Directorate-General for Energy and Transport

EUROPEAN COMMISSION

TRANSPORT AND THE ENVIRONMENT

Contents

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Additional information on transport research programmes and related projects is available on the Transport Research Knowledge Centre website at **www.transport-research.info**

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Executive summary

This Policy Brochure focuses on transport and its effects on the environment. Its aim is to inform transport policy makers and to assist them in designing transport policies that take better account of the environmental impacts of transport. This is broadly defined to include effects of transport on land, air, water and resources. We have chosen to omit those aspects such as vibration and water quality which are more limited in their impacts.

We have grouped the research issues on environment and transport into three areas: identifying and measuring the impacts on the environment (pollution levels, noise emissions, etc.), technological solutions to environmental problems from transport, and behavioural solutions to environmental problems from transport. Where relevant, solutions cover both mitigation and adaptation. Research results related to these are drawn from the Fifth and Sixth EU Framework Programmes (FP5 and FP6), and a selection of national research projects on which information is available within the **Transport Research Knowledge Centre (TRKC).** The brochure describes the research programmes and projects which have contributed to these areas, and their principal findings.

Environmental impacts were central to the **European Commission's 2001 White Paper "European transport policy for 2010: time to decide"** and were emphasised even more strongly in the 2006 review, which focused on the need for sustainable mobility and indicated the need for all modes of transport to become more environmentally friendly, safe and energy efficient. These concerns have become even more critical given the likelihood that peak oil levels will be reached in the next decade and that urgent action is needed to reduce the contribution of transport to global warming.

The brochure draws a number of policy recommendations from the research it reviews. There is a strong case for promoting the more rapid development of alternative fuels and vehicle designs, both to offset the impacts of oil depletion and to tackle climate change. However, technology alone will not meet climate change targets; behavioural change will be needed as well, and the focus should be on integration of these two approaches. While technology has played a significant part in reducing local air pollution, oxides of nitrogen and particulates remain significant threats to health, and the health effects of noise are only now being fully appreciated. These challenges too, will require a combination of technological and behavioural solutions. While behavioural change is politically more difficult, it can offer much more immediate impacts than the pursuit of new technology. Government policy therefore needs to address the social challenges of encouraging more environmentally sensitive approaches to travel.

Further research is needed on the speed and likely impacts of oil depletion and climate change, and on the impacts of pollution and noise immissions on health. A holistic strategy is needed, involving both new technologies and behavioural change, if the challenge of climate change is to be addressed effectively. Among technologies, further research is needed on making vehicles and infrastructure more recyclable, on producing new fuels and engines more sustainably, and on encouraging greater market penetration of these technologies. Social science research is needed into ways of achieving behavioural change in personal travel, and in understanding the behavioural change options for freight and for transport suppliers. Finally, future research could usefully take a long-term view of ways of ensuring that transport systems generate environmental benefit in the very long term.

1

Transport and the environment: The subject area

Transport has significant detrimental effects on the built and natural environment, and hence on individuals' lives. It also contributes significantly to global warming. On both these counts, transport will be unsustainable in the medium to long term without mitigation measures. The environmental aspects of transport sustainability are concerned with atmospheric and noise pollution, land take, resource use, the effects of waste disposal on the natural environment, and the effects of the above on humans, flora and fauna. These environmental aspects of transport cover the full life-cycle of transport. The largest impacts come from transport use, but the effects from development and construction of infrastructure and vehicles, as well as the waste from their disposal, add to the environmental costs of transport.

This brochure covers those problems which have the most wide-ranging impacts. For this reason it does not consider construction materials, vibration or water quality.

Various mitigation and adaptation measures have been developed to combat these effects, including recycling wastes, development of alternative fuels to reduce reliance on non-renewable resources and pollution from the burning of fossil fuels, new technologies that lessen the adverse impacts of transport, more resilient transport systems and demand-side measures to reduce the use of more environmentally intrusive modes. As a result of application of these measures, there has already been a marked decrease in pollutants such as lead, nitrogen oxides, carbon monoxide and particulates.

Counteracting these measures are the current trends of increasing vehicle ownership and travel demand. The **Transport and Environment Reporting Mechanism (TERM)** report for 2008, from the **European Environment Agency** (EEA), concludes that "the current economic turmoil may lessen the demand for transport, but the transport sector still contributes significantly to rising emissions of greenhouse gases, noise exposure,

Main environmental problems from transport (taken from Banister et al., 2000):

Resource use
- Large amounts of oil-based resources used for transport
- Extraction of infrastructure construction materials

Climate change
- Emissions of CO_2 and other global warming gases

Waste
- Vehicles, fluids, tyres

Air pollution
- Local emissions of CO, PM, lead, VOCs, hydrocarbons and NO_x

Noise and related vibration
- Quality of life for those living nearby roads, airports, stations, ports

Land take
- Land used for infrastructure
- Habitat fragmentation

Water impacts
- Pollution from spillage
- Pollution from runoff
- Changes to water systems by infrastructure

air pollution, fragmentation of habitats and impacts on wildlife.… Although there is growing awareness of the transport sector's disproportionate impact on the environment, the report shows that there is little evidence of improved performance or a shift to sustainable transport across Europe" (EEA, 2009). The increasing volume of transport is challenging the central EU transport policy of decoupling transport usage from economic growth. Similarly, increases in road and air travel are challenging policy regarding reductions in atmospheric pollution.

The EEA's TERM report for 2007 also sends a strong message regarding the need to reduce transport volumes. The situation is summarised as follows: "Previous and current EU policies have mainly focused on improving vehicle technology and fuel quality to reduce pressures on the environment. Trends and projections clearly show that these policies have not been enough to succeed in reducing greenhouse gas emissions from transport and that the effect of introduced mitigation measures has been more than offset by increased transport volumes. To achieve emission reductions, measures and policy instruments must therefore also address demand for transport in a serious way" (EEA, 2008). Furthermore, the report suggests that "to address transport demand, measures and policy instruments must go beyond the transport sector itself and be introduced into sectors of the economy such as households, industry and service, within which the demand for transport actually originates" (EEA, 2008).

This brochure considers the full range of these mitigation and adaptation measures, and reviews research results separately for those involving technological and behavioural interventions. The following sections are structured to consider in turn **impacts, technology** and **behaviour**.

2

The policy background: Mobility, energy and climate change

The **European Commission's White Paper "European transport policy for 2010: time to decide"** (CEC, 2001) clearly states that transport must become sustainable from an economic, social and environmental standpoint. These three pillars of sustainability represent a change in thinking on transport policy as the long-term requirements of environmental aspects often require different paths to be chosen from those related to economic development.

More recently, the general context of EU transport policy established in the 2001 White Paper has changed. However, the objectives of EU transport policy set up by the 1992 and 2001 White Papers remain valid. The mid-term review of the European Commission's 2001 White Paper restates these objectives, which aim to provide European citizens with "efficient and effective transportation systems that:

- **offer a high level of mobility to people and businesses throughout the Union;**
- **protect the environment, ensure energy security, promote minimum labour standards for the sector and protect the passenger and citizen;**
- **innovate in support of the first two aims of mobility and protection by increasing the efficiency and sustainability of the growing transport sector; and**
- **connect internationally, projecting the Union's policies to reinforce sustainable mobility, protection and innovation, by participating in international organisations" (CEC, 2006).**

To be able to adapt the instruments of the 2001 White Paper to the new context, the European Commission has identified the need for additional policy tools. The mid-term review concludes that "a European sustainable mobility policy therefore needs to build on a broader range of policy tools, achieving shifts to more environmentally friendly modes where appropriate, especially long distance, in urban areas and on congested corridors. At the same time each transport mode must be optimised. All modes must become more environmentally friendly, safe and energy efficient. Finally, co-modality, i.e. the efficient use of different modes on their own and in combination, will result in an optimal and sustainable utilisation of resources. This approach offers the best guarantees to achieve at the same time a high level of both mobility and environmental protection" (CEC, 2006).

The most significant external influence on European policy is the pressure for action on climate change. The **Copenhagen Scientific Conference** in March

2009 drew several challenging conclusions: "Recent observations confirm that, given high rates of observed emissions, the worst-case IPCC scenario trajectories (or even worse) are being realised. For many key parameters, the climate system is already moving beyond the patterns of natural variability within which our society and economy have developed and thrived. These parameters include global mean surface temperature, sea-level rise, ocean and ice sheet dynamics, ocean acidification, and extreme climatic events. There is a significant risk that many of the trends will accelerate, leading to an increasing risk of abrupt or irreversible climatic shifts. Rapid, sustained and effective mitigation based on coordinated global and regional action is required to avoid `dangerous climate change´ regardless of how it is defined. Weaker targets for 2020 increase the risk of crossing tipping points and make the task of meeting 2050 targets more difficult. Delay in initiating effective mitigation actions increases significantly the long-term social and economic costs of both adaptation and mitigation" (ISC, 2009).

A reduction of CO_2 was called for in the international **Kyoto treaty**, and has since been converted into more challenging targets for 2050 in many European countries. The Kyoto agreement targeted a real reduction in CO_2 emissions economy-wide, but due to growth on current trends, CO_2 from transport will be some 40% higher in 2010 compared to 1990. In the EU, growing transport volumes have driven emissions up by 27% between 1990 and 2006 (excluding the international aviation and marine sectors) (EEA, 2009). Energy demand from the transport sector increased by 37% over a similar period (EEA, 2008). The result is that the energy and climate change impacts of transport are moving up the political agenda and more research in this area is being conducted. It appears that these targets may need to be further intensified. There is an urgent need for policy measures which address these targets.

The response to climate change involves adaptation to the impacts, as well as measures to limit climate

change. The **European Commission's Green Paper "Adapting to climate change in Europe – options for EU action"** on response to climate change says, for transport: "Adapting existing transport infrastructure to changing climate conditions, while ensuring its continued and safe functioning, will require substantial additional investments. New transport infrastructure and related transport means should be made climate proof from the early design phase.… Sound planning, including the spatial aspects of site selection, should take into account expected future climate conditions. Guidance on the interpretation of the existing community framework for port authorities and managers of waterborne infrastructures would also be helpful for the adaptation of such infrastructure" (CEC 2007).

Since the publication of the 2001 White Paper, the **European Environment Agency** has been closely following the trends in the development of the transport sector in Europe and has been regularly reporting on its impact on the environment (EEA, 2004a; EEA, 2004b; EEA, 2006; EEA, 2007; EEA, 2008; EEA, 2009). The EEA's summary of progress towards environmental transport objectives over the past decade suggests that transport policy with regard to environmental aspects is not likely to change significantly in the near future. Increasing attention will continue to be paid to the sector's contribution to climate change.

3

The research context:
Impact reduction, new technologies and demand management

Environmental impacts

Resource use, climate change and waste
Transport infrastructure is heavily dependent on fossil fuel-based systems which are threatened by peak oil forecasts. Transport consumes over a quarter of Europe's CO_2 emissions, even when air and maritime transport are excluded, and the trend is towards rapidly increasing emissions. Vehicle scrappage rates are expected to rise rapidly. Research has focused on the effects of climate change and, to a lesser extent, fossil fuel depletion.

Local air pollutants, noise and land take
The health implications of air pollution are now better understood, and some research has been conducted into acceptable levels of oxides of nitrogen (NO_x) and particulates (PM_{10}; $PM_{2.5}$). Much less is known about the health effects of annoying levels of noise (over 55 L_{den}) estimated to affect 67 million European citizens. The increasing demand for travel is leading to the destruction of vital green space and farming land. A greater understanding is needed of the effects on food security and biodiversity.

Technology

Research into technological improvements has focused on three ways to lessen the environmental impacts of transport supply:

- Vehicles – ease of recycling, use of fuel, noise emitted
- Fuels – reducing the dependence on fossil fuels, cutting emissions and energy use
- Infrastructure – reduced land take and noise, water and air pollution.

There has been less consideration of technological improvements to enable the transport system to adapt to the impacts of climate change. While new technologies have considerable potential, they face problems with their uptake and distribution. Research is still needed to identify those technologies which are likely to have the highest success in implementation: ease of use, wide applicability, and limited infrastructure requirements.

Behaviour

Research has been conducted into policy measures which influence the demand for travel, and hence lessen the environmental impacts of transport. These measures include

- regulations on the use of vehicles and the effective enforcement of those regulations;
- demand management approaches which reduce the need to travel or the use of less sustainable modes;
- pricing measures;
- soft options such as travel plans and informational and behaviour change campaigns; and
- land use planning.

Such measures can also complement new technological solutions by stimulating their uptake or imposing restrictions on those who choose not to use them. Further research is needed into ways of making such policy measures, and the switch to a lower carbon society, more acceptable.

4

Research programmes: Increased focus on transport

European Union-funded research

A selection of research results from the following programmes has been included in the Transport Research Knowledge Centre (TRKC).

The **Fifth Framework Programme (FP5)** was divided into research, technological development and demonstration activities. This was further divided into themes, with the following being relevant to transport: "User-friendly information society" (IST), "Competitive and sustainable growth" (GROWTH) and "Energy, environment and sustainable development" (EESD).

The **Sixth Framework Programme (FP6)** includes transport in two main thematic areas: "Sustainable surface transport" and "Aeronautics and space". For all surface modes there is an emphasis on environmentally friendly transport systems and (new) means of transport, using new technologies and concepts as well as advanced design and production techniques. Research on the **GALILEO** satellite system and Global Monitoring for the Environment and Security **(GMES)** using satellite signals has potential for use in improving the environment. Research on sustainable energy systems includes clean energy sources, savings and efficiency, alternative fuels and, in the longer term, fuel cells, carriers/ transport storage, renewable energy technologies and capture and sequestration of CO_2. Finally the thematic area "Global change and ecosystems" has supported research into macro environmental impacts, where transport is just one element.

The **Seventh Framework Programme (FP7)** is currently underway, and it is too early to include results in this policy brochure. However, details of ongoing projects are included in the TRKC. FP7 continues the objectives of FP6 and extends the focus on environmental aspects of transport to all modes. Aeronautics research focuses on reduction of emissions, work on engines and alternative fuels, as well as environmentally efficient aviation. On the ground, clean vehicles are the primary target, including clean and efficient engines, power trains and appropriate infrastructure construction and maintenance. Intermodality and the efficient use of satellite navigation **(GALILEO** and **EGNOS)** are particular elements in achieving a reduction in the impact of transport on climate change.

INTERREG III is a European Community Initiative to promote trans-national cooperation on spatial planning by encouraging harmonious and balanced development of European territory. The overall aim is to ensure that national borders are not a barrier to balanced development and the integration of Europe, and to strengthen co-operation among regions to their mutual advantage. The initiative ran from 2000 to the end of 2006.

European Cooperation in Science and Technology (COST) focuses on transport research mainly through the Europe-wide exchange of best national practice, improvement of existing methods and recommendations for their harmonisation at a European level.

National research

National research projects are included selectively within the TRKC to cover areas not well represented by European research. At the time of publication, the results of several national research projects from Belgium, the Czech Republic, Denmark, France, Germany, Ireland and the United Kingdom were available, and are reflected in this policy brochure. More information on national research programmes is available from the **TRKC Programme Compendium**.

5

Research results: Understanding the impacts of transport

Environmental impacts

Resource use

The world's total energy consumption is expected to increase at an average annual rate of 1.7% to 2.0% (IEA, 2006; EIA, 2006; WETO-H2). All studies agree that non-OECD energy demand will expand more rapidly than OECD energy demand, especially in non-OECD Asia. The greatest demand increase in energy will be oil-based fuels, notably in the transport sector. Both passenger and freight transport are expected to increase, the latter to a greater degree. Worldwide oil consumption is predicted to reach about 118 million barrels per day (mb/d) in 2030 (IEA, 2006; EIA, 2006). Estimates from the European FP6 **WETO-H2** project provide lower figures; the world oil consumption will reach 108 mb/d in 2030 and 120 mb/d in 2050. The transport sector will represent 63% of the increase in global oil demand over the period 2004 to 2030 and in non-OECD countries transport will be the biggest contributor to oil demand growth (**HOP**).

Forecasters quoted in a report prepared by the **Oil Depletion Analysis Centre** and the **Post Carbon Institute** expect global oil production to peak between now and 2020; an increasing number of these forecasters expect peak oil to occur within the next five years. The **International Energy Agency** (IEA) quoted in the same report has forecast that a critical point in global oil supply will be reached by 2012. The report claims that some analysts even believe the peak may already have happened, since global oil production was essentially flat between early 2005 and mid 2008, despite the soaring oil price (ODAC and PCI, 2008). The peak of oil production highlights the need to develop alternative technologies not dependent on fossil fuels. EU policy considerations regarding energy security, resource depletion and the need to reduce greenhouse gas emissions in the

medium and long term mean that a transition to low-CO_2 or CO_2-neutral technologies will be required. Action is required urgently to ensure the future of hydrogen technologies in the transport field. This involves further technological research, but also policies to support the introduction of such technology before it can become fully cost competitive (**HyNET**). Demonstration projects and trials will need to be sponsored to prove new technologies in practical situations (**ELODIT**).

Climate change

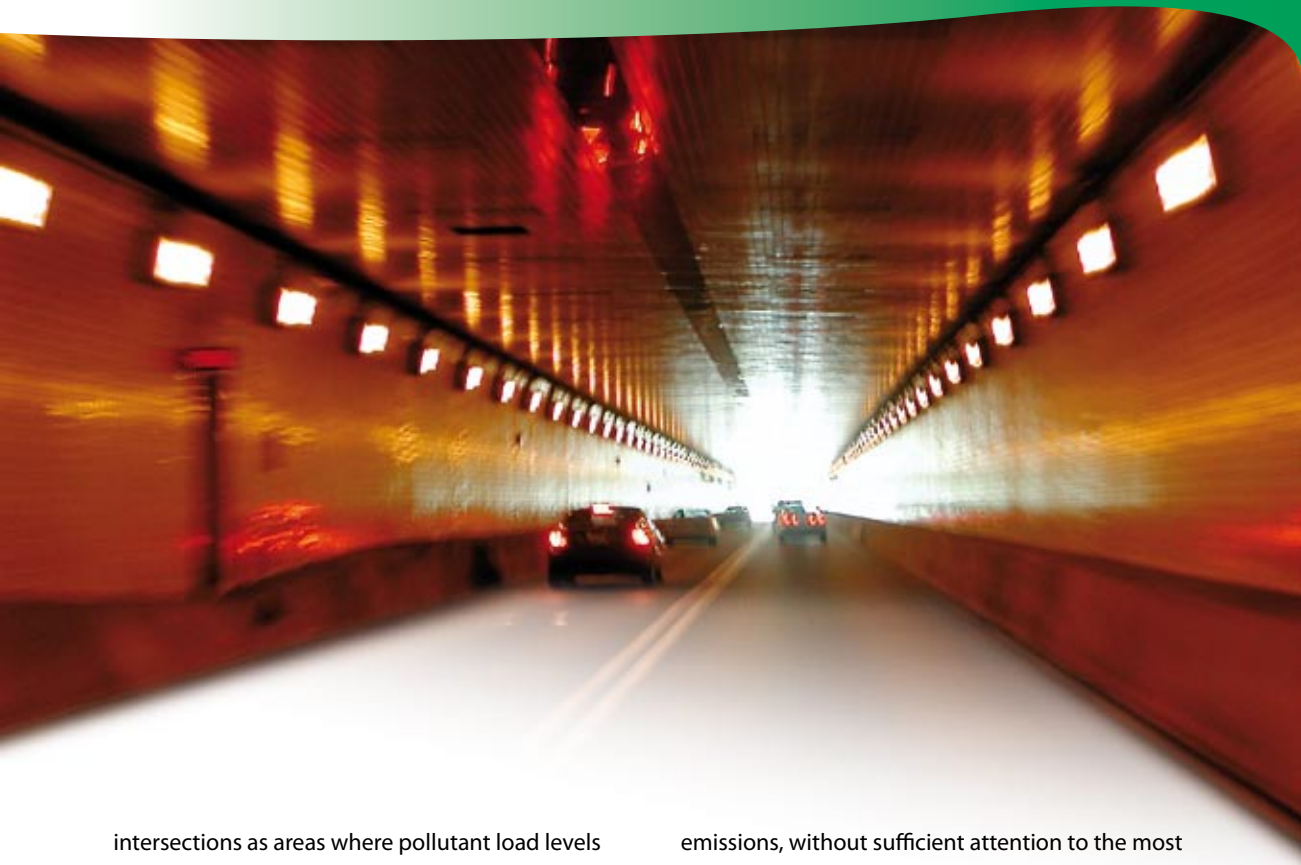
Research on climate change for the UK government from the **Tyndall Centre for Climate Change Research** (Bristow et al., 2008; Banister and Hickman, 2006) has shown that limiting carbon emissions from transport in order to achieve sustainability targets will be extremely difficult to achieve. There is a clear view that any forthcoming technological advances in transport (especially aviation) will at least partially be offset by increases in demand and intensity (Bows et al., 2006). The potential implications of climate change on biodiversity, health, society and the economy have been well documented (Stern, 2006; IPCC, 2009).

Waste

Existing cars contain materials such as lead, mercury, cadmium, hexavalent chromium and other environmentally harmful substances. By weight, about three-quarters of a car is steel and aluminium, which is recycled. The rest, which is mainly plastics, is disposed of by incineration or in landfills. Cars also contain dangerous liquid substances (anti-freeze, brake fluid, oil, etc.) that are harmful to the environment if not handled properly (EEA, 2003). There has been relatively little recent research on this problem.

Air pollution

Over 100,000 deaths are brought forward each year by transport-related pollutants, of which over 70% are generated in urban areas (CEC, 2007a). Research has shown that most local air pollutants have been reduced significantly through technological improvements (driven by regulation) since the mid-1990s, though some, in particular particulates and NO_x, are still a source of considerable ill health and premature death, especially among vulnerable groups of the population. Future projections show that some emissions can be decreased with the aid of technology, but especially in urban areas the increasing demand for travel will cause more problems with pollutants such as NO_x and PM. The improvements in emissions from the use of catalytic converters are being compromised by the increasing amounts of traffic and the identification of 'new' pollutants whose health effects are still poorly understood, such as smaller sizes of particulate matter. The identification of smaller and smaller levels of particulate matter is also necessary, as these tiny particles seem to have the most adverse effects on human health. Air pollution 'hot spots' are highlighted by Australian research (Greaves, 2006) that points to locations such as street canyons, tunnels and



intersections as areas where pollutant load levels are much higher than the recorded averages for the area. These findings show that an area average is not effectively measuring the exposure that different groups of people are receiving.

Research in Ireland into strategies for reducing diesel particulate emissions has estimated that in 2003 over 3000 tonnes of diesel particulate matter was emitted nationally by the fleet of some half a million diesel vehicles. The majority of these emissions occurred in urban areas and from light goods vehicles (responsible for 60% of all emissions). Older vehicles with EURO1 or older engines were responsible for some 55% of these emissions. These issues suggest that emissions reduction strategies can be broadly grouped under the categories of technological improvements to vehicles, use of cleaner fuels, better inspection and maintenance programmes and better fleet management. Such research has also highlighted the danger of focusing particulate emission reduction strategies on reducing the total mass of emissions, without sufficient attention to the most damaging volatile matter (**Evaluation of options for reducing Irish diesel particulate emissions**).

A series of European projects has provided estimates of the externality costs of pollution and noise from transport. The most recent of these, **NEEDS**, drew in turn on a fuller study of the transport sector, **HEATCO**, which refers to earlier studies in **EUNET**. A more specific Swiss research project investigating the external health costs of airborne pollutants has found that these costs are highly significant, with by far the largest proportion being attributable to the intangible costs of premature death or years of life lost. Chronic bronchitis among adults is the next largest cost, with all other health outcomes being far less costly to society (**Air pollution costs**). A similar study into building damage caused by transport found that by far the largest impact was caused by air pollution, with over 90% of this emanating from road traffic (mostly in urban areas) and much smaller effects from rail and air transport (**Building damages**).

Noise

There is increasing evidence of health effects from noise, particularly through aggravation of heart conditions. Recent estimates of noise-related health impacts in the Netherlands suggest that current noise levels may be associated with annoyance in 1.5 - 2 million people (out of a population of 16 million), disturbed sleep in 0.5 - 1 million and about 220,000 cases of hypertension. In total, 1 - 2% of the total disease burden could be attributed to traffic noise (WHO, 2004). The EEA's TERM 2008 report states that 67 million people in the European Economic Area are exposed to noise levels in excess of 55 L_{den}, the EU benchmark for excessive noise (EEA, 2009). Extrapolation from a German study suggests that perhaps 20,000 deaths might be brought forward in Europe each year as a result of traffic noise (Schade, 2003). A Swiss study into noise costs has found that the external costs of (road and rail) transport noise amount to some 0.25% of national GDP, with some 88% of this attributable to reduced house rental values and 12% down to various health costs associated with noise (**NOISE COSTS**). The implications of this for transport policy are considerable, especially with predicted increases in both ground-based and air transport.

The **CALM** project has set the research priorities for environmental noise reduction in accordance with the goals of the EU noise policy. The goal of halving the perceived level of road traffic noise by 2020 requires research into rolling noise, demanding low noise tyres, quiet, maintainable road surfaces, reduced propulsion noise from the engine, transmission and exhaust, and better traffic management. The **SILENCE** project developed an integrated methodology and technology for improved control of surface transport noise in urban areas looking at noise control at source, noise propagation, noise emission and human perception of noise for road, rail, infrastructure and cities. With a combination of the individual results of **SILENCE**, a reduction of urban noise emission from surface transport by up to 10 dB(A) is feasible in the near future.

The Decision-Support System (DSS) developed within the **HEAVEN** project aims to improve the quality of life in European cities by reducing transport-related noise and air pollution and to support European cities in implementing existing and forthcoming EU legislation on air quality and noise. An advanced software suite for the analysis of the effects of short-term actions and long-term policies to improve the quality of the environment, citizens' health and conservation of monuments has been built in the **ISHTAR** project. Tools developed in this research allow noise data to be obtained from traffic and the number of inhabitants exposed to noise from such traffic. Overall, a set of indicators has been designed for the assessment of transport in relation to sustainable development (**Research of environmental burden of transportation**).

For rail traffic, the **CALM** project investigated targets for noise reduction at source of up to 20 dB(A) for freight trains and 5 dB(A) for high-speed trains. The major areas of further research are rolling noise (mainly for freight trains), curve squeal, brake screech noise and aerodynamic noise. For air traffic, research is planned into noise reduction from aircraft and from optimised aircraft operation to meet the target for 2020 of a 10 dB (A) noise reduction per operation. This requires research into in-use compliance, how single and combined noise sources affect noise perception, and the correlation between noise emission, performance parameters and real operation nuisance.

Land take

Between 1990 and 1998, it is estimated that 30,000 hectares (ha) of land (about 10 ha every day) were taken for motorway construction alone in the EU-15 (EEA, 2004b). On average about half of designated nature areas in Europe are affected by transport (EEA, 2004b). Research has been conducted to identify best practices towards land use and transport policy, in order to achieve a sustainable pattern of transport and land use in European cities and regions, promoting environmental as well as economic and social improvement. Trends in land use and transport planning have been analysed and likely future trends have been considered. Best practice case studies relating to integrated land use and transport policies and to overcoming the barriers to successful implementation of such policies have been disseminated. Consideration has been given to the development of a consistent set of indicators for the evaluation of integrated land-use and transport policy packages and to ways of promoting consistency and transferability of approaches between countries (**TRANSPLUS**).

Urban sprawl is a major challenge to transport planners in European metropolitan areas because it is problematic for the implementation of improved suburban public transport. The mechanisms by which urban sprawl occurs and its impacts on transport have been evaluated in order to design effective measures for its control or reduction. Policy recommendations have been made available to cities to assist them in improving public transport services in sprawling urban areas. An integrated approach to the problem is advocated, using a range of measures such as transport pricing (both of public and private transport), office location strategies, design of housing estates and influencing suburban residential development through fiscal policy (**SCATTER**).

Technology: New fuels and vehicles

The use of new technology is often heralded as a way to continue our current travel demands while reducing environmental impacts. The current focus is on the move from a system based on fossil fuels to one based on hydrogen or fuel cells. As the supply of oil becomes uncertain and much more expensive, the emphasis on alternatives will grow, as will the demand for smaller vehicles with lower operating costs. Similarly, efforts to limit CO_2 emissions from transport will drive development of new technologies that are not carbon based. There are three major categories of solutions: the improvement of the conventional car or bus to provide hybrid propulsion, the introduction of new lightweight and electric

vehicle designs, and the more revolutionary development and demonstration of fully-automated, lightweight electric personal rapid transit (PRT) and cybernetic transport systems (CTS).

ERTRAC (www.ertrac.org) identified the following research targets in the areas of environment, energy and resources:

- **Improvements in vehicle efficiency should deliver as much as a 40% reduction in CO_2 emissions for cars and 10% for heavy vehicles for the new vehicle fleet in 2020.**
- **Fuel consumption and CO_2 emissions should fall by at least 10% for cars and 5% for heavy vehicles as a result of better vehicle maintenance and driving for fuel efficiency.**
- **Further reductions in fuel consumption of 10 - 20% should result from improvements to road infrastructure, better use of transport modes, IT systems, higher car occupancy rates and freight loading factors.**
- **Further reduction of carbon emissions associated with fuel production should be achieved.**
- **By 2020, fuel cell vehicles and low carbon or hydrogen fuels should start contributing to carbon reduction, provided sustained research efforts are begun now.**
- **By 2020, Euro-5 and 6 vehicles should be well established in the vehicle fleet.**
- **Transport noise should be reduced by up to 10 dB(A) through a systems approach, including better indicators and improvements to vehicles, tyres and infrastructure.**
- **Sustainable use of resources and recycling of vehicles and road infrastructure materials should contribute to the preservation of the environment.**

Significant progress has been made in the development of alternative fuels (such as ethanol) and of electric vehicles, while the infrastructure to support them is now making significant progress. These upgrades and the resulting vehicles should contribute to lowering emissions. However, a source to wheel analysis is needed to ensure that these new energy sources are less dependent on fossil fuels than current ones. For biofuels, the impacts of production on food supplies and on biodiversity also need to be carefully assessed.

Biofuels can be implemented in many standard diesel vehicles today using existing fuelling infrastructure (**PREMIA**). Policies to allow biofuel blends at all pumps can help to extend current oil supplies while other fuels such as hydrogen are developed. However, they need innovative policies to encourage increased public uptake. Opportunities to "test-own" these vehicles in the **TRENDSETTER** project helped convince businesses that they were just as trustworthy as a conventional vehicle. The promotion of electric vehicles in dense urban areas is also highlighted. Ongoing pilots of city distribution centres for either large retail stores, or construction sites have also been used to demonstrate increased efficiency through logistics technology. In part, some of the success of biofuels is due to their ready absorption by existing infrastructure. Hydrogen technology is available to run in pilot schemes (**ECTOS, HYNET, Fuel Cell Bus**) but many changes are needed for movement and storage of hydrogen, and hydrogen produced using fossil fuel-based electricity does not address dependence on fossil fuels.

The development of new generations of propulsion systems for all vehicles and modes involves the introduction of better materials and better understanding of combustion and flow phenomena. This can result in lower emissions and less fuel consumption, as well as less vibration

and external noise. **HYICE** has demonstrated hydrogen combustion with 46% efficiency for truck applications and 44% for a single-cylinder passenger car engine, and these figures do not yet represent a technical limit. As shown by the hydrogen bus project, infrastructure changes will be gradual as new systems are tested for flaws. Further research into integrating and modifying new technologies into existing infrastructure will clear the way for uptake of new technology. Adoption by large players, such as city taxi fleets moving to biofuels in Graz, can lead to greater demand and thus faster uptake.

The FURORE project developed a roadmap for alternative fuels and propulsion systems:

- **In the year 2020 and beyond, there will be an increased range of propulsion technologies, though still with a main focus on internal combustion engines.**
- **A higher variety of fuels, conventional and advanced, as well as alternative fuels, will be on the market, with new fuels designed for new combustion processes.**
- **Most of all, it will be essential to save energy wherever possible, independent of future scenarios on propulsion systems or fuels.**
- **For fuel cell and hydrogen based powertrain systems, only improvements in production and distribution will make them a competitive alternative.**
- **The main challenge for electric vehicles is the development of cost-effective advanced batteries or energy storage systems.**
- **Vehicle weight reduction is crucial for fuel consumption savings. Intensive research for new materials and production processes, including recycling technologies, is needed.**

The viability of electric bicycles, electric tricycles and electric scooters in urban areas has been proven, by testing around 1300 electric two-wheelers and facilitating infrastructure in 10 different sites within **E-TOUR**. These demonstrations have also shown the (local) environmental benefits. There are no sound objections to the use of electric bicycles and scooters in urban transport, whether from users, the general public or local authorities. The development of a more reliable and better performing battery could substantially increase their market share, but price will remain an obstacle.

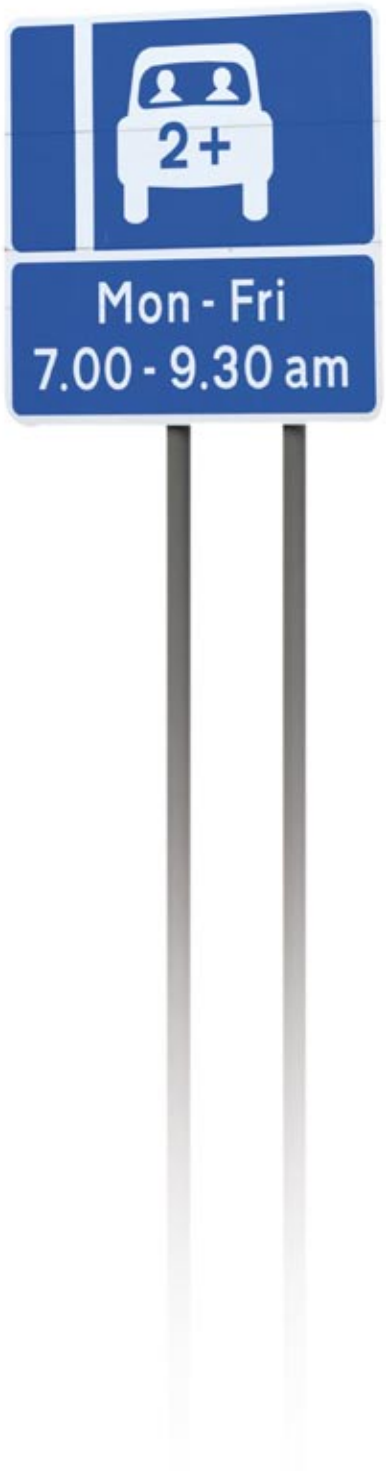
The more revolutionary, fully-automated personal rapid transit and cybernetic transport systems (**EDICT, CYBERCARS, CYBERMOVE, NETMOBIL**) offer significant direct energy savings and reduction of environmental pollution compared to existing public transport modes. They emit very low noise and vibration and no local emissions, and have indirect benefits by reducing the use of cars and conventional public transport.

Research by the **COMPOSIT** project has also identified new ways of constructing vehicles so that they are easier to recycle and use lighter composite materials. This research will help to identify ways to cut the waste from end-of-life vehicles, but composite materials still pose great challenges for recycling. Efforts have also been undertaken to make better use of recycled materials on roads and to improve the maintenance processes. Infrastructure changes can help to make current technology more efficient, while changing over from our current infrastructure will take time and many new policies are needed to ensure safety and reliable supply.

Changing behaviour: Supportive measures

Technological change alone cannot achieve current carbon reduction targets for transport; large-scale behavioural changes are needed (Åkerman and Höjer, 2006; Banister and Hickman, 2006; Bristow et al., 2008). A Swedish study demonstrated that scenarios that achieved the needed carbon savings combined technological improvements with planning solutions for dense nodal development, with much travel such as commuting and shopping replaced by IT solutions (Åkerman and Höjer, 2006).

Behaviour-based policy measures such as traffic management, pricing measures and promotion of public transport offer ways of supplementing the gains from vehicle technology by acting on modal split and/or the total demand for travel. Integrated land-use and transport modelling of various future scenarios for fuel technologies and fuel prices has shown that demand management appears to be more cost-effective in the long term than investment in new technology, because new technologies may possibly increase the demand for long distance travel (**STEPS**). Research demonstrates the need for a combination of behavioural approaches rather than relying on any one particular method. The need to combine behavioural measures with technological solutions or infrastructure improvements was illustrated by the **TRENDSETTER, PROPOLIS, SPRITE, FORESIGHT for TRANSPORT, PROSPECTS, SCATTER** and **TRANSPLUS** projects. Continued use of integrated land-use and transport planning is required in order to encourage development in a way that is most amenable to the use of public transport, walking and cycling (**TRANSPLUS, SCATTER**).



Given the high level of private car use, car sharing or car-pooling are amongst the most attractive options for better vehicle utilisation. Car sharing can be made to work on a relatively informal basis, but there has also been research into how car sharing can benefit from more formalised technological and operational support and the adoption of IT-based technologies in areas such as reservation systems and payment processing, including a demonstration study undertaken in Bologna with the support of the public transport operator and taxi operators (**TOSCA**).

In order to improve public transport use it is important to improve access to public transport, provide enhanced safety and security, introduce attractive integrated fares and ticketing systems and to create bus lanes, park and ride facilities and improved multimodal nodes. In addition, public transport service quality must be constantly monitored and maintained. Information offices, real-time public transport information systems and trip-planning tools on the web can all help boost patronage, and marketing activities have been shown to be an effective way of changing peoples' behaviour and encouraging them to choose public transport (**TRENDSETTER**).

Non-motorised modes are particularly environmentally-friendly transport options; their greater use offers considerable potential to reduce environmental impacts while improving health and city life. Cities involved in the **TRENDSETTER** programme have tended to focus on greater use of public transport but several including Lille and Graz have introduced initiatives to make cycling an attractive alternative even over longer distances, by marketing cycling, extending their cycling networks and equipping tram and bus stops and metro stations with bike and ride facilities. Internet-based walking and cycling route finders can be made available. Other cities, such as Pécs, have implemented car-free zones which also encourage walking and cycling. There is considered to be great potential for transfer of lessons learnt and best practice to many other cities.

Other research highlights the importance of both technical solutions (such as infrastructure changes) and non-technical actions (such as education and planning) in encouraging such modes of transport, with safety and bicycle security identified as major concerns to be addressed. Recommendations include better cycle parking and security and insurance arrangements and better promotion of walking and cycling, including the focusing of marketing efforts on major employers and large establishments such as schools, colleges frequented by younger people whose travel habits can be influenced for the longer term. Appointment of a pedestrian and cycling officer is a useful way of advocating and promoting change, and incentives such as ¨Car-Free Days˝ can be adopted. It may also be necessary to enforce reduced car speed limits to encourage walking and cycling (**ADONIS**).

Research conducted in Denmark has constructed a model of commuting which incorporates tele-working as one of the modal options. This allows the future impact of tele-working on transport, and hence the impact of this on emissions, to be estimated. As part of this research, the causal mechanisms behind the growth of tele-working have been analysed, the types and characteristics of firms or organisations which promote tele-working have been investigated and the barriers to its implementation have been studied. Whilst tele-working leads to an overall reduction in transport use, the net effect is reduced because often a family car becomes available for other travel purposes (**COMMUTING, TELEWORKING AND TRANSPORT**).

Marketing campaigns can help to bring awareness of improvements in public transport, walking and cycling, and emphasise the need to change travel demand. These campaigns work to change individual attitudes and travel behaviour. They can be supplemented with the use of travel plans to offices, schools and for new residential developments, helping to inform users of alternatives to driving to the site. Public participation in transport plans is also an important aspect of gaining public acceptance for new alternatives.

Mobility Management centres which coordinate information about travel options have been shown to support travel awareness programmes. Such ¨soft options˝ have been shown to have potential for up to an 11% reduction in car use in the UK over roughly the next 10 years, but will require considerable commitment from government and other relevant stakeholders (Cairns et al., 2004). Such soft measures are relative inexpensive and are efficient, especially when combined with other measures such as infrastructure improvements (**TRENDSETTER**). Policies need to be designed carefully to avoid unwanted effects; for example, car sharing may reduce the use of public transport, whilst encouragement of tele-working may simply divert car use to other trips (**COMMUTING, TELEWORKING AND TRANSPORT**).

Urban road user charging has shown that it is possible to achieve reductions of 20% in traffic and 30% in congestion in the areas to which it applies. It is thus able to contribute significantly to reductions in the environmental impact of urban traffic, while promoting the use of alternative modes. There are a number of barriers to its implementation, of which the most serious is public acceptability. Guidance is now available on ways of designing charging systems to overcome these barriers (**CURACAO**).

6

European policy implications: What to do now?

The key impacts

Resource use

While the extent of fossil fuel reserves remains uncertain, action is needed to reduce the risk of resource depletion, which in turn will lead to escalating costs and increased market insecurity. Governments need to stimulate greater energy efficiency and encourage the uptake of those alternative fuel technologies which can be shown to be less damaging to the environment. They can do this by providing incentives for development of alternative fuels, by leading by example through demonstration projects and mandatory adoption of alternative vehicles for government fleets, and by pursuing the policies outlined in the next paragraph.

Climate change

Scientific evidence now indicates that climate change is inevitable, and will bring with it increased risk of flooding and of drought, greater volatility in weather systems and serious ecological and economic damage. However, action can still be taken to reduce the scale of these threats over the coming decades. Governments need to set demanding targets for the reduction of greenhouse gas emissions from transport. It is now clear that the targets required cannot be achieved by technological enhancements alone. Behavioural change is needed as well, both as a policy in its own right and to stimulate the take up of new technologies. Adaptation policies are also needed which ensure that the transport system is more resilient to the effects of climate change.

Waste

There is a growing problem of waste within the EU and transport is contributing an important and growing share. Continued action is needed to make vehicles more recyclable and to require the industry to recycle used vehicles.

Local air pollutants

Technology has had a major role in reducing emissions of local air pollutants per vehicle, in particular through the development of more efficient engine and fuel technologies and through the widespread implementation of catalytic converters. However, more needs to be done to reduce the emission of particulates and oxides of nitrogen. As with other pollutants, the imposition of increasingly demanding targets is the single most effective way of stimulating improvements in the vehicle fleet. There is also the danger that past improvements will be offset by rising traffic levels. While increasing emissions are of concern, it is immissions, which are determined also by the distribution of the population, which give rise to health effects. Governments therefore need to impose more demanding air quality standards, and to require action to achieve these standards first in those areas where larger numbers of people are exposed.

Noise

The impacts of noise on health and on morbidity are now much more clearly understood. German research suggests that 20,000 deaths might be brought forward each year in Europe as a direct result of traffic noise (Schade, 2003). Technological development has a potentially important role in terms of mitigation of noise nuisance, particularly in the area of air transport, where expected growth in Europe is likely to bring greater demands for noise reduction. Key issues will be whether the technological improvements can keep pace with the expected growth in transport activity, whether appropriate incentive structures are in place to encourage further such developments and whether any side effects can be effectively compensated.

Land take

Land consumption for transport infrastructure can adversely affect biodiversity and contribute to urban sprawl. These issues highlight the requirement for transport plans to be designed in conjunction with land use plans. The interaction between land use and transport planning will help to steer transport infrastructure away from protected areas.

The potential for technological solutions

Technological improvements are an important contributor to the reduction of all of these environmental impacts. The most important emerging technologies involve new fuel sources, including biofuels, fuel cells, lightweight advanced batteries and more efficient electric motors and actuators. However, care is needed to ensure that these new power sources are sustainable and can be generated without deterioration in the food chain or biodiversity. These new fuel sources can be complemented by improvements in vehicle technology, and novel transport systems, including high power density and combustion efficient hydrogen engines, more efficient aero-engines, advanced cost-efficient composite materials with enhanced recycling, automated vehicles and flying wing aircraft.

Technological advances can be stimulated most effectively by imposing tighter standards on the performance of vehicles and infrastructure. However, some technologies need government support, either to create an initial market which will drive economies of scale, or to provide the enabling infrastructure, or to share the risk in pilot applications. The development of electric vehicle fleets illustrates all of these requirements. The public will not buy them until the price is substantially reduced, but this will only occur once the market grows. An infrastructure of charging points will be needed, and will almost certainly be the responsibility of highway authorities. The introduction of electric vehicle fleets will raise risks, which should ideally be shared by vehicle providers, fleet owners and the government.

The potential for behaviour and lifestyle change solutions

There are limitations on the potential of technology to deliver all the improvements required in each of the impacts outlined above. This is particularly the case with the issues of resource depletion and climate change, where it appears that technology is only likely to achieve around half of the reductions required over the next four decades. Significant changes in behaviour will be needed if greenhouse gas emission targets are to be achieved. This will involve reducing the need for travel, reducing the use of the least sustainable modes, and encouraging the take-up of novel modes and vehicle types. Governments need to have a behaviour change strategy in place, and be prepared to introduce less popular measures such as marginal cost pricing and travel restrictions. Effective demand management can have more immediate effects than the introduction of new technologies. Further effort is needed to increase the acceptability of demand management measures and of a switch to a lower carbon society.

7

Future research developments: What next?

Environmental impacts

While the principles of oil depletion and climate change are now well understood, further research is needed to understand the speed with which they might occur and the likely consequences for infrastructure, society, health and international policy. Research on local air pollution and noise needs to focus more directly on human and ecosystem exposure to immissions, and the likely impacts on health and biodiversity. Noise impacts remain a seriously under-researched area.

There is an urgent need for further research on the most effective means to curtail demand for transport carbon use. Given the international nature of this problem the EU needs to work closely with others around the world to achieve this goal. It would also be prudent to examine further how vulnerable the transport system in Europe is to changing climate conditions and how it can best be adapted to accommodate such changes.

Technological solutions

Several technologies have the potential to make significant contributions. Each will need support in making it more sustainable and in overcoming the barriers to their increased use. For biofuels, research is needed to identify ways of ensuring that they are sustainably produced and do not jeopardise the food chain. For electric vehicles, further developments are needed in the sustainable generation of electricity and the infrastructure required. For hydrogen fuel cells, research is needed on whether it will be possible to meet a sizeable proportion of their energy requirements from carbon-free sources. Research into the marketing and uptake of these technological solutions is a crucial component for success of new technologies, and links closely to the agenda for research into behavioural change.

Greater emphasis is needed on the design of vehicles and infrastructure which are fit for purpose, use recyclable and low density materials and help improve the life-cycle sustainability of the transport system.

Behavioural changes

There is a broad understanding of the ways in which behaviour needs to change if personal travel is to be more sustainable. The barriers to achieving such change are now social and political rather than technical, and more social science research is needed into ways of achieving behavioural change. The same is not true of freight transport, where a greater understanding is still needed of the options for change in patterns of freight demand and transport. More generally, research is needed into ways of making the operational responses of commercial suppliers more consistent with the needs of government policy on the environment.

It is clear that neither a technological, nor a behaviour management approach alone will be sufficient to achieve many environmental targets. There is a requirement for a flexible package of alternatives that combines different approaches to achieve environmental goals. Research is needed on the design of such holistic solutions, and into the move to a lower carbon society.

Longer term futures

Research on climate change is already looking 40 years ahead, with projections of impacts into the next century. There is a case for a longer term vision which would help develop transport systems designed for long-term global environmental benefit.

8

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Glossary

CEC	Commission of the European Communities – formal title of the European Commission
CO_2	Carbon Dioxide
CO	Carbon Monoxide
CTS	Cybernetic transportation system
dB(A)	Decibels – a measure of the loudness of sound
EC	European Commission
EEA	European Environment Agency
EGNOS	European Geostationary Navigation Overlay Service
EU	European Union
FP	EU Framework Programme for Research and Technological Development
GALILEO	Europe's initiative for a state-of-the-art global navigation satellite system, providing a highly accurate, global positioning service under civilian control
GMES	GMES (Global Monitoring for Environment and Security) is a European initiative for the implementation of information services dealing with environment and security
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IT	Information technology
L_{den}	Level day-evening-night – an indication of noise levels
mb/d	million barrels per day
NO_x	Nitrogen oxides
PM_{10}, $_{2.5}$ etc	Particulate matter (numbers refer to the diameter of particulates in micrograms)
PRT	Personal rapid transit
TRKC	Transport Research Knowledge Centre
VOC	Volatile organic compounds
WHO	World Health Organisation

Transport's effects on the environment continue to be of concern as the problems of global warming and 'new' pollutants such as smaller particulates and noise enter the policy arena. Transport policies affect air quality, neighbourhood liveability, social exclusion and green space. Actions are needed both through improved technologies and through behavioural change.

This Policy Brochure aims to inform transport policy makers and to assist them in designing transport policies that take better account of the environmental impacts of transport. This is broadly defined to include effects of transport on land, air, water and resources. The research issues on environment and transport are grouped into three areas:

- Identifying and measuring the impacts on the environment (pollution levels, noise emissions, etc.)
- Technological solutions to environmental problems from transport
- Behavioural solutions to environmental problems from transport.

Where relevant, solutions cover both mitigation and adaptation.

The brochure draws a number of policy recommendations from the research it reviews. It concludes that there is a strong case for promoting the more rapid development of alternative fuels and vehicle designs, both to offset the impacts of oil depletion and to tackle climate change. However, technology alone will not meet climate change targets; behavioural change will be needed as well, and the focus should be on integration of these two approaches. While technology has played a significant part in reducing local air pollution, oxides of nitrogen and particulates remain significant threats to health, and the health effects of noise are only now being fully appreciated. These challenges, too, will require a combination of technological and behavioural solutions. While behavioural change is politically a more difficult aim, it can offer much more immediate impacts than will the pursuit of new technology. Government policy therefore needs to address the social challenges of encouraging more environmentally sensitive approaches to travel.

Finally the brochure identifies areas in which further research is needed.