



# **Climate change and London's transport systems**

## Summary Report

September 2005

**Greater London Authority  
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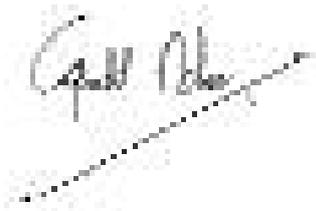


## foreword

London is a dynamic world city. It depends upon a multi-modal transport system with 26 million trips made each day for work, education or leisure. Extreme weather in recent years has brought challenges to keeping London moving – flooding, heatwaves and storms have all brought about delays and increased costs that have affected London's economy and the well being of Londoners. Predicted climate change will increase the frequency and intensity of extreme weather on top of a general trend towards hotter, drier summers and warmer, wetter winters.

The London Climate Change Partnership is committed to helping London prepare for climate change through raising awareness of the impacts of climate change and enabling partners to realise their responsibilities in adapting to those changes.

This report is a first step in ensuring that London has a transport network that is fit for the 21st century and supports its world city function. I would commend it to you and hope that the information and recommendations presented here are helpful to you. This is more than just a wake up call about responsibilities, all Londoners should recognise the opportunities to gain competitive advantage from innovation, adaptation and early action. I urge you to consider the issues presented here and consider the impact they do, can, or will have on your business and on the economy of our great city.



**Gerry Acher**

Chair, London Climate Change Partnership





## London Climate Change Partnership

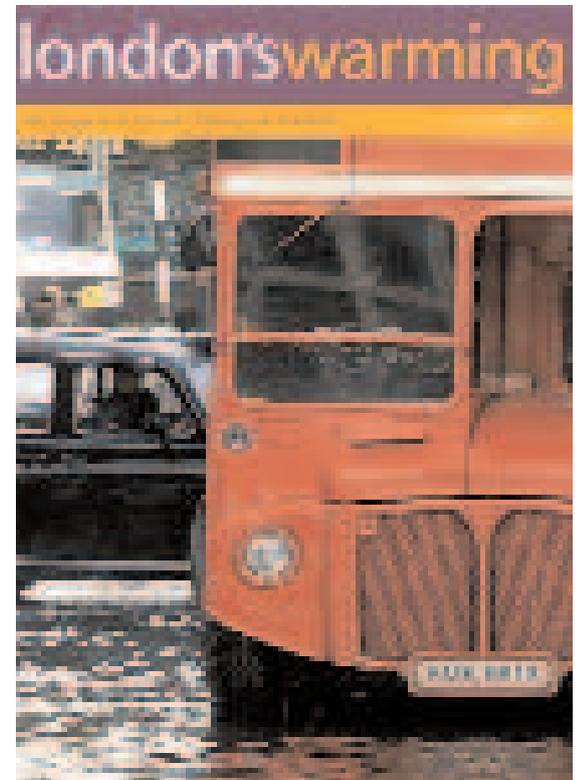
The London Climate Change Partnership (LCCP) was established in 2001 in order to help London prepare for climate change. A study on the impacts of climate change, *London's Warming*<sup>1</sup> was launched in October 2002 by the Mayor, Ken Livingstone, and the then Minister of the Environment, Michael Meacher. One key conclusion from the report was that London's transport systems are particularly vulnerable to climate change.

The LCCP transport group was set up in 2003 and identified a need for more detailed research to evaluate the potential risks of climate change to London's transport systems, the consequent impacts and costs (eg of disruption) and how the management of the risks identified should be incorporated into transport management strategies. Atkins Consultants were appointed to carry this out, and this is the high-level summary of their work, which sets out some of the most pressing issues.

The LCCP has produced this report in partnership with London's key transport decision makers. Officers in Transport for London and other transport organisations in London have been represented on the group steering the study, but it is important that senior management across these same organisations consider the issues raised in this report, and ensure that climate change is integrated into decision-making processes.

Our current climate already presents challenges to maintaining an efficient transport network. Recent extreme weather events have had serious effects on London's transport systems, for example in terms of high temperatures on the Underground and flooding of major transport interchanges. Future climate change has the potential further to affect adversely passengers' comfort and London's economy.

This report describes some of the actions which could reduce or eliminate these adverse effects. Early action, especially at the design stage, can require little or no extra cost while ensuring that Londoners can travel comfortably and that infrastructure remains useable throughout its design life. Priority should be given to assessing the risks to infrastructure with the longest asset life; some transport infrastructure such as tunnels, bridges and earthworks have effective lives of 50-100 years.



The Partnership will be promoting this report to key decision makers. It disseminates information on the impacts of climate change and on how London can adapt. It will also monitor how prepared London is for climate change – and this includes its transport networks. A major role of the Partnership is to advise the GLA on the development of London's Climate Change Adaptation Strategy.

**London Climate Change Partnership September 2005**



## Climate change and transport

This report describes some of the challenges faced by London's transport systems that will be exacerbated by climate change, what is already being done to address them, and what still remains to do.

### Climate Change

Climate change is now firmly established as an issue of concern for us all. Scenarios of climate change<sup>2</sup> for London show that we can expect:

- Warmer, wetter winters
- More intense downpours of rain
- Hotter, drier summers, with more frequent and extreme high temperatures
- Sea level to rise further, with an increased risk of tidal surges.

### Temperatures

- Rise in global average air temperature of 0.6°C over the twentieth century
- The warmest ten years on record include 1990, 1991, 2002, 1997, 1995 and 2003.

By the 2050s, London is expected to experience:

- Increase in winter ambient air temperatures of 1.0 to 2.0°C
- Increase in summer ambient air temperatures of 2.0 to 3.5°C.

Analysis of daily climate change data for Heathrow suggests that the number of days with a maximum temperature of at least 25°C is likely to double by the 2020s and increase by 3 to 5 times by the 2050s. Days

with temperatures exceeding 30°C will also become more common, as will extreme temperatures such as those experienced during the heatwave of August 2003.

#### *Heat island*

- Intensification of the urban heat island effect, whereby the centre of London can currently be up to 6°C hotter than the surrounding countryside. The greatest difference tends to occur on summer evenings.

#### *Precipitation*

Over the last century, an 11 per cent increase in winter and 10 per cent decrease in summer precipitation.

By the 2050s, London is expected to experience:

- Increase in winter precipitation by up to 20 per cent
- Decrease in summer precipitation by 20 to 40 per cent
- Intense rainfall events (summer and winter) are likely to become more common and more severe.

#### *Sea level*

- Relative mean sea level is expected to rise by between 26 and 86cm by the 2080s.
- The 50 year return period storm surge heights could increase by between 0.8m and at least 1.4 m by the 2080s (including mean sea level rise), although this is highly uncertain.

### **Transport**

In the context of climate change, transport is often viewed simply as a source of greenhouse gas emissions. In London a wide range of measures have been established to encourage a more sustainable balance of transport, including encouraging the use of public transport and restricting the use of cars. Technical measures have included the pioneering trial of hydrogen fuel cell buses.

However, it is also essential to consider the impacts of climate change on transport infrastructure and users and how we can plan ahead to adapt in the context of these impacts. For example, assessing the requirement and feasibility of cooling and ventilation in the various modes of transport used by Londoners as hotter summers become more frequent needs to be made a higher priority.

### This Study

The study has focused on the following four future impacts on London's transport systems:

- Tidal and river flooding affecting new infrastructure in the Thames Gateway
- Local flooding of Underground, rail and road infrastructure, including station closures
- Damage to national rail and road infrastructure from hot weather
- Passenger comfort on the Underground in hot weather.

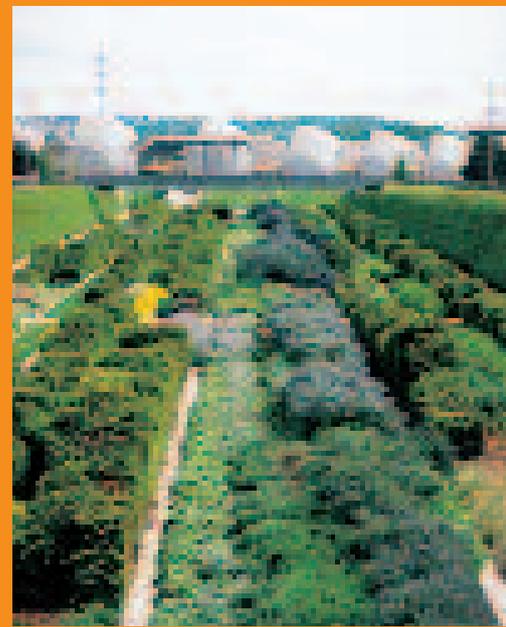
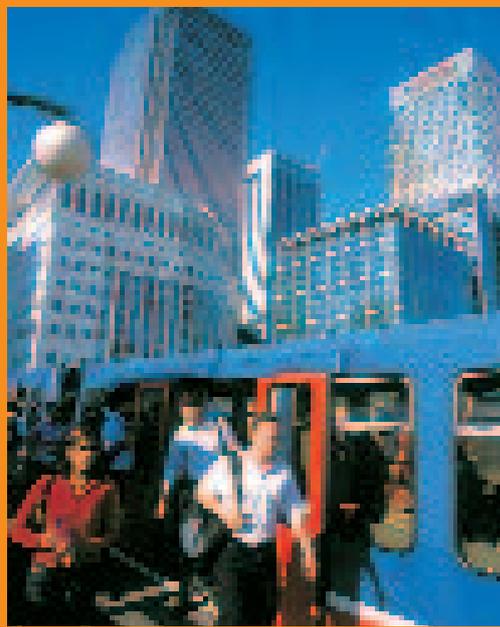
There are other impacts of climate change on the transport system which have not been considered in this study, either because other research is already considering them, due to a lack of available data, or because they fell outside the scope of the study. These include:

- Effects of climate change on embankments, tunnels and other major earthworks, where research has already been completed or is ongoing, including projects in the EPSRC<sup>3</sup>/UKCIP 'Building Knowledge for a Changing Climate' (BKCC) portfolio
- Effects of high temperatures on choice of transport mode
- Effects of high temperatures on passenger comfort on buses and overground trains
- Flooding as a result of rising groundwater levels, which has been addressed by GARDIT<sup>4</sup>
- Air and water based transport systems, where the potential for impacts are expected to be less significant than for other modes.

### Footnotes

- 1 LCCP. 2002. London's Warming: The Impacts of Climate Change on London. Technical Report. London Climate Change Partnership, London
- 2 Hulme, M., Jenkins, G.J., et al. 2002. Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report. Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia, Norwich
- 3 EPSRC: Engineering and Physical Sciences Research Council; UKCIP: United Kingdom Climate Impacts Programme
- 4 GARDIT: General Aquifer Research, Development and Investigation Team.





## Case Study 1: Tidal and river flood risk and London Thames Gateway

### **The issue now**

The Thames Tidal Defences comprise the Thames Barrier, 185 miles of floodwalls, 35 major gates and over 400 minor gates. They provide some of the highest standards of flood defence in the world, currently protecting London and most of the Thames Estuary against storm events that might happen on average only once every 2,000 years. The likelihood of a tidal flood is therefore extremely low. In the event of an extreme tidal flood event, a significant proportion of the proposed Thames Gateway development would be in the floodplain. However, much of the development in the Royal Docks, Lower Lea Valley, Greenwich and Isle of Dogs is protected by the Thames Barrier and in some places is defended to an even higher standard ; and key components of the Thames Gateway transport network infrastructure have been designed to be above potential flood levels. Current standards of protection need to be maintained to a high standard if they are to continue to be effective.

### **How climate change will affect the future**

Sea levels are rising and the risk of tidal surges increasing. Therefore the risk of tidal flooding is increasing, and the area at risk is growing. Heavier and more frequent intense downpours will also increase the risk of river flooding.

Developers have assumed that these defences will provide a high level of protection to infrastructure for the next 100 years. However, the level of protection provided by the Thames barrier will drop to it's design specification by 2030 and unless further investment takes place, the standard of flood defence will continue to decline thereafter.

The additional annual cost of flood damage arising from the Gateway development has been estimated at £47 million<sup>5</sup>. An extreme event could

incur damages of £16–20 billion of which £4 to £5 billion could be in relation to new development in the Gateway.

It is not clear at this stage how the costs of future flood risk management will be met and whether there will be an additional premium expected from developers of the Gateway transport infrastructure.

There is a risk that individual transport components of the Gateway are being developed in isolation from the rest of the transport network and general development. As a result whilst key elements of transport infrastructure may be resilient to climate change, flooding will remain an issue for the wider Gateway development and key points on the transport network, for example access and egress from stations.

However, because the development of many of the transport projects is still at an early stage, design adaptations to address climate risks can still be incorporated. The additional cost of design adaptations is considered by the infrastructure developers to be low, as a proportion of the total costs (although no figures have been calculated). However, the actual cost may still be significant and will have to be paid for as part of the development.

### **Action already undertaken or underway**

A Checklist for Development<sup>6</sup> is being prepared by the Three Regions Growth Areas Group. A separate research study funded by Defra and the Three Regions Group is looking at flood risk in the Growth Areas and is due to report in 2006; work by Association of British Insurers has been recently reported<sup>7</sup>.

Some aspects of the Thames Gateway developments considered in this study have included climate adaptation eg the height of discharge points for runoff from Thames Gateway Bridge and the elevation of DLR extensions compared to flood levels.

A Strategic Flood Risk Assessment has been undertaken by Thames Gateway London Partnership to evaluate the potential flood risk and can be used to guide the appropriate location and type of development.

### **Recommendations**

Given the current pace of development of the Thames Gateway, the following actions will require immediate attention:

- Following publication of the East London Strategic Flood Risk Assessment (SFRA), the integrated impacts on transport eg access

problems, options for design adaptation and potential costs, should be evaluated. Where adaptations for flood risk have already been included, these should be checked against the SFRA.

- Development proposals should:
  - Use the Checklist for Development during the design and development of new transport projects and strategies.
  - Seek to minimise risk within the defended floodplain, for example by building the most vulnerable infrastructure away from the river edge to reduce the potential for impact, or above extreme flood levels.
  - Consider flood proofing in high risk areas, for example planning for flooding at stations (eg use of flood boards) and ensuring critical components (eg switch gear, substations) are above flood levels or can be isolated.
  
- To minimise flood risk, close liaison is needed between the Environment Agency, Defra, ODPM, the Mayor and transport planners with regards to development of the Thames Gateway and in respect of Thames Estuary 2100 (the Environment Agency's long-term project for managing tidal and fluvial flood risk).

#### *Footnotes*

- 5 Association of British Insurers (ABI). February 2005. Making Communities Sustainable: Managing Flood Risks in the Government's Growth Areas, Summary Report. Association of British Insurers, London.
- 6 Three Regions Climate Change Group. February 2005. Adapting to Climate Change: A Checklist for Development. Guidance on designing developments in a changing climate.
- 7 See ref 3.



## Case 2: Infrastructure damage and station closure caused by local flooding

### **The issue now**

In the period from 1992 to 2003, over 1200 flooding incidents and 200 station closures were recorded by London Underground Limited (LUL). Of these approximately half were related to flash flooding.

Flooding of the London Underground between September 1999 and March 2004 has cost approximately £14.6 million in passenger delays alone, with the flooding of 7 August 2002 costing approximately £0.74 million.

The costs of flooding in the London Borough of Camden on 7 August 2002 were well in excess of £1 million<sup>8</sup>. The associated traffic disruption during peak period flows are estimated to cost at least £100,000 per hour delay on each main road affected, excluding infrastructure damage costs.

Current flooding problems are mainly associated with intense summer downpours and restricted capacity of storm drainage systems.

A recent report<sup>9</sup> published for the water industry concluded that even a small increase in storm rainfall could require the significant modification of drainage systems to maintain current service levels.

### **How climate change will affect the future**

Under climate change, intense rainfall incidents are expected to be more frequent and more intense. As well as an increasing risk of summer flash flooding (albeit subject to uncertainty), winter floods are also likely to become more common.

This will alter the distribution and increase the risk of flooding and the disruption it causes to surface rail, the Underground and highways. Significant modification of drainage systems will be needed.

### Action already undertaken or underway

A number of areas subject to recurrent risk have been mapped. LUL have mitigation measures in place to help manage flood risk at key stations. This includes the use of physical barriers. Further work is currently being scoped by LUL to assess the future risks of flooding from climate change. In addition Network Rail is undertaking research into the effect of climate change on earthworks, scour and flood risk.

London Underground's Quantified Risk Assessment (QRA) includes modelling of flooding-related hazards. The model allows identification of reasonably practicable engineering and operational means of reducing risk, and these risks have recently been reviewed.

Options being considered by the Thames Tideway Strategic Study<sup>10</sup>, including Sustainable Drainage Systems (SuDS) and source control, may provide some benefits in reducing flood risk. The recent work undertaken by UK Water Industry Research will need to be fully assessed in the context of this work and broader London drainage network issues.

### Recommendations

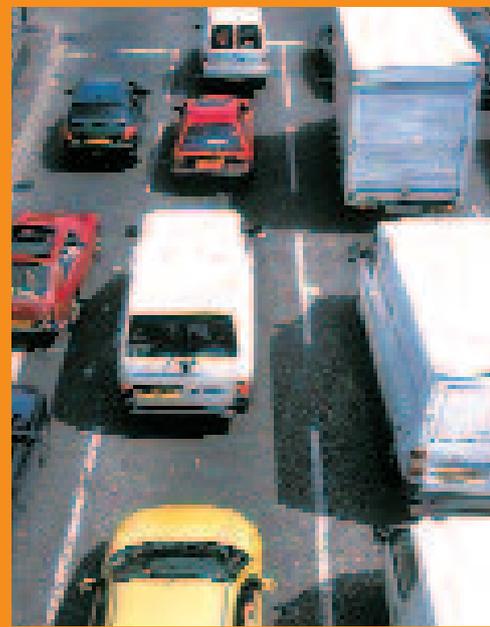
- Action is required now to assess fully the risks of flooding, including an improved understanding of flood sources, pathways and receptors (including Underground and railway stations), and how this might change in future, wherever this is not already being undertaken.
- The areas (eg stations) which are most likely to flood should be identified, taking account of future changes. These should then be the focus of adaptation options appraisals.
- Measures to reduce flood risk should be implemented. These may include source control (eg green roofs, pervious pavements), flood storage, construction of higher capacity drains, better drain maintenance, flood warning, construction and operation of barriers to prevent water ingress to stations, and better information on flooding to transport users.
- Risk assessment, as well as adaptation planning, should involve all relevant agencies including Transport for London, London Boroughs, LUL, Network Rail, the Highways Agency, Thames Water and the Environment Agency.

- Data collection needs to cover all costs and impacts incurred as a result of flooding – including infrastructure rehabilitation as well as passenger delays – to ensure that the full costs are considered in any future risk assessment.
- Research is required to assess the impact on transport caused by potential changes in groundwater levels under climate change. Climate change may have implications for flooding beneath ground as well as over ground, particularly in wetter winters.

Flooding is an existing problem that is likely to worsen. Adapting to climate change in the short to medium term eg by implementing the measures discussed above, will reduce long-term costs as well as providing more immediate benefits of improved resilience to weather.

#### *Footnotes*

- 8 LBC. June 2003. Floods in Camden. Report of the Floods Scrutiny Panel. London Borough of Camden, London
- 9 UKWIR. 2004. Climate Change and the Hydraulic Design of Sewerage Systems (Executive Summary). Report 03/CL/10/2. UK Water Industry Research, London
- 10 Thames Tideway. February 2005. Thames Tideway Strategic Study, Executive Summary. Mayor of London, OFWAT, Environment Agency and Thames Water.



## Case Study 3: Infrastructure damage in hot weather

### **The issue now**

On the railways, recent hot weather has caused significant problems, in particular requiring speed restrictions. Progressive speed restrictions are applied by Network Rail at air temperatures of 36 and 41 °C, and at lower temperatures where the rail and track is at anything less than ideal condition.

In the hot summer of 2003 there were 165,000 delay minutes nationally (compared with just 30,000 in the cooler summer of 2004). The number of buckled rails (approximately 130) was also high and consistent with other hot years (1976 and 1995). The economic cost of the delays in 2003 in four of the railway sectors around London was at least £0.75 million. The costs of repair are unknown.

No evidence of problems with the road network was found in London in summer 2003; most of the problems recorded occurred in surrounding counties.

### **How climate change will affect the future**

The number of days with temperatures exceeding 30 °C will become more common and temperatures as high as 36 °C are expected to occur for up to three days in the average 2080s summer. The temperatures of summer 2003 may become the norm by the 2040s.

In the absence of adaptation measures (engineering improvements or shading of rails) speed restrictions are likely to become far more common in future as average, and in particular extreme temperatures, rise.

Although London's road network appears resilient, hot weather impacts that are only experienced mildly at present, or not at all, may become serious issues later in the century. Potential impacts include carriageway rutting, embankment subsidence, deterioration of concrete, problems with expansion joints, increase in dust levels and reduction in skid resistance.

Indirect impacts on roads are also likely, arising for example through the need to respond to increased repairs as a result of shrinkage and expansion effects of the London clays on underground services such as water mains (as was the case during 2003).

### **Action already undertaken or underway**

Network Rail is undertaking a number of measures to improve safety, which will also increase resilience to higher temperatures. Network Rail believes these improvements will help avoid heatwave related problems such as those experienced during 2003. Network Rail has created a senior post within its Civil Engineering team with a remit that includes climate change research.

Network Rail and RSSB<sup>11</sup> are involved in further research in the EPSRC/UKCIP BKCC portfolio, including the BIONICS project, which will investigate the impact of climate change on embankments, and will have practical implications for both rail and road.

Research into methods to reduce the overheating and damage to roads is currently being undertaken by the Transport Research Laboratory.

Thames Water is currently embarking on a major programme of mains replacement in London to reduce leakage and manage growth in demand. Drier summers linked to climate change increase the urgency of this work. The company believes this work will lead to a reduction in the potential for future bursts and leaks, minimising the disruption caused by streetworks.

### **Recommendations**

- Further work is needed to cost the potential future impact of delays on the railways as well as the infrastructure costs (such as repairs and renewals). This is important for evaluating the costs and benefits of adaptation measures.
- Further research is required to quantify the effect of better maintenance and improved standards currently being undertaken by Network Rail, to understand the residual implications of hot weather and to assess what further actions are needed in the face of climate change.

- There is a need to review Network Rail's duty to maintain the network at 1994 'asset condition'. This duty may impose constraints on engineering standards and funding and is likely to pose problems for dealing with climate change.
- Some of the climate impacts on the road network are related to long-term infrastructure eg bridges and should therefore be investigated now, with finance and construction plans established, so that major reactive adaptation measures are not required in a few decades. A broader survey and risk assessment to test the resilience of existing and planned assets to climate change within London is recommended.
- Indirect impacts associated with roads should be explored in more detail, with the aim of understanding the future risk of disruption to traffic through streetworks. This will require liaison between Thames Water, Transco, the National Joint Utilities Group and Highways authorities.

#### *Footnotes*

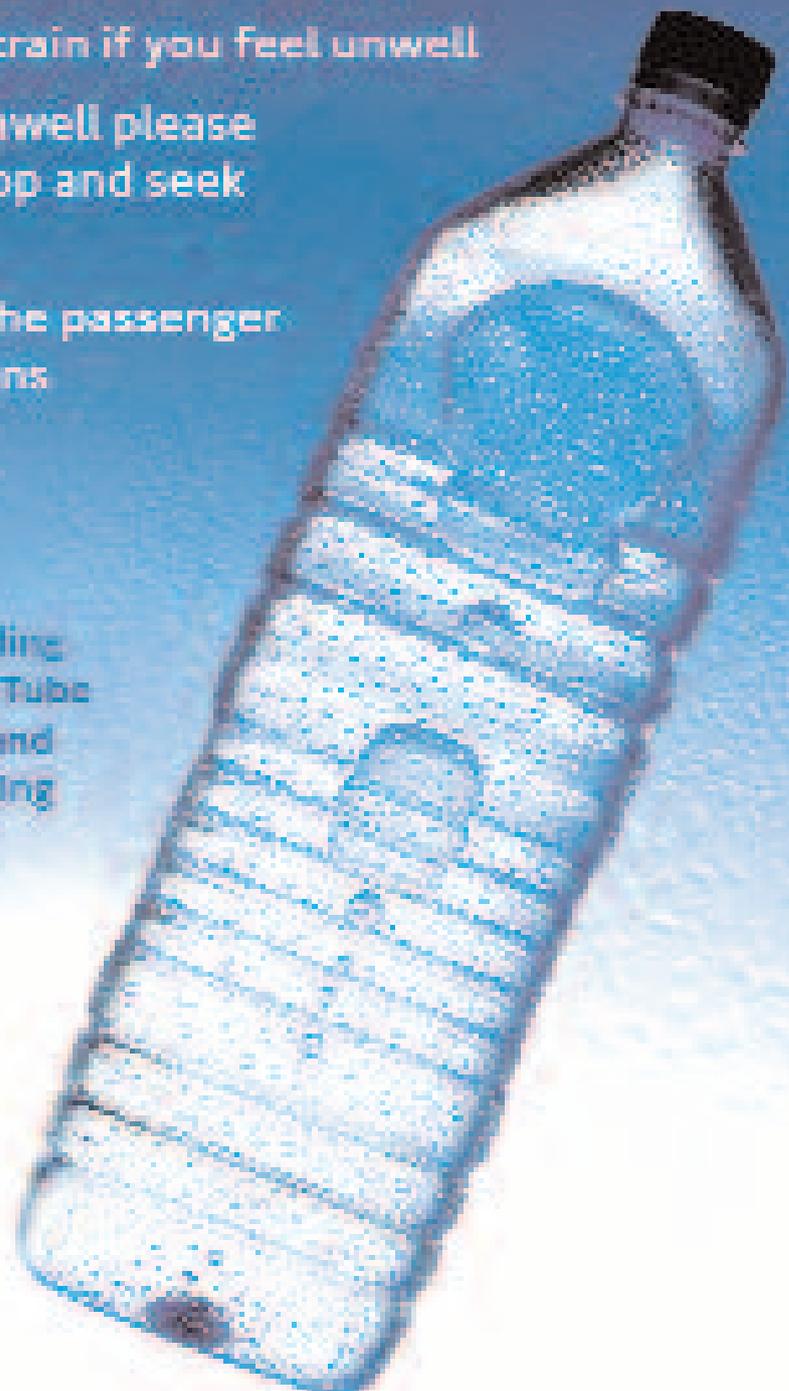
- 11 RSSB: Railway Safety and Standards Board

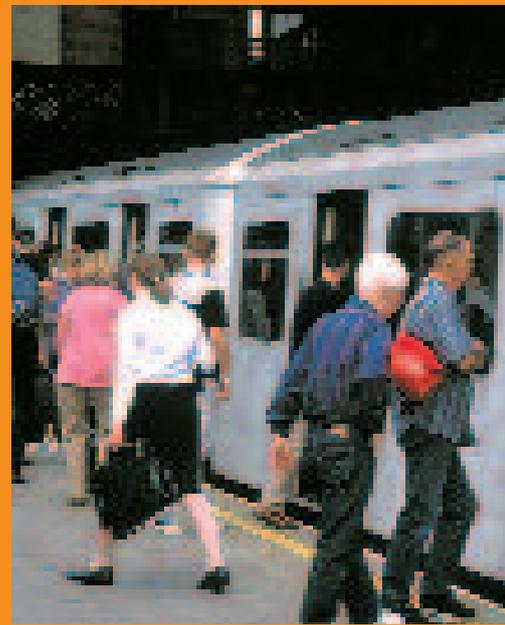
# Beat the heat

We know the Tube can be uncomfortable in hot weather. Here are a few tips, which will help to take the edge off the heat and minimise delays:

- Always carry a bottle of water with you
- Please don't board a train if you feel unwell
- If you begin to feel unwell please get off at the next stop and seek help from our staff
- Please avoid pulling the passenger alarm between stations

We are committed to finding a solution to keeping the Tube cool during hot weather and are continually investigating new technologies to achieve this aim.





## Case study 4: Passenger comfort on the Underground

### The issue now

This section sets out the situation as the researchers found it without taking into account either the effects of climate change, set out in the second section, or TfL's and others' planned investments and improvements set out in the third section below.

The London Underground is the oldest underground railway in the world, a vital part of London's public transport infrastructure, and passenger demand is growing.

High temperatures are regularly experienced by passengers in hot weather on the Underground, particularly during summer evening peak time.

On stations such as King's Cross, Waterloo, Victoria and Oxford Circus, the temperature can be 11°C above ambient temperature above ground. In some instances recorded temperatures have reached 40°C.

Temperature is the main factor affecting passenger thermal comfort, although air movement is also significant. Survey work in summer 2003 commissioned by LUL<sup>12</sup> identified the average temperature range for thermal comfort as between 21 and 26°C in trains and between 17 and 25°C in stations. This compares with average observed temperatures over the same period of 28°C in trains and 26°C in stations.

LUL standards for ventilation specify maximum temperatures, although there is inconsistency between the temperature thresholds quoted. Consistency in standards would be beneficial for measuring exceedence. Compliance with LUL's own standards is not achieved in all situations.

Temperatures are not continuously monitored by LUL but the measurements undertaken in summer 2003 revealed a maximum temperature of 41.5°C recorded in a train and 36.2°C recorded on a station. Average train temperatures were at least 27.0°C and were nearly 2.0°C warmer on deep level lines.

The current ventilation system, based on fans and draft relief shafts is already inadequate for cooling the Underground.

Existing passenger demand models indicate that weather currently has little effect on users switching between the bus and Underground.

### **How climate change will affect the future**

The analysis in this section is based on the situation if no actions are taken. Some actions already undertaken or underway are described in the following section.

As outside temperatures increase under climate change, so will those in the Underground, although not in direct relation, as the exchange of heat between the atmosphere and the underground tunnels is limited. Very high open air temperatures are likely to become far more common. By the 2050s London will experience between 28 and 45 days per summer on average in excess of 25°C. This will mean that many Underground lines will experience temperatures approaching 30°C, with certain hotspots reaching 35°C in peak periods. On the hottest days Underground temperatures may exceed 40°C in the hotspots.

This anticipated increase in temperatures has implications for Underground users. Overcrowding, and failed or delayed services further compound the problem of over-heating, particularly for passengers within the trains.

Passengers are likely to be increasingly dissatisfied with the thermal environment of the Underground in future unless adaptation measures are implemented. Comparison of climate change scenarios with research commissioned by LUL<sup>13</sup> suggests that the Underground thermal environment will be considered uncomfortable by the majority of passengers for several weeks to months each year by the 2050s, even allowing for some acclimatisation.

The increase in temperatures, particularly extremes, and the numbers of people this is likely to affect (over 3 million journeys are currently made every weekday) poses the greatest challenge of climate change to keeping London moving.

Plans to enhance capacity (more frequent trains and the related impacts of acceleration and braking) are anticipated to generate significantly higher temperatures than would be the case under climate change alone. Furthermore, as the population of the UK ages, the vulnerability of passengers to hot weather is likely to increase.

Under a changing climate, hotter weather may alter passenger preferences – particularly if the Underground thermal environment cannot be improved – putting more pressure on an already busy road transport system through increased use of buses, or worse (in terms of carbon dioxide emissions, air pollution and congestion) the increased use of air conditioned cars.

Perception and reputation of comfort on the Underground will be important and could influence tourism as well as regular users. Changes in use may occur in the short-term ie users may travel off-peak when conditions are cooler, or avoid the Underground on particularly hot days. Alternatively people may make a long-term switch to other forms of transport.

#### **Action already undertaken or underway**

A £100,000 prize which the Mayor offered to anyone who could come up with a workable solution for cooling the Tube in summer has not been awarded, as none of the 3,500 entries were deemed workable.

LUL has set up a Steering Group composed of senior management to address the challenges posed by heat and climate change to the Underground. £178m has already been allocated through TfL's 5-year £10bn Investment Programme for this purpose. This does not include the investment in air-cooled trains due to be delivered on the Underground's sub-surface lines (see below) through the Public Private Partnership.

Current projects to help cool the Underground include:

- An audit is currently being conducted by engineers of fan and ventilation capacity
- LUL have also begun to identify where new ventilation capacity could be added to existing lines
- Centrally operated and remotely controlled systems to manage fans and local cooling installations are being designed.
- LUL have been working with South Bank University on laboratory tests of local cooling installations, and a location has been chosen for an on-site trial in 2006
- LUL through the Public Private Partnership have ordered air-cooled

trains on the sub-surface lines – Circle, District, Hammersmith & City and Metropolitan lines – due to be delivered from 2009

LUL ventilation standards are being reviewed with a view to developing common standards. This is intended to help with prioritisation of investment decisions.

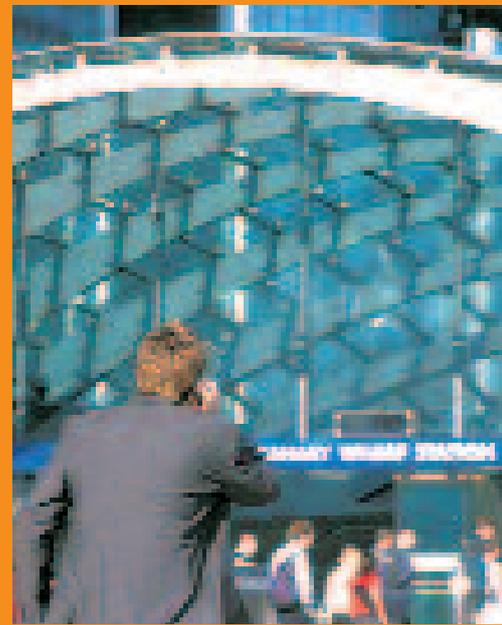
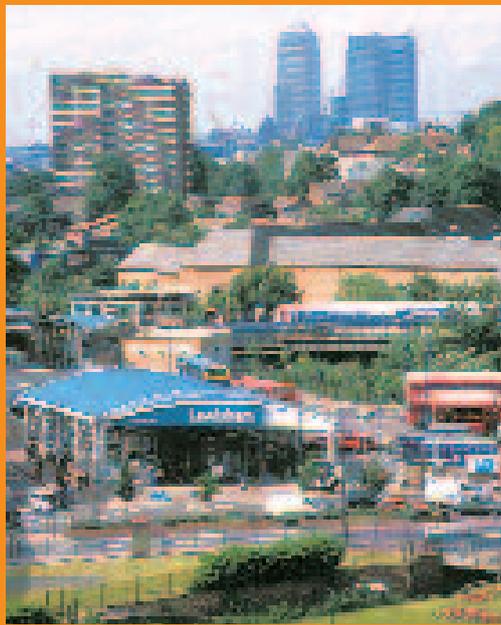
London Underground's Quantified Risk Assessment (QRA) includes modelling of ventilation hazards. The models allow identification of reasonably practicable engineering and operational means of reducing risk, and these risks are currently being reviewed.

### Recommendations

- A detailed, strategic monitoring programme of temperature and humidity in the Underground, both in stations and inside trains, is recommended.
- There is also a need to review passenger comfort on the Underground in a warmer world. The LUL commissioned research on the physiological aspects of heat has begun to address this.
- Further research by TfL is recommended to examine the behaviour of passengers in response to higher temperatures. This research should:
  - assess passenger behaviour in response to recent hot weather
  - establish the costs and benefits of adaptation measures (eg air conditioning). Potential solutions need to address both temperature and air movement. Substantial creativity and innovation will be required to overcome the constraints imposed by the inherited design of the existing network. Adaptation is likely to require multiple solutions ranging from awareness campaigns and distribution of cold water through to structural measures related to cooling stations, tunnels and trains. All factors that contribute to temperature increases and passenger vulnerability need to be considered.
  - identify potential risks and thresholds where a change in transport mode (eg a switch from the Underground to buses) may be triggered.

### Footnotes

- 12 BRE. 2004. Understanding Thermal Comfort on London Underground Trains and Stations – Summer Survey. Report No. 211738. Report by the Building Research Establishment for London Underground Limited, London.
- 13 BRE. 2004. Understanding Thermal Comfort on Trains and Stations. Report No. 216996. Report by the Building Research Establishment for London Underground Limited, London.



## Managing the risks – taking action

There are a number of basic principles that should be incorporated into transport planning strategies for London in order to manage the risks of climate change. These principles have been developed by UKCIP from their experience of helping to develop regional and sectoral climate change studies and adaptation strategies<sup>14</sup>.

- Incorporating climate risks into routine risk management procedures will help prepare for future adverse events.
- The costs of adapting to climate change can be minimised if adaptation is built in:
  - At the planning stage for new developments
  - When infrastructure is upgraded routinely
  - When plans come up naturally for review
  - Before organisations are forced to act by a sudden extreme climatic event or mounting maintenance costs.
- Decision-makers should ensure, where practicable to do so, that climate risk management measures are sufficiently flexible, that schemes can be adapted if necessary, to manage uncertainty in future impacts.
- Where possible, decision-makers should avoid actions that will make it more difficult and costly to cope with future climate impacts. For example, new infrastructure projects (such as storm drainage) should include a reasonable allowance for climate change risks where the costs of subsequent upgrading would be prohibitive or very difficult to engineer.

### Key actions

There will always be extreme weather events such as heatwaves and floods. This research is about the long-term trend of climate change, which is already underway, and will make some of these events more likely and more extreme.

Key actions identified are to:

- **Monitor temperatures and humidity in the Underground, both in trains and at stations.**
- **Design new infrastructure, rolling stock and vehicles for the climate throughout its design life.**
- **Instigate a review of existing infrastructure to determine the risks posed by climate change, including consideration of the appropriate Strategic Flood Risk Assessment, and set out actions to address them.**
- **Consider how use of transport may change in the future as a result of climate change.**

In addition, the research has identified many areas where better information is needed to enable the risks arising from climate change to be better assessed and addressed.

### Next steps

The aim of the London Climate Change Partnership is to help ensure that London is prepared for climate change, and it therefore tries to ensure that adaptation to climate change is integrated into planning and decision-making processes. The work of the LCCP is set out at: **[www.london.gov.uk/climatechangepartnership](http://www.london.gov.uk/climatechangepartnership)**

The Transport Group of the LCCP will:

- Continue to work with London transport organisations to help raise the profile of climate change adaptation as an issue that needs to be considered, as set out in the Key Actions above
- Monitor the recommendations made in this report
- Comment on future London Transport Strategies and other key policy documents.

If you would like further information about the LCCP or think your

organisation might consider joining the LCCP, please contact the Co-ordinator of the LCCP at:  
**[climatechangepartnership@london.gov.uk](mailto:climatechangepartnership@london.gov.uk)**

*Footnotes*

- 14 Willows, R.I. and Connell, R.K. (Eds), (2003). Climate adaptation: risk, uncertainty and decision-making. UKCIP Technical report. UKCIP, Oxford.

## Other formats and languages

For a large print, Braille, disc, sign language video or audio-tape version of this document, please contact us at the address below:

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### Chinese

如需索取印刷版本的文件，  
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### Vietnamese

Nếu bạn muốn có bản bản in của  
tài liệu bằng ngôn ngữ của mình, hãy  
liên hệ theo số điện thoại hoặc địa  
chỉ dưới đây.

### Greek

Αν θέλετε να ανακτήσετε αυτήν την έκδοση  
στα ελληνικά του βιβλίου του "The London  
Development Plan 2008-2011", επικοινωνήστε  
με το 020 7983 4100 ή επικοινωνήστε μαζί μας  
απευθείας στο 020 7983 4458.

### Turkish

İster İngilizce istediğiniz dilinizde  
kaynaklarımızı bir nüshasını  
almak için, lütfen aşağıdaki  
telefon numaralarını arayınız.

### Punjabi

ਜੇ ਤੁਸੀਂ ਇਸ ਦਸਤਾਵੇਜ਼ ਦੀ ਕੋਈ ਵੀ ਭਾਸ਼ੀ ਵਿਚ  
ਕਿਸੇ ਵੀ ਢੰਗ ਨਾਲ ਕੋਪੀ ਕਰਨਾ ਚਾਹੁੰਦੇ ਹੋ ਤਾਂ  
ਕਿਸੇ ਵੀ ਢੰਗ ਨਾਲ ਸੰਪਰਕ ਕਰੋ:

### Hindi

यदि आप इस दस्तावेज़ की किसी  
भाषा में कपी हैं, तो कृपया निम्नलिखित  
नम्बर पर फोन करें या हमें नीचे दिये गये  
पते पर लिखें।

### Bengali

আপনি যদি বাংলায় কপি এই দস্তাবেজ  
করতে চান, তাহলে দয়া করে নিচের  
নম্বরে ফোন করুন অথবা নিচের  
পাঠিকানা অনুসরণ করে যোগাযোগ করুন।

### Urdu

اگر آپ اس دستاویز کی نقل اپنی زبان میں  
چاہتی ہیں، تو براہ کرم نیچے دی گئی نمبر  
پر فون کریں یا ہمیں گئی پتی پر رابطہ کریں

### Arabic

إذا أردت نسخة من هذه الوثيقة بلغة  
الـعربية، يرجى الاتصال، أو إرسال  
البريد الإلكتروني

### Gujarati

જો તમે આ દસ્તાવેજ-11-1591 ની કોઈ ભાષામાં  
કોપી કરવા ઇચ્છો છો, કૃપા કરી આપેલા નંબર ઉપર  
ફોન કરો અથવા નીચેના સરનામે સર્કાર આપો

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