change Adaptation

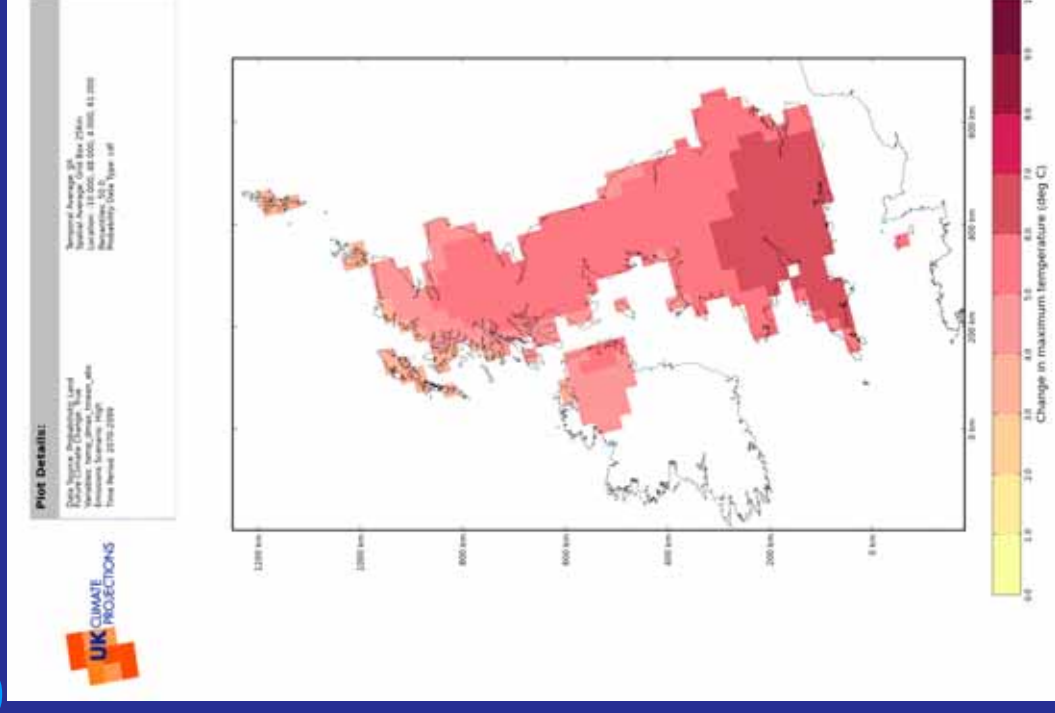
- Systematic risk assessment
- New standards/technical specifications
- Plans to introduce new standards/specifications
- Asset Register

Highways Agency



Primary Climate Change

- Increase in average temperature
- Increase in maximum temperature
- Increase in winter rainfall
- Reduction in summer rainfall
- More extreme rainfall events



Secondary Climate Changes

- Longer growing season
- Reduction in soil moisture
- Change in groundwater level
- Flooding
- Reduction in fog days in winter
- Reduction in icy days in winter
- Frequency in extreme storm surges
- Road users.....



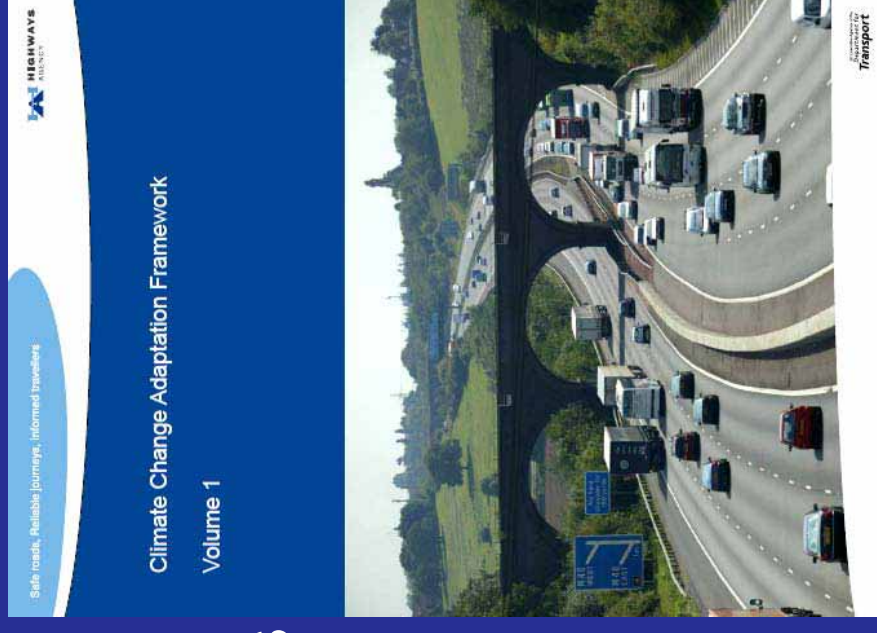
Systematic risk assessment: process

- Identify the activities of the Highways Agency that will be affected by climate change
- Determine associated risks and opportunities
- Identify preferred options to systematically address them
- Everyone aware.....

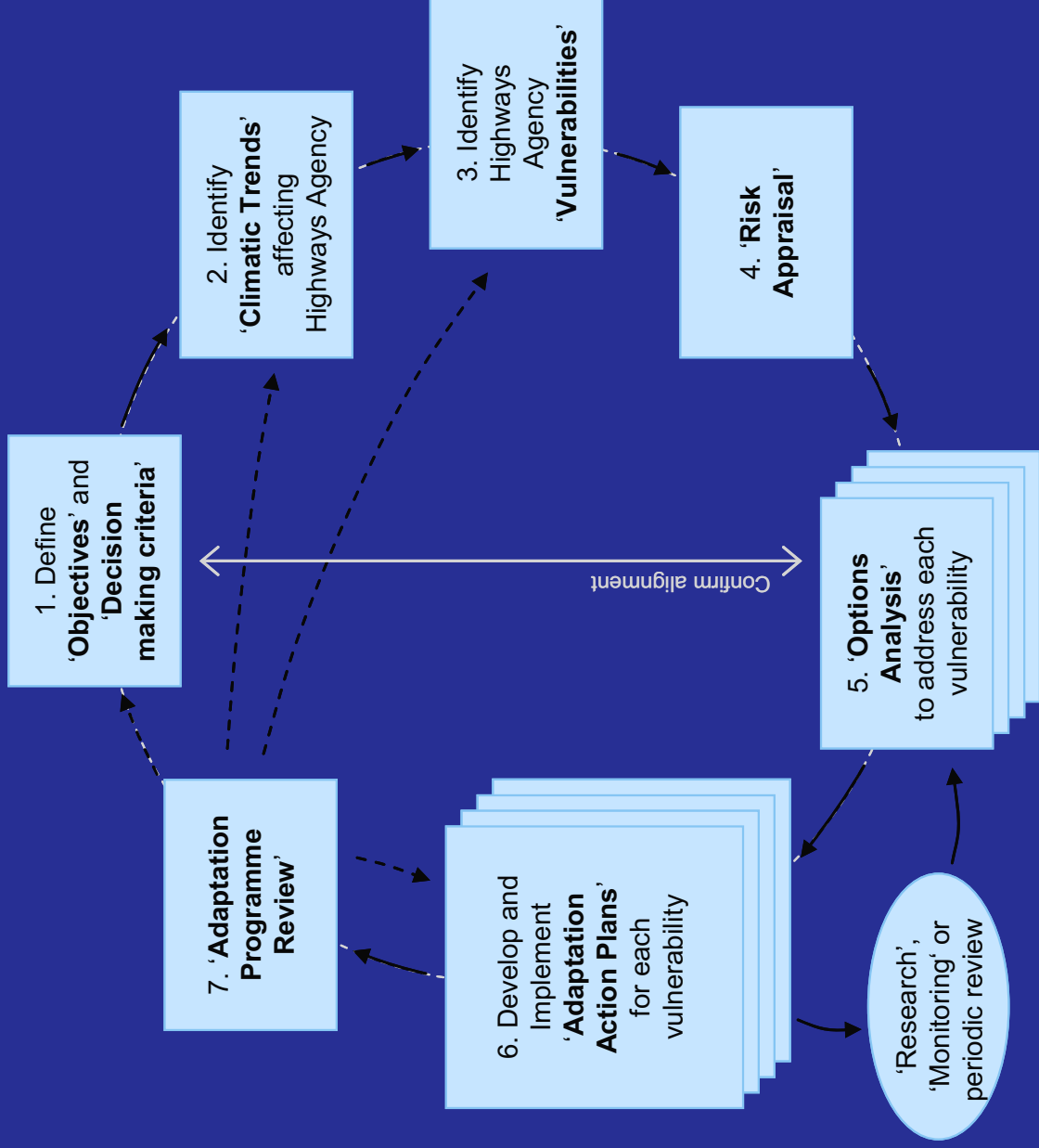


Systematic risk assessment: Elements of Adaptation Framework

- Defining climatic changes
- Assessing + prioritising risks
- Examining adaptation options
 - Cost benefit analysis
 - Timescales for adaptation + impacts
- Produce Adaptation plans
- Implement Adaptation measures



Adaptation: Framework Model



Adaptation: Risk Criteria

- **Uncertainty:** compound measure of current uncertainty in climate change predictions and the effects of climate change on the asset/activity.
- **Rate of climate change:** measure of the time horizon within which any currently predicted climate changes are likely to become material, relative to the expected life/time horizon of the asset or activity.

Adaptation: Risk Criteria

- **Extent of disruption:** measure taking account of the number of locations across the network where this asset or activity occurs and/or the number of users affected if an associated climate-related event occurs.
- **Severity of disruption:** measure of the recovery time in the event of a climate-related event e.g. flood, or landslide. This is separate from ‘how bad’ the actual event is when it occurs

Top level Highways Agency risks

- Reduces asset condition and safety
- Reduced network availability and/or functionality
- Increased costs to maintain safe and serviceable network
- Increased safety risk to road workers
- Increased programme and quality risks due to required changes in construction activities
- Current Highways Agency internal operational procedures not appropriate
- Increased business management costs

New standards/technical specifications: Generic Options

- Do minimum
- Future proof designs
- Retro fit solutions
- Develop contingency plans
- Update operating procedures
- Research
- Monitor



Plans to introduce new standards/ specifications: Structures (incl. gantries)

- Thermal action (loads) applied to superstructures
- Wind action (loads) applied to superstructures
- Increased thermal range giving rise to increased earth pressures for integral bridges
- Changing design requirements through modifying temperature/wind maps (National annex Eurocode)
- Design of structure drainage
- Use of temperature sensitive components or materials in construction and rehabilitation
- Design of bearings and expansion joints

Highways Agency: Asset register(s)

- Structures
- Pavements
- Earthworks
- Soft estate
- Drainage
- Lighting and signs
- Asset and systems interdependency.....



Day After Tomorrow....

- ...recognising to some degree of change...
- A process that:
 - Is aligned with our objectives
 - Focuses on activities
 - Identifies priorities for action
 - Integrates with current processes
 - Overview of progress and management of residual risk
 - Can accommodate changing demands and developments in climate science





Celebrating
50 Years

ciria

Infrastructure adaptation & resilience to natural hazards

Engineering, Infrastructure & Climate
Change Adaptation workshop – July 2010

Ben Kidd, CIRIA

www.ciria.org

Overview

Celebrating
50 Years



- CIRIA's role
- C688 industry "review"
- Developing consensus
- Utilising current research
- Future guidance development



*Walham substation, Gloucestershire,
courtesy Geodesign Barriers Ltd*

CIRIA's role

Celebrating
50 Years



- **Projects & publications**
 - Infrastructure asset management
 - Flood & coastal erosion risk management
 - Green infrastructure

- **Networks**

- LANDFoRM



- CPN



- CIEF

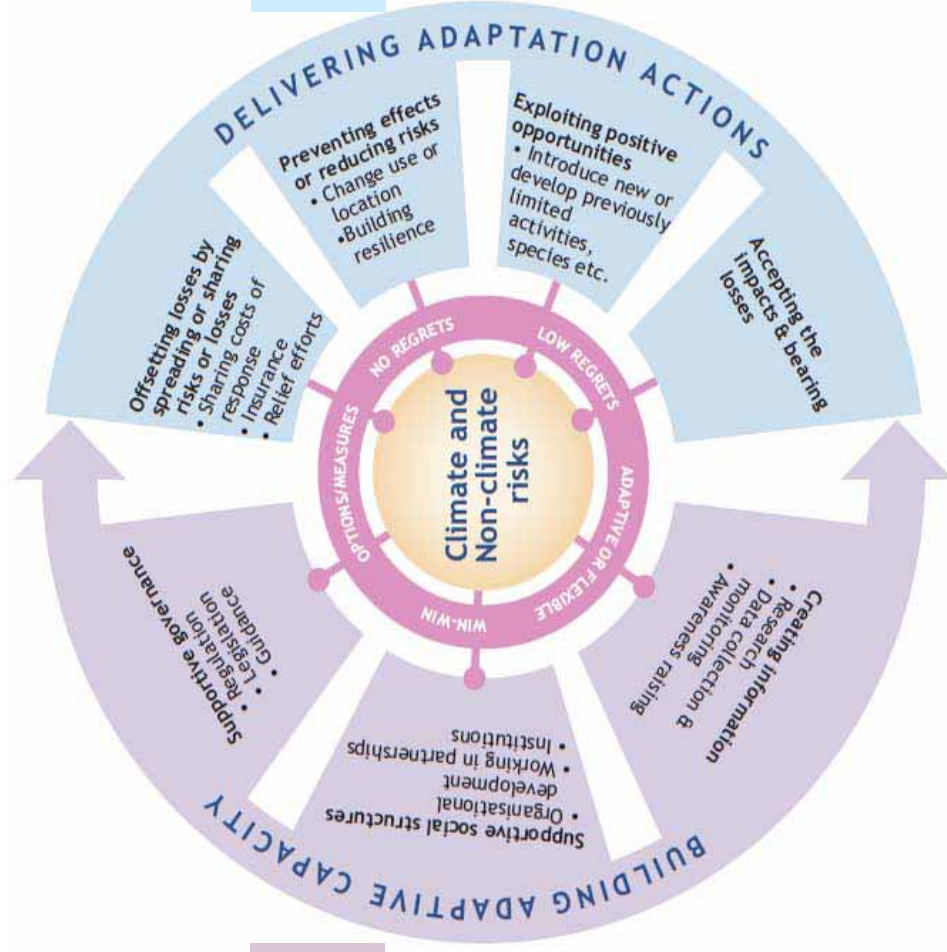


- MBE KTN



Adaptation options

Celebrating **ciria**
50 Years



Building adaptive capacity

Delivering adaptation actions

- CIRIA C688 *Flood resilience and resistance for critical infrastructure (2010)*



- Benchmarking exercise of critical infrastructure in UK



- www.ciria.org/service/c688

www.ciria.org



C688 Project development

Celebrating
50 Years



<i>Autumn 2000</i>	<i>Widespread floods</i>
<i>May 2003</i>	CIRIA & EA flood protection products guidance
<i>Jan 2005</i>	<i>Carlisle flooding</i>
<i>Jun 2005</i>	CIRIA C623 & C624
<i>2006</i>	<i>Project proposal developed</i>
<i>May 2007</i>	CLG (2007)
<i>Jun 2007</i>	<i>Widespread floods</i>
<i>June 2008</i>	MBE KTN workshop
<i>Dec 2008</i>	Pitt Review
<i>Jan 2009</i>	CIRIA project commences
<i>Nov 2009</i>	<i>Cumbrian floods</i>

C688 Project development

Celebrating
50 Years



- Pitt Review
 - Recommendation 51
 - identify vulnerability & flood risk, develop SRPs
 - Recommendation 52
 - collaboration
 - Recommendation 53
 - duty on regulators



C688 Project information

Celebrating
50 Years



• Research contractor: ARUP

• Funders:



www.ciria.org

C688 Project information

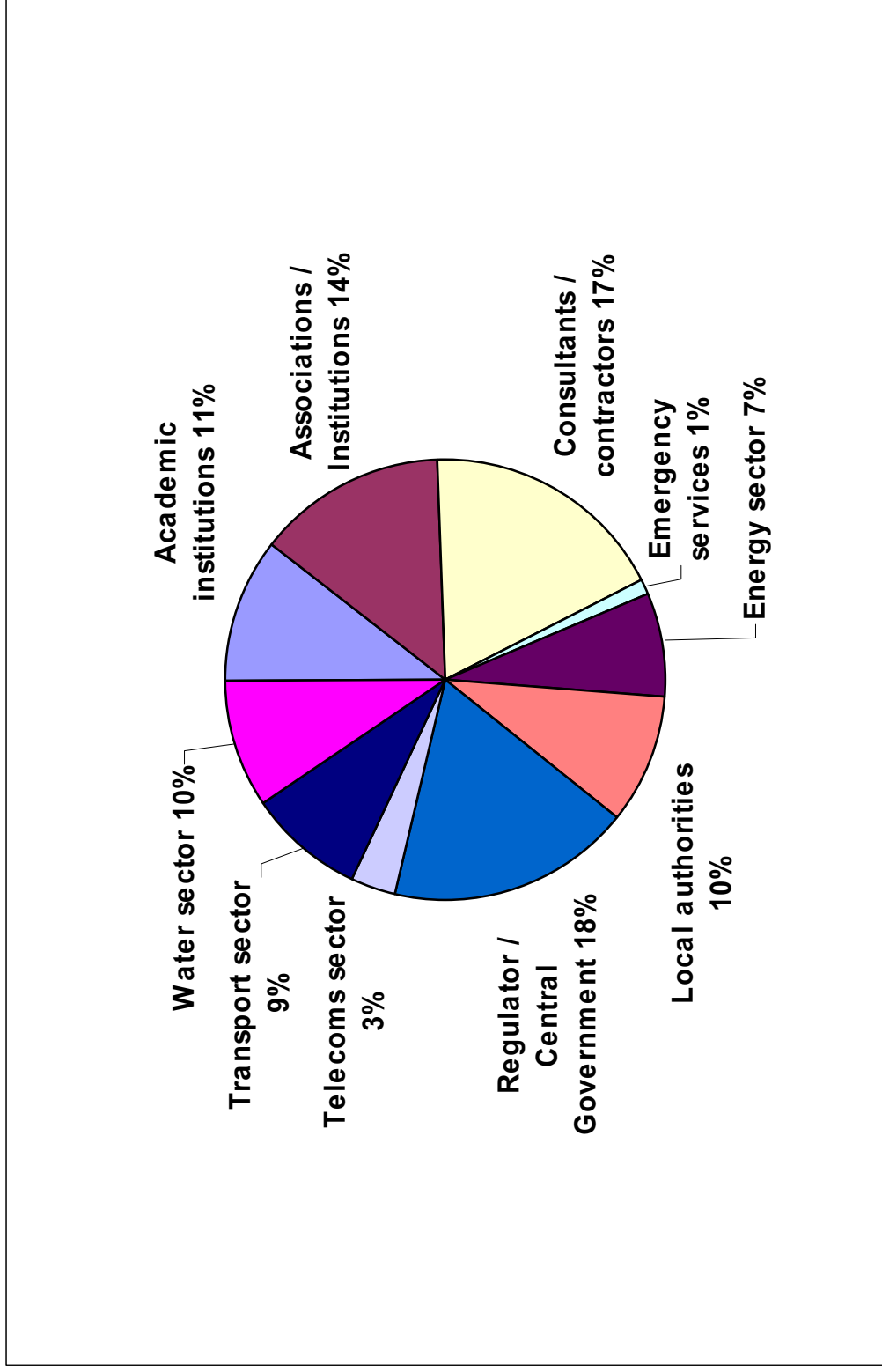
Celebrating
50 Years



- Objectives
 - collect and collate information on currently available flood resilience and resistance measures
 - identify approaches to improve the adaptation to flood risk (internationally & nationally)
 - promote cross-sector collaboration and consensus

Developing consensus – C688 stakeholder engagement

Celebrating
50 Years



C688 contents

Celebrating
50 Years



- Agreed definitions
- Regulatory context (CCA, FWMA)
- Lessons identified from historic incidents
- Current practice in:
 - FRA, adoption of measures (structural & non-structural), investment prioritisation
- Interdependencies & cross-sector collaboration

C688 project outcomes & findings (contd)

Celebrating
50 Years



- Complex regulatory context
 - Public / private sector mix
- Complex interdependencies
- Proposed framework for development of standards (risk-based & prioritised based on criticality)
- More data!!

C688 overall recommendation

Celebrating
50 Years

ciria

'Flood resilience measures should be implemented as an integral part of organisations' business continuity management processes, whole life asset management plans and climate change adaptation strategies'

- smarter investment planning required
- joined-up thinking
- greater focus on WLC (long term maintenance & renewal)

Subsequent activities since C688

Celebrating
50 Years



- MBE KTN climate change activities
 - UKCIP, ARCC & other research (LWIC)
- Helping ACC programme scoping
- Providing input to CCRA
- Natural Hazards Team CIRP
- EA flood warnings
- CIRIA good practice toolkit on infrastructure resilience to natural hazards
 - Workshop in August

In summary...

Celebrating
50 Years



- Guidance available
- More required...?
- CIRIA's here to help in both:
 - Industry consultation & dissemination
 - Building adaptive capacity
 - Developing consensus
 - Producing collaboratively-funded good practice guidance on implementation of adaptive measures

Celebrating
50 Years



Thank you

Ben Kidd

ben.kidd@ciria.org

020 7549 3300

www.ciria.org

CLIMATE CHANGE ADAPTATION

Network Rail

John Dora

Date 14.07.2010

Infrastructure Portfolio etc

31,000 km track	$\frac{3}{4}$ Earth's Circumference
12,000 km electrified railway	$\frac{2}{3}$ Overhead line – $\frac{1}{3}$ third rail
43,000 bridges	Largest single bridge owner in UK
700 tunnels	200 miles of railway in tunnel
23,000 culverts	250 miles of subterranean water courses
300 coastal and estuarine defences	150 miles of coastal railway
2500 stations	Large property portfolio
25,000 km of major earthworks	Twice the length of UK's entire motorway and trunk road network
Rail vehicles, TOC interface	24 Passenger Train companies

“Maintain, enhance and renew the existing network” (ORR)

Operations

- The train operators run more trains across Great Britain than are run in most European countries
- 24,000 trains per-day
 - more than Spain, Switzerland, the Netherlands, Portugal and Norway combined
- 50% more than France
- 60% more than Italy

Risk Assessment

Where to start?

Risk Assessment

Where to start?

Grouping by Assets or Systems

Risk Assessment

RSSB-funded Tomorrow's Railway and Climate Change Adaptation project (TRaCCA)

Seven workshops:

Track

Civils and Buildings

Signalling, Power, Communications

Operations and Train Companies

Maintenance

Renewals

Systems

Workshop output = Priorities

Climate Impact Group	Cluster	Consequence
Heat	Track	Management of track buckle risk
Heat	Track	Reduced window of opportunity to carry out maintenance/ renewals work due to heat
Heat	People	Passenger health and impact on freight from train failure in extreme temperatures, including heat and cold
Heat	People	Staff working conditions, eg: use of heat watchmen
Heat	Power/ Telecoms/ Signalling	Floating electrical earth leading to stray earth currents caused by dry ground/ low groundwater; heat (solar gain) affecting lineside equipment; sag in tethered overhead line systems at terminal stations
Rainfall	Fluvial flood	Track and lineside equipment Failure
Rainfall	Groundwater flood	Track and lineside equipment Failure
Rainfall	Pluvial flood	Track and lineside equipment Failure
Rainfall	Fluvial flood	Scour and water effects at bridges
Rainfall	Fluvial flood	Scour at embankments due to high river levels and culvert washout
Rainfall	Fluvial flood	Safety of workforce carrying out inspections during an extreme flood event
Rainfall	Pluvial flood	Landslips
Rainfall	Fluvial flood	Accessibility of fleet and of maintenance depots
Insolation/ heat/ rainfall/ wind	Vegetation	Change in type, falling trees causing obstructions, poor adhesion, and track-circuit non-activation
Sea level rise and storms	Coastal and estuarine defences	Wave overtopping and flooding at defended coastal and estuarine railways

Current position

- Contract with Met Office Hadley Centre
- Correlation and modelling impacts
- Mostly 'Delay Minutes' measures
- High-level overview mid September 2010
- Detailed outputs February 2011

.....ie: meeting Adaptation Reporting power timescales and feeding into Regulatory negotiation timescales

Plans

- To develop a tool to evaluate Policy Options for Adaptation (APET)
- Inputs might be:
 - Asset type *Infrastructure, Vehicle*
 - Reliability, location, condition
 - Future investment profile
 - Expected resilience/ reliability
 - Future climate
- Outputs might be:
 - Reliability of vehicles
 - Performance in delay minutes
 - Maps showing change

New Standards – Civil Engineering

- Civil Engineering Policy Statement issued May 2008
 - Scope - Renewal and Enhancement of *existing* Civils assets
 - Essentially says ‘*Follow PPS 25*’
 - Implications of Ciria C688 ‘Flood resilience etc’ being briefed
- Drainage standards being introduced December 2010
 - Full ‘asset management’ Manual
 - Design to allow for 20% increase in flow
 - Also 20% ‘safety factor’
 - Design for new, not existing

New Standards - Others

- Track, Signalling, Power, Comms, Vehicles....?
 - Follows ENs and other Industry requirements – based on existing climate
- Future ‘Policy’ will *likely* come under consideration following TRaCCA outputs

ALSO:

- Consider
 - *Regulatory timescales and*
 - *When decisions need to be made*
 - *System impacts*

Asset registers

- It's more than just the Asset Registers!
 - Safety management records
 - Performance databases for delay attribution
 - Line closure information
 - Assets condition, faulting, hazard reporting
- Linking relevant Measures with Assets is important
 - Good for track buckle risk but mostly correlations need established using historic, high-level data

Database issues

- Database consistency across 'silos'
 - Example: Drainage requires *consistent asset register* but is managed in more than one department
- Delays measured nationally for some years
 - Line closures not!
- Prime purpose of databases is not *weather management*
- Little in way of weather/ asset behaviour correlation

Conclusion

- Much work is in progress
- Much data has been sourced
- It's not all Asset Register dependent
- Challenges include use of data gathered for other purposes

THERE'S A LOT YET TO DO!

But do we need decisions on everything, tomorrow?...

What's needed?

- How do we get to Utopia? (Utopia = resistant and resilient Railway Systems)
- New build v legacy infrastructure
 - *one is easier but still faces challenges*
- Ideally – we need intelligence (are asset registers enough?)...
 - *location and condition...and*
 - *system dependencies internally and across sectors...*
- Assessment of **current** capability of 'System' with respect to weather and performance
 - *Meaning Standards against which we can assess..*
 - *Meaning a framework allowing this (funding??)..*

Suggestions welcome!

Adaptation at Airports A Heathrow Perspective

Dr Graham Earl

Engineering, Infrastructure & Climate Change Adaptation Study

14 July Workshop, Institution Of Chemical Engineers, One Portland Place, London



Heathrow is the UK's only hub airport



Background

- Identified as a Strategic Airport by DfT
- Requirement to produce an Adaptation Report to Defra by May 2011
- Working together as a sector (through AoA) to generate standardised and consistent approach
- Share many commonalities
- Airports at different levels of preparedness

Emerging Issues

- **Buildings**
 - Increased cooling demand for terminals and aircraft
 - Shortages of power, fuel, water
 - Flooding terminals (and airfield)
- **Operations**
 - Payload limitation or need for longer runways
 - Slower climb rates – airspace redesign
 - Diversion of incoming aircraft if temperature too high
 - Changes in prevailing wind conditions affecting optimal runway orientation
 - Reduced de-icing (opportunity)
 - Bird hazards may change
- **Passengers**
 - Changes to seasonal passenger demand
 - Road , rail and tube disruption
- **Business**
 - Delays and loss of capacity
 - Increased investment

At Heathrow

- Rising up the agenda
- Water management risks well understood (next 20 years)
- Continued need to understand
 - broader agenda
 - longer time horizon
 - implications on capital plan

Summary

- **Has a systematic risk assessment been completed for your sector?**
 - No but outputs from ARP will provide basis
- **Have new standards / technical specifications been necessary to reflect the risk assessment?**
 - Still early days – Airports applying EA advice. New standards may emerge
- **Are there plans for the sector to introduce the new standards / specifications?**
 - At Heathrow a key outcome from the ARP.
- **Is there a reasonably up-to-date Asset Register for the sector?**
 - Probably – nothing central but exists at airport level
- **If “No” to any of the first 4 questions is work underway to fill the gaps?**
 - Yes, at least at Strategic Airports



Hutchison Ports (UK)

**Port of Felixstowe:
Responding to Climate Change**

Our Environment ...



Our Environment ...



Port Authority



- The Felixstowe Dock and Railway Company as a Harbour Authority is required to report to DEFRA by 31/03/2011.
- Ports handling over 10 million tonnes of commercial cargo annually.

Beyond Navigation ...?



1. For FDRC as Harbour Authority the impact that climate change is forecast to have on its **navigation** statutory function is '**low risk**'.
2. With an increase in sea level rise navigation **benefits** - a requirement for **less dredge**.
3. OUR REPORT DONE!

However... this would be to assess the port in **isolation**, the port is an integral part of the UK's vital transport infrastructure network enabling the movement of goods around the UK and providing global links.



UK plc – ‘Trading Nation’



“The port is an integral part of the UK’s vital transport infrastructure network enabling the movement of goods around the UK and providing global links.”



Interdependencies



Impact on Port Operations



Impacts of climate change on infrastructure:

- **Higher temperatures:** effects on road surfaces and rail lines, sewage treatment, power supply efficiency, and IT systems
- **Drought:** pressure on water supplies, especially in the south east
- **Flooding and sea level rise:** higher risks for transport, water treatment, electricity substation and power stations
- **Storms:** affecting power and telecommunications networks and operations at ports and airports



Managing Resources



Effects of climate change are reasonably foreseeable.

- ★ Need to assess & minimise the risk.
- Proactive to minimise disruption & costs.

Hazards:

- Increased exposure to UV radiation.
- Short term sun burn.
- Long term increased skin cancer risk.
- Thermal discomfort.
 - Work: affecting concentration
 - Home: affecting sleep patterns

Mitigation:

- Additional facilities, eg cold water dispensers.
- Altering systems of work to limit exposure, eg flexible working patterns, job rotation, workstation rotation etc.
- Allowing sufficient breaks to enable employees to get cold drinks or cool down.
- Relaxing formal dress code – but beware personal protective equipment.



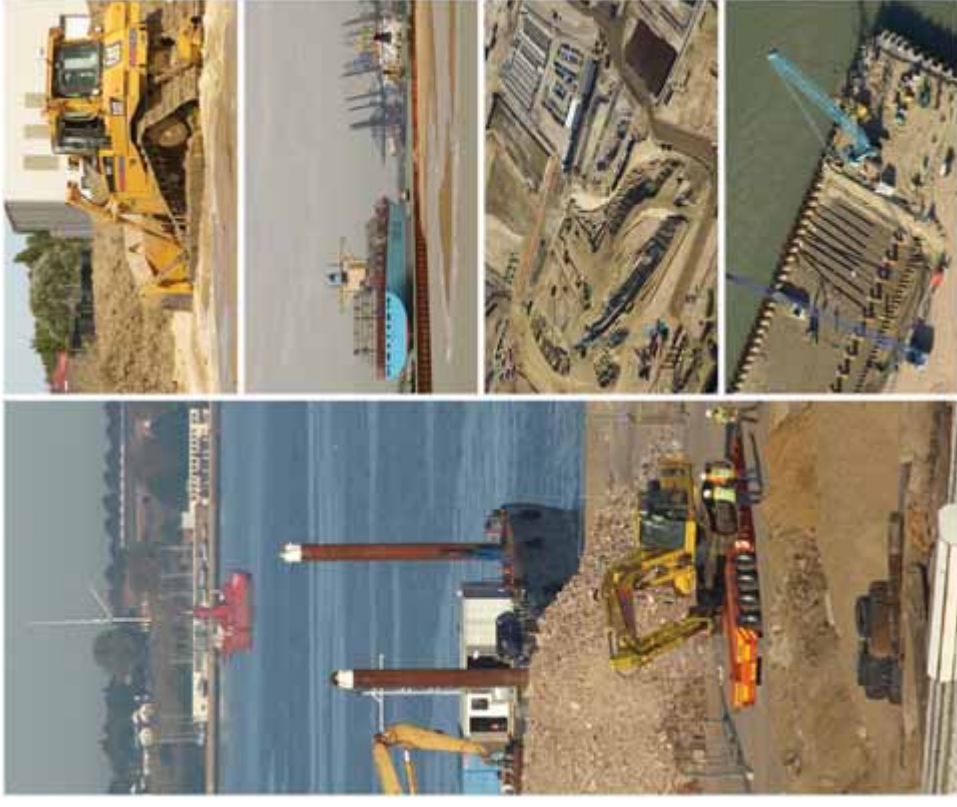
Port Build Specification



Did we design for Climate Change?

“No ... not really.”

- **Compliance with regulations** i.e. Flood Risk to secure consents.
- As a service industry we designed to what our **customers needed**.
- **Future proof** the design by enabling additional dredge to 18m, higher cranes.
- Future development?



Business Needs



Legal CC adaptation requirements

- We will comply
- Cold ironing demand / continuity

Business needs – reactive we are a service industry

- Possible increase requirement for reefers
- Temperature controlled facilities

In-turn driven by consumers

- Demand for chilled goods
- Out of season goods



Energy & Utilities



Fuel costs

- Increased demand likely.
- Reefers up to 30% of our electricity use.
- Any ambient temperature increase will therefore have a significant effect on our energy consumption.
- Demand for 'cold-ironing'.

Fuel availability

- Increase in number and intensity of extreme weather events (anywhere around the world), will impact on fuel/energy security and therefore cost.

Water

- Increased pressure on water resource in the South East will impact on price and availability.





Conclusions

- **The Climate is changing the debate is over how and when**
- Climate change is reasonably foreseeable, we are therefore duty bound to assess the risk and act on it
- **It's simply good business practice to consider risks and adapt**
- Action is better business sense than reaction
- **Ports are critical to UK plc and the hinterland**
- Ports (and UK plc) need reliable hinterland infrastructure
- **Climate change projections will change, so review regularly**



HPH

Our Mission

**To be the global market leader in
port development, operations and logistics services**