



Urban Transport and Health

Module 5g

Sustainable Transport: A Sourcebook for Policy-makers in Developing Cities

OVERVIEW OF THE SOURCEBOOK

Sustainable Transport:

A Sourcebook for Policy-Makers in Developing Cities

What is the Sourcebook?

This *Sourcebook* on Sustainable Urban Transport addresses the key areas of a sustainable transport policy framework for a developing city. The *Sourcebook* consists of more than 31 modules mentioned on the following pages. It is also complemented by a series of training documents and other material available from <http://www.sutp.org> (and <http://www.sutp.cn> for Chinese users).

Who is it for?

The *Sourcebook* is intended for policy-makers in developing cities, and their advisors. This target audience is reflected in the content, which provides policy tools appropriate for application in a range of developing cities. The academic sector (*e.g.* universities) has also benefited from this material.

How is it supposed to be used?

The *Sourcebook* can be used in a number of ways. If printed, it should be kept in one location, and the different modules provided to officials involved in urban transport. The *Sourcebook* can be easily adapted to fit a formal short course training event, or can serve as a guide for developing a curriculum or other training program in the area of urban transport. GIZ has and is still further elaborating training packages for selected modules, all available since October 2004 from <http://www.sutp.org> or <http://www.sutp.cn>.

What are some of the key features?

The key features of the *Sourcebook* include:

- A practical orientation, focusing on best practices in planning and regulation and, where possible, successful experiences in developing cities.
- Contributors are leading experts in their fields.
- An attractive and easy-to-read, colour layout.
- Non-technical language (to the extent possible), with technical terms explained.
- Updates via the Internet.

How do I get a copy?

Electronic versions (pdf) of the modules are available at <http://www.sutp.org> or <http://www.sutp.cn>. Due to the updating of all modules print versions of the English language edition are no longer available. A print version of the first 20 modules in Chinese language is sold throughout China by Communication Press and a compilation of selected modules is being sold by McMillan, India, in South Asia. Any questions regarding the use of the modules can be directed to sutp@sutp.org or transport@giz.de.

Comments or feedback?

We would welcome any of your comments or suggestions, on any aspect of the *Sourcebook*, by e-mail to sutp@sutp.org and transport@giz.de, or by surface mail to:

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Further modules and resources

Further modules are under preparation in the areas of *Energy Efficiency for Urban Transport* and *Public Transport Integration*.

Additional resources are being developed, and Urban Transport Photo CD-ROMs and DVD are available (some photos have been uploaded in <http://www.sutp.org> – photo section). You will also find relevant links, bibliographical references and more than 400 documents and presentations under <http://www.sutp.org>, (<http://www.sutp.cn> for Chinese users).

Modules and contributors

- (i) *Sourcebook Overview and Cross-cutting Issues of Urban Transport* (GTZ)

Institutional and policy orientation

- 1a. *The Role of Transport in Urban Development Policy* (Enrique Peñalosa)
1b. *Urban Transport Institutions* (Richard Meakin)
1c. *Private Sector Participation in Urban Transport Infrastructure Provision* (Christopher Zегras, MIT)
1d. *Economic Instruments* (Manfred Breithaupt, GTZ)
1e. *Raising Public Awareness about Sustainable Urban Transport* (Karl Fjellstrom, Carlos F. Pardo, GTZ)
1f. *Financing Sustainable Urban Transport* (Ko Sakamoto, TRL)
1g. *Urban Freight in Developing Cities* (Bernhard O. Herzog)

Land use planning and demand management

- 2a. *Land Use Planning and Urban Transport* (Rudolf Petersen, Wuppertal Institute)
2b. *Mobility Management* (Todd Litman, VTPI)
2c. *Parking Management: A Contribution Towards Liveable Cities* (Tom Rye)

Transit, walking and cycling

- 3a. *Mass Transit Options* (Lloyd Wright, ITDP; Karl Fjellstrom, GTZ)
3b. *Bus Rapid Transit* (Lloyd Wright, ITDP)
3c. *Bus Regulation & Planning* (Richard Meakin)
3d. *Preserving and Expanding the Role of Non-motorised Transport* (Walter Hook, ITDP)
3e. *Car-Free Development* (Lloyd Wright, ITDP)

Vehicles and fuels

- 4a. *Cleaner Fuels and Vehicle Technologies* (Michael Walsh; Reinhard Kolke, Umweltbundesamt – UBA)
4b. *Inspection & Maintenance and Roadworthiness* (Reinhard Kolke, UBA)
4c. *Two- and Three-Wheelers* (Jitendra Shah, World Bank; N.V. Iyer, Bajaj Auto)
4d. *Natural Gas Vehicles* (MVV InnoTec)
4e. *Intelligent Transport Systems* (Phil Sayeg, TRA; Phil Charles, University of Queensland)
4f. *EcoDriving* (VTL; Manfred Breithaupt, Oliver Eberz, GTZ)

Environmental and health impacts

- 5a. *Air Quality Management* (Dietrich Schwela, World Health Organization)
5b. *Urban Road Safety* (Jacqueline Lacroix, DVR; David Silcock, GRSP)
5c. *Noise and its Abatement* (Civic Exchange Hong Kong; GTZ; UBA)
5d. *The CDM in the Transport Sector* (Jürg M. Grütter)
5e. *Transport and Climate Change* (Holger Dalkmann; Charlotte Brannigan, C4S)
5f. *Adapting Urban Transport to Climate Change* (Urda Eichhorst, Wuppertal Institute)
5g. *Urban Transport and Health* (Carlos Dora, Jamie Hosking, Pierpaolo Mudu, Elaine Ruth Fletcher)

Resources

6. *Resources for Policy-makers* (GTZ)

Social and cross-cutting issues on urban transport

- 7a. *Gender and Urban Transport: Smart and Affordable* (Mika Kunieda; Aimée Gauthier)

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Module 5g

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1. Introduction

Transport has a powerful impact on health – and that influence on health is growing globally along with increased mobility. The transport sector also offers major potential for reducing greenhouse gas emissions, making transport policies an important area of attention in the climate change field. This module aims to describe the health risks and benefits that arise from transport, and to identify transport systems that protect and promote people's health both in the short-term, *e.g.* reducing immediate risks from air pollution and injuries, as well as over time by supporting the development of healthier and more sustainable cities.

The module starts by providing an overview of the key pathways by which transport can influence health, and the scale of transport-related health risks in OECD and developing countries. It then discusses instruments that are available to assess and counter transport-related health risks. It offers some principles that can be used to guide the development of healthy transport systems, and concludes with some case studies illustrating good practice in diverse cities of the world.

2. Health: challenges for the transport sector

2.1 Health impacts of transport

Transport has a major impact on health, and a transport system's development may either enhance health or, conversely, increase health risks. The most familiar health risks of transport include exposure to air pollutants, noise emissions from motorised vehicles, and risks of road traffic injury. Less well known, but equally important, are the health benefits that can be realised if travel involves a certain amount of physical activity such as cycling to work or walking briskly (*e.g.* 15–20 minutes daily) to a transit stop.

Along with the journey itself, transport impacts health by providing access to employment, education, health services and recreational opportunities – all of which influence health status and health equity. However, policies and infrastructure that improve access for one type of travel, particularly motor vehicle traffic, may also create barriers for those travelling by other modes, *e.g.* train, bus, bicycle or on foot. That, in turn, can lead to severe inequities in access to health services, education, employment, food choices, and restrictions in mobility for many groups – all of which impact health.

Significant health and health equity impacts from transport may also occur more indirectly – in terms of the ways that roads shape the design and character of neighbourhoods and cities. For instance, heavily trafficked roads that cut through neighbourhoods can limit street activity and constrain social interactions that strengthen social networks and communities. When expansion of road and parking space in cities takes place at the expense of potential walking and green corridors, opportunities for healthy mobility may be lost to everyone – impacting children, women and the elderly most severely. And when cities develop around road-oriented patterns of low-density sprawl, this in turn, over time, may create a vicious cycle of increased dependency on motor vehicles for essential travel, increasing even more direct health impacts from pollution and injury as well as the more indirect health impacts

related to access, physical activity patterns and social interaction.

The following sections provide more information on the key transport-related health impacts that are most relevant to developing cities. More extensive reviews of individual impacts are noted in the Reference section.

2.1.1 Air pollution exposures

The transport sector is responsible for a large and growing proportion of urban air pollutants that impact health. The sector also is responsible for a significant proportion of global emissions of CO₂ and other global warming pollutants that contribute to climate change, and its long term health impacts. This latter issue is discussed in a separate section of this report. Air pollution concentrations are, on average, particularly high in developing cities, where transport has become one of the major sources

of health-damaging air pollutants (see Section 2.3). However, serious and quantifiable health damage occurs at the levels of air pollution typically found today in both developed and developing countries. The higher air pollution levels, the worse the associated health problems.

Health impacts of air pollution

Fuel combustion produces a number of air pollutants substances that have been linked to ill health and premature mortality. The evidence regarding their health impacts is summarised below, and described in more detail in the WHO air quality guidelines (WHO 2006a).

Transport-related air pollutants that affect health include: particulate matter, oxides of nitrogen, ozone, carbon monoxide and benzene. They increase the risk of a number of important health problems, including cardiovascular and respiratory disease, cancer and adverse birth outcomes, and are associated with higher death rates in populations exposed (Table 1) (Krzyzanowski *et al.*, 2005). Exposure to heavy traffic (*e.g.* living near a major road) is itself associated with poorer child and adult health and increased death rates (Brugge *et al.*, 2007, Health Effects Institute 2010b). Children's health and development is particularly at risk from ambient air pollution (WHO 2005). In many developing countries, old and poorly-performing diesel vehicles often are responsible for the greatest proportion of small particle emissions from vehicles, and visual assessments of "black smoke" emissions from trucks and buses can be a rapid and inexpensive "proxy" indicator of excessive tailpipe particle emissions (Krzyzanowski *et al.*, 2005).



Figure 1
Rapid motorisation in developing cities contributes to high levels of air pollution.

Photo by Jinca, Nanjing, PR China, 2010

Table 1: Health outcomes associated with transport-related air pollutants

Outcome	Associated transport-related pollutants
Mortality	Black smoke, ozone, PM _{2.5}
Respiratory disease (non-allergic)	Black smoke, ozone, nitrogen dioxide, VOCs, CAPs, diesel exhaust
Respiratory disease (allergic)	Ozone, nitrogen dioxide, PM, VOCs, CAPs, diesel exhaust
Cardiovascular diseases	Black smoke, CAPs
Cancer	Nitrogen dioxide, diesel exhaust
Adverse reproductive outcomes	Diesel exhaust; also equivocal evidence for nitrogen dioxide, carbon monoxide, sulphur dioxide, total suspended particles

PM: particulate matter; PM_{2.5}: PM < 2.5µm in diameter; VOCs: Volatile Organic Compounds (including benzene); CAPs: Concentrated Ambient Particles

Source: adapted from Krzyzanowski *et al.*, 2005

Key health-harming air pollutants from transport

Small particles of less than 10 microns in diameter (PM₁₀) and fine particles of less than 2.5 microns in diameter (PM_{2.5}) are linked most closely to impacts on public health. Such particles bypass the body's usual defences against dust, penetrating and lodging deep in the respiratory system. Small particles emitted by road vehicles may be comprised of elemental carbon or carbon compounds, heavy metals and sulphurs, and also carcinogens, *e.g.* benzene derivatives. Such pollution is measured in terms of the mass concentration of particles smaller than PM₁₀ or PM_{2.5} per cubic meter of air, *e.g.* micrograms per cubic meter (µg/m³).

Health effects from fine particulates have been observed at all ranges of observed annual average concentration levels – from average annual concentrations of 8 µg/m³ for PM_{2.5} and 15 µg/m³ for PM_{10.6}. New WHO *Air Quality Guidelines*, issued in 2006, set guideline values of 10 µg/m³ for PM_{2.5} (annual average concentrations) and 20 µg/m³ for PM₁₀ (WHO 2006a).

Cumulative, long-term exposure to elevated levels of small and fine particulates is associated with reduced lung function, increased frequency of respiratory disease and reduced life expectancy. Most of the long-term studies of such health impacts in large urban populations, to date, have been conducted in the United States and Europe (WHO – Regional Office for Europe 2000, 2002 and 2004).

Box 1: CO and NO_x

Two other important health-harming pollutants from transport are carbon monoxide (CO) and oxides of nitrogen (NO_x). CO in ambient air forms a bond with haemoglobin and impairs the oxygen-carrying capacity of blood. Health impacts from short-term exposure to the levels of CO typically found in ambient air pollution may include cardiovascular effects, such as the aggravation of angina symptoms during exercise, and impaired exercise performance (UNEP, ILO and WHO 1999). Health impacts of exposure to NO_x include reduced lung function and increased probability of respiratory symptoms (WHO – Regional Office for Europe 2000).

In developing as well as developed cities, short-term exposures to increased fine particulate concentrations have also been studied, and associated with increased rates of daily mortality and hospital admissions, mostly as a result of chronic respiratory and cardiovascular conditions (WHO – Regional Office for Europe 2004).

Fuel combustion particles may contain or carry more toxic compounds (*e.g.* metals) than particles from natural sources such as dust storms. But at present, total PM₁₀ or PM_{2.5} mass concentrations per volume of ambient air are considered to be the best indicators of potentially health-damaging exposures for risk reduction purposes (WHO – Regional Office for Europe 2000 and 2004).

Global burden of disease from air pollution

Urban outdoor air pollution from small particles is estimated by WHO to cause about 1.3 million deaths globally per year (WHO 2011a). A reduction in average particulate concentrations from 75 µg/m³ for PM₁₀ (a level common



Figure 2
The number of cities in developing countries with air quality monitoring systems is increasing rapidly: An information board displaying concentrations of PM₁₀, O₂, CO, SO₂ and NO₂ in Bangkok.

Photo by Dominik Schmid, Bangkok, Thailand, 2010

in many cities) to 20 $\mu\text{g}/\text{m}^3$ for PM_{10} (the WHO guidelines) would be expected to lead to a reduction in mortality of 15%.

Burden of disease from air pollution in developing cities

Average concentrations of health-harming air pollutants in major developing cities are estimated to far exceed those in developed cities of comparable size (Figure 3). The worst levels of air pollution today are found in cities in Asia, Africa and the Middle East. Air quality monitoring systems to measure air pollution exposures in developing cities are often still limited, and need to be improved to allow better analysis of local sources of air pollution, its impacts on health, and scenario planning.

Urban air pollution attributable to transport

There has been no global systematic review of transport's contribution to urban air pollution. However, available data suggests that in developing cities transport is a significant and growing contributor to urban air pollution – often more so than in certain developed cities. This is due to factors such as the age and composition of the vehicle fleet, poorer maintenance/regulatory environments, as well as rapid motorisation

and weak public transport systems that often characterise developing city environments.

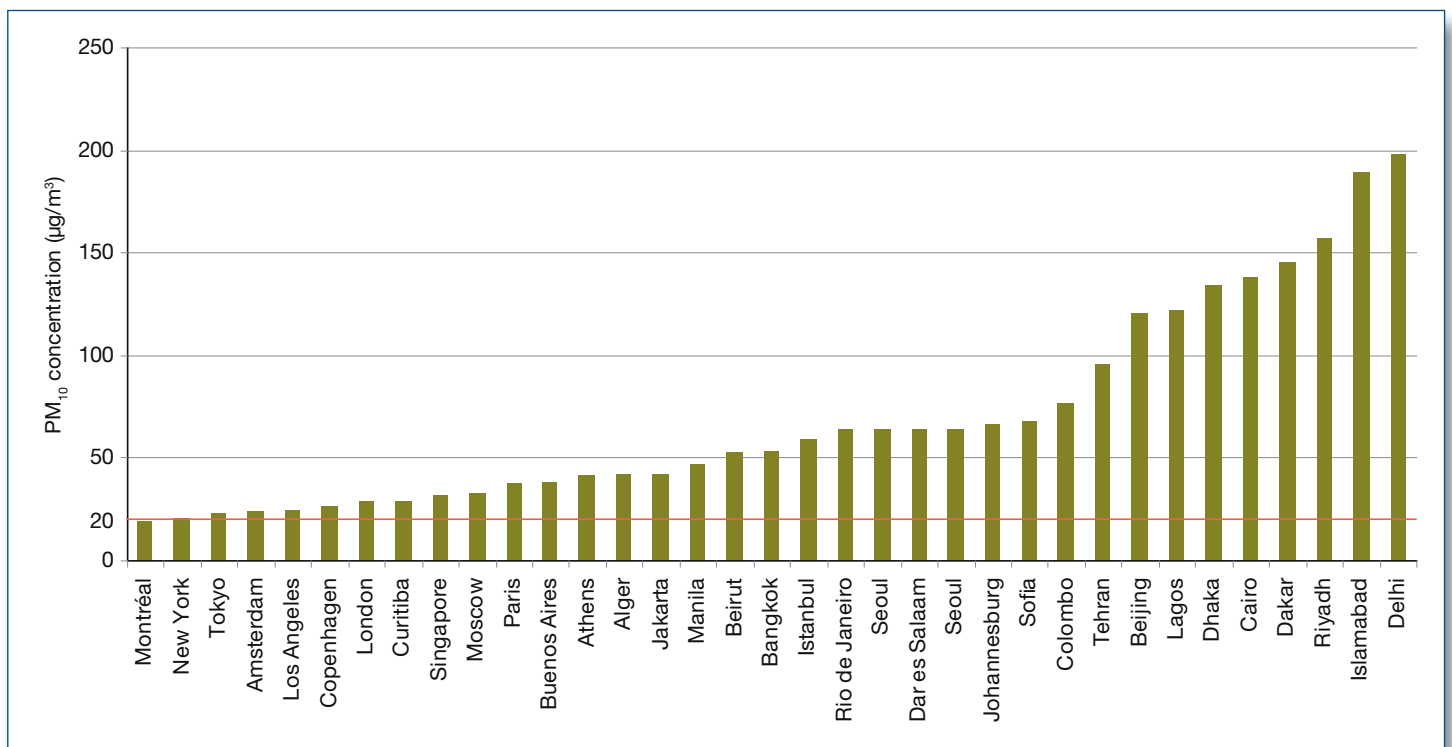
Road transport is estimated to contribute up to 30% of $\text{PM}_{2.5}$ in European cities (Krzyzanowski *et al.*, 2005), while experimental monitoring of $\text{PM}_{2.5}$ concentrations in major developing cities has yielded contributions ranging between 12% and 69% (UNEP/WHO 2009). In many urban settings, transport is also a leading source of other air pollutants, including: carbon monoxide (CO), oxides of nitrogen, and benzene, as well as contributing to the formation of ground-level ozone (Krzyzanowski *et al.*, 2005).

In Asian cities, transport has been estimated to contribute 40–98% of total CO emissions and 32–85% of total NO_x emissions (Zhongan *et al.*, 2002, IGES 2006, Haq 2002, Kebin *et al.*, 1996, Suksod 2001, ADB 2002a and 2002b, Benkhelifa *et al.*, 2002). In Mexico City and São Paulo, mobile sources were estimated to comprise 97–98% of CO emissions and 55–97% of total NO_x emissions (Vincente de Assunção 2002, Landa 2001). In Europe, vehicles are the main contributors to NO_x (Krzyzanowski *et al.*, 2005).

Until recently, transport was a major contributor to environmental lead exposure, a highly toxic substance to humans, particularly

Figure 3
Average annual PM_{10} concentrations in urban areas between 2003 and 2009: Micrograms/ m^3 ($\mu\text{g}/\text{m}^3$) in relation to WHO recommended levels.

Source: WHO 2011a



children. While most countries have now eliminated leaded gasoline, lead remains an important transport-related hazard in countries where it is still used.

In many developing cities, a sizable proportion of transport-related air pollution emissions is from motorcycles – which may comprise up to 80 % of the vehicle fleet (*e.g.* in the so-called “motorcycle cities” of Asia). Two stroke engine motorcycles emit particularly large proportions of CO, NO_x and PM per person-kilometre of travel.

Legislation replacing two-stroke engines with four-stroke engine motorcycles, as well as regulations requiring regular engine maintenance, has, in some settings, significantly reduced motorcycle pollution. However, the rapidly increasing volume of motorcycle and motor vehicle traffic tends to outpace the impacts of such technological improvements, so that the net gain in ambient air pollution reductions is somewhat less.

In addition, technological improvements do not address the other health risks of motorcycles – traffic injury, noise emissions, and barriers motorcycles pose to healthier cycling and walking. Strategies to reduce the dependence on motorcycle transport in developing cities are therefore required alongside measures to improve vehicle and fuel quality. Land use plans and traffic planning can make cycling and walking alternatives more efficient and safe, and avoid the encroachment of vehicles into spaces used by non-motorised transport modes. Additionally, policies encouraging development and use of electric bicycle technologies can be explored. Electric bicycle technologies combine some of the advantages of motorcycle travel (greater range and speed) with those of a bicycle (clean fuel source and opportunities for moderate physical activity). All in all, an emphasis on multi-modal transport development in cities is integral to air pollution mitigation strategies as well as to traffic demand management more generally.

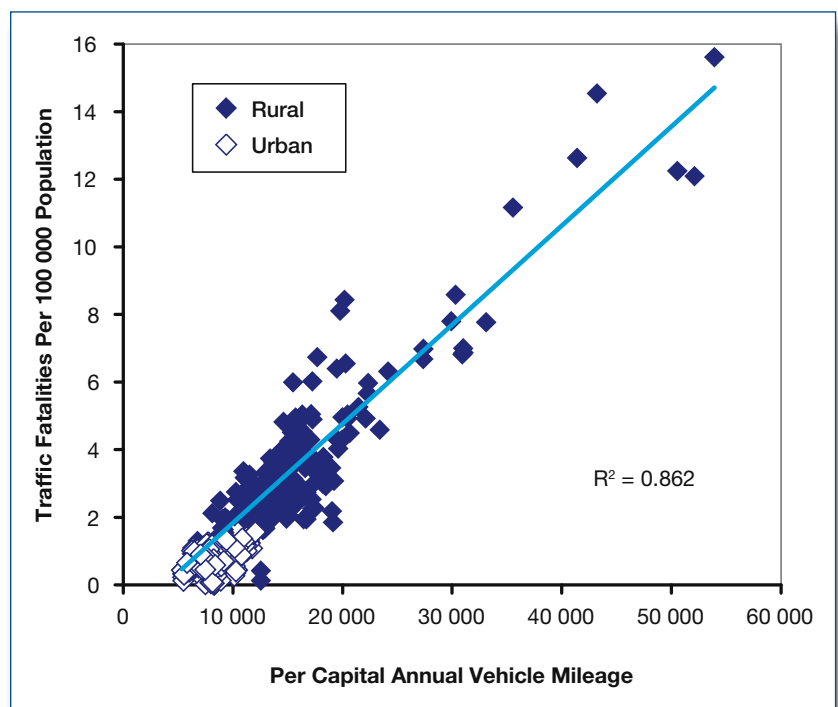
SUTP Air Quality Management Module

Further information on how to tackle air pollution issues can be found in SUTP Module 5a (Air Quality Management), available for download at <http://www.sutp.org>.

2.1.2 Road traffic injuries

Road traffic injuries cause 1.3 million deaths per year globally (WHO 2008c), with up to 50 million people injured (Peden *et al.*, 2004). The burden of road traffic injuries is growing along with increased motorisation. It is projected that by 2030 road traffic will account for nearly 5 % of global disease burden, and rank as third-highest cause of death overall (WHO 2008c). Around 90 % of road traffic injury disease burden occurs in low- and middle-income countries, which tend to have more hazardous travel environments. Road traffic injury affects especially young people, and it is the second highest cause of death between ages 5 and 29 years.

The correlation between vehicle kilometres travelled (VKT) and road safety is so strong (Figure 4) that VKT has even been proposed as a proxy indicator for road safety, particularly since traffic injury statistics are often incomplete (Lovegrove *et al.*, 2007).



a pedestrian in a 30 km/h collision (Dora and Phillips 2000).

Walkers and cyclists are more likely than motor vehicle occupants to be injured if a crash occurs, and are typically described as “vulnerable road users”. Other vulnerable road users include children, the elderly and motorcyclists (Peden *et al.*, 2004). Higher traffic volumes are a particularly strong risk factor for child pedestrian injury, and falls in traffic volumes have previously been accompanied by falling child pedestrian deaths (Peden *et al.*, 2004). Motorcycles are a particularly important factor in injuries in low-income cities, where they may be the dominant mode of motorised transport. In Delhi, 75% of road traffic injury deaths have been estimated to involve pedestrians, cyclists and users of

higher (Elvik and Mysen 1999). Road traffic injuries are also caused by factors such as the use of alcohol, medicinal or recreational drugs, the use of hand held mobile phones, or the disregard for personal protective equipment like helmets (for cyclists) or seat belts. Other factors affecting road traffic injuries include design of the street environment, pedestrian and cycling spaces and facilities, as well as enforcement of legislation.

Despite the scale of the problem, road traffic injury is largely predictable and preventable (Peden *et al.*, 2004). However, effective measures to address risks cannot rely solely upon modifying individual behaviour alone. Rather, the traffic system needs to be designed in a way that helps users to cope with increasingly demanding conditions. The vulnerability of the human body should be a limiting design parameter for the traffic system.

Traffic calming interventions that reduce speed, including 20 mph urban residential zones, physical barriers and pavement design, have also been shown to significantly reduce injury rates (Bunn *et al.*, 2003, Grundy *et al.*, 2009). Traffic interventions that reduce speed can also remove safety barriers to active travel – thus helping reduce car use, and further reducing both injuries and emissions.

Additionally, greater emphasis on public transport can help improve the safety of the transport system. In comparison to private vehicles,



Figure 5a/b

Motorised two-wheelers have a high modal share in many developing cities, and are frequently used to transport numerous family members, including children, without proper safety measures such as helmets.

Photos by Santosh Kodukula, Delhi, India, 2008



motorised two- and three-wheelers (UNEP/WHO 2009).

Globally, a WHO survey found that these vulnerable road users accounted for 46% of road traffic deaths (WHO 2009b). However, crashes involving pedestrians or cyclists are poorly reported in official road traffic injury statistics, so actual injuries in these groups may be even



Figure 6

Elderly people are among the most vulnerable groups.

Photo by Carlos F. Pardo, Pereira, Brazil, 2007

rail and bus transport are often the safest mode of travel per passenger kilometre. The risk of injury for bus users in the United States, for instance, is much lower than the risk to car users (Beck *et al.*, 2007).

Poor road safety tends to perpetuate a “vicious cycle” which deters many pedestrians and cyclists while improving road safety can encourage a “virtuous cycle” that encourages more walking and cycling. Traffic calming measures that slow motor vehicle speeds, for instance, are associated with increased walking and cycling (Cervero *et al.*, 2009, Centers for Disease Control and Prevention 2000). Improving road safety by reducing traffic volumes and speeds are thus important ways to both help prevent injury and also to encourage healthy physical activity.

Increased numbers of walkers and cyclists may also lead to a “safety in numbers” effect, since higher walking and cycling rates are associated with lower per capita injury risks for walkers and cyclists (Jacobsen 2003, Robinson 2005). However, this association could also plausibly be due to environmental improvements in the system. In addition, while more walking or cycling may be associated with a lower risk per walker or cyclist, the total number of injuries may still increase due to the larger volume of walkers and cyclists, who remain at a higher injury risk than car drivers (Bhatia and Wier 2011, Elvik 2009). This underlines the need to ensure that measures increasing walking and cycling are accompanied by strong environmental measures (such as reducing motor vehicle speeds and volumes) to prevent injury among these vulnerable road users.

Overall, strategies that reduce the need for private motor vehicles improve public transport services and encourage walking and cycling, are recommended as key road safety actions for governments. “Smart growth” land use policies that support compact, mixed use, urban development also helps to reduce the need to travel longer distances; this in turn may also reduce the extent to which people are exposed to the risk of road traffic injury (Peden *et al.*, 2004).

Many recommended strategies to prevent road traffic injury also have the potential to reduce greenhouse gas emissions (GHGs). For instance, speed reductions on motorways can not only



Figure 7
Speed limits and dedicated infrastructure for non-motorised transport modes help to reduce risks for pedestrians and cyclists.

Photo by Jeroen Buis, Rio de Janeiro, Brazil, 2007

reduce road traffic injury risk, but also fuel consumption and thus GHG emissions (Kahn *et al.*, 2007). Enforcement of a speed limit reduction from 100 km/h to 80 km/h in the Netherlands lowered PM₁₀ emissions by 5–25% and NO_x emissions by 5–30% (Keuken *et al.*, 2010), while air quality monitoring showed reductions in PM₁₀ and PM₁ concentrations (Dijkema *et al.*, 2008).

SUTP Road Safety Module

Revised in early 2011, the SUTP Sourcebook Module 5b (Urban Road Safety) presents up-to-date figures on the challenge of road safety in developing cities, and outlines measures to address the problem. To find out more, download the document at <http://www.sutp.org>.

2.1.3 Lack of physical activity, obesity and non-communicable diseases

Lack of physical activity is responsible for over three million deaths per year globally (WHO 2009a). It is a leading risk factor for poor health, and is one of the factors driving global increases in major causes of death and illness such as cardiovascular disease, type II diabetes and some types of cancer. These non-communicable diseases (NCD) are no longer just major contributors to disease burden in developed countries. In fact, most deaths from non-communicable diseases now occur in developing countries (WHO

2004). Rising rates of overweight and obesity are one consequence of inactivity, but physical activity has health benefits regardless of whether or not a person is obese (Hu *et al.*, 2005).

Active transportation (*e.g.* walking and cycling to work or daily destinations) is an important means of incorporating more physical activity into people's lives (WHO 2006b, Branca *et al.*, 2007, Cavill *et al.*, 2006, Boone–Heinonen *et al.*, 2009). In fact, a recent WHO systematic review of health literature found that one of the most effective means of encouraging physical activity generally was through transport and urban planning policies (WHO 2009c).

There is also a growing body of scientific research which has found that people commuting by bicycle live longer lives and have less cardiovascular diseases than people who commute by motor vehicles (WHO 2004). Two long-term studies, for instance, in Copenhagen and Shanghai, found that the annual mortality rates of cyclist commuters were 30% lower, on average, than commuters who did not travel actively or exercise regularly (Andersen *et al.*, 2000, Matthews *et al.*, 2007). Evidence from systematic review has also shown that walking reduces cardiovascular disease (Boone–Heinonen *et al.*, 2009), and that physical activity more generally also improves many other facets of health (Table 2).

Along with the positive aspects of active transport, there may be drawbacks. For instance, people walking or cycling in polluted urban areas may experience higher air pollution exposures as compared with car users due to changes

in respiratory rate and travel times. This exposure is likely to be dependent on route taken (*e.g.* bike paths through parks) as well as on local traffic conditions, weather and emissions.

Likewise, risk of traffic injury is a problem for pedestrians and cyclists in most settings, as they lack the protective shield of an automobile. Yet overall, in cities and settings where air pollution rates are comparatively lower and well-defined pedestrian/cycle paths, streets and pedestrian/cycle right-of-ways exist, the evidence shows that health benefits from walking and cycling far outweigh its risks (WHO 2008b, de Hartog *et al.*, 2010, Andersen LB *et al.*, 2000, Matthews *et al.*, 2007). For example, estimates for the United Kingdom population identified 20 fold larger health benefits from increasing cycling for transport, after considering the physical activity benefits and the risks from injuries and air pollution (Rutter 2006, Hillman *et al.*, 1990). In car-oriented developed cities and in developing cities with heavy mixed traffic volumes, aggressive air pollution and traffic injury mitigation measures are particularly important to minimise the risks of active travel.

Countries with a higher proportion of trips made by walking, cycling or public transport also have lower obesity rates on average, although such studies do not demonstrate causality (Bassett *et al.*, 2008). A very wide range of confounding variables must also be considered in terms of diet, culture, development, etc. Outdoor physical activity, such as walking and cycling, may be particularly important, as sunlight exposure can increase people's vitamin D levels, which is associated with reduced risks

Table 2: Health effects associated with physical activity

Lower all-cause mortality**	Less coronary heart disease**
Less high blood pressure**	Less stroke**
Less type 2 diabetes**	Less metabolic syndrome**
Less colon cancer**	Less breast cancer**
Less depression**	Better fitness**
Better body mass index and body composition**	More favourable biomarker profile for preventing cardiovascular disease, type 2 diabetes and bone health**
Better functional health in older adults**	Better quality sleep*
Less risk of falls in older adults**	Better health-related quality of life*
Better cognitive function**	

Key: **: strong evidence; *: modest evidence. Source: U.S. Department of Health and Human Services (2008)



of cardiovascular disease, type 2 diabetes and some cancers (Pearce and Cheetham 2010). As high sun exposure also increases risks to health from ultraviolet radiation (such as skin cancers) a balanced approach is needed. Overall, access to outdoor activities and urban green spaces can thus help to maintain both physical activity and vitamin D levels for urban residents. Compared with motorised transport, walking and cycling improve health both through reduced air pollution emissions and through physical activity.

2.1.4 Noise

Road traffic is the biggest cause of community noise in most cities. Noise levels are increased by both higher traffic volumes and higher traffic speeds, with the level of human exposure also determined by other factors such as the proximity of the source of noise (Berglund *et al.*, 2004). Community noise exposure has a range of health effects. As well as more general effects such as causing annoyance, noise is linked to stress levels and increased blood pressure. There is increasing evidence that noise-induced stress raises the risk of cardiovascular disease, and noise may also have negative effects on mental health (Berglund *et al.*, 2004, Moudon 2009, Babisch W. 2008). It also leads to annoyance

Figure 8a/b ▲

Transport infrastructure occupies an increasing share of urban space, while recreational facilities are hard to find in many developing cities: Urban highways (above) and the popular Lumpini park (below) in Bangkok.

Photos by Dominik Schmid, Bangkok, Thailand, 2010

Figure 9 ▼

Traffic is the most serious source of noise in many developing cities.

Photo by Andreas Rau, Beijing, PRC, 2009

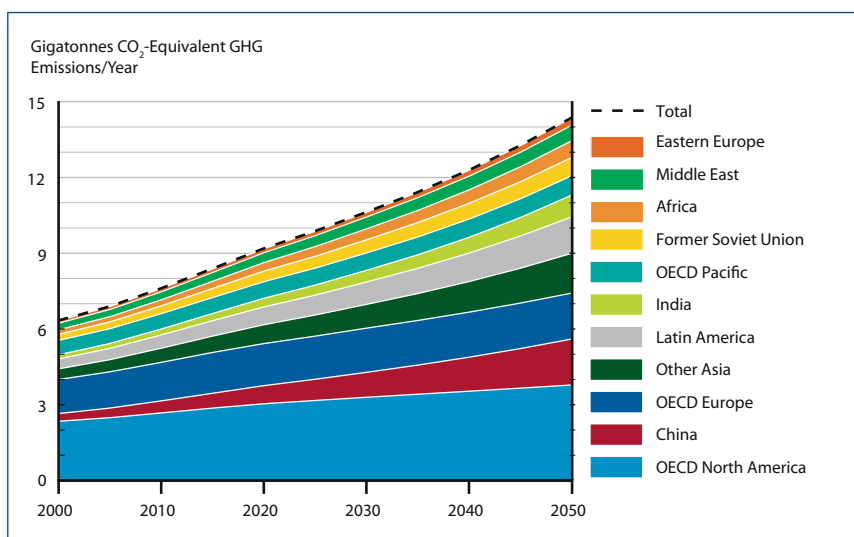
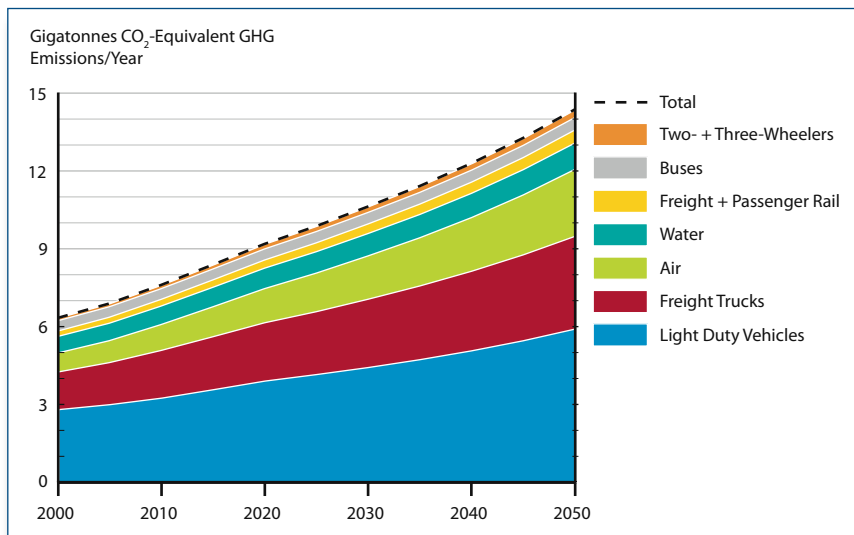


and sleep disturbance. Children living in areas of high aircraft noise have been shown to have delayed reading age, poor attention levels and high stress levels (Haines *et al.*, 2001), and high levels of road traffic noise have been associated with impaired reading and mathematics performance (Ljung *et al.*, 2009).

An assessment of the burden of disease from environmental noise concluded that traffic-related noise accounts for over 1 million healthy years of life lost annually to ill health, disability or early death in the Western Europe countries. This burden was due to annoyance and sleep disturbance but also to heart attacks, learning disabilities and tinnitus (WHO – Regional Office for Europe 2011).

Figure 10a/b
Transport-related well-to-wheels CO₂ emissions by mode (above) and region (below).

Source: WBCSD 2004



Some strategies to reduce noise exposure can reduce both health impacts and emissions, such as reducing traffic volumes. Other measures to reduce community noise levels, such as lowering traffic speeds and diverting traffic away from residential streets, can help remove safety barriers to active transport in neighbourhoods, so may indirectly reduce emissions by promoting mode shift towards walking and cycling.

SUTP Noise Module

In-depth information on policies to reduce traffic noise are outlined in SUTP Module 5c (Noise and its Abatement), which will be available at <http://www.sutp.org> in revised form by the end of 2011.

2.1.5 Climate change, transport and health

Climate change poses major risks to health through a range of pathways. Extreme weather events, such as heat waves, floods, droughts and storms are becoming more frequent and intense (Costello *et al.*, 2009). Some infections, especially vector-borne diseases carried by mosquitoes, other insects and snails (*e.g.* schistosomiasis), are changing their geographical distribution in response to changing temperature and climate zones. Climate-induced water and food shortages resulting from reduced agricultural production in drought-prone areas of Africa and elsewhere may, in turn, precipitate population displacement and conflict (WHO 2009d).

Transport is a leading contributor to greenhouse gas emissions. As well as accounting for 24% of global energy-related emissions, growth in energy use is higher for the transport sector than any other end-use sector. About 80% of transport energy use is due to land transport, with most of this attributable to light-duty vehicles (LDVs) including cars, followed by freight transport (Kahn *et al.*, 2007). As land transport leads to more health impacts than shipping and air travel, and also accounts for the majority of emissions, this report focuses on land transport.

The potential for present-day emission reductions is highest in high-income countries, which have the highest per-capita transport emissions. However, many developing countries are undergoing rapid motorisation (Figure 10a/b),

making mitigation strategies increasingly important in developing countries for limiting future emissions. In many developing countries, however, even preserving the current mode share of walking, cycling and public transport is likely to require substantial efforts. An important underlying principle, however, is that potential health co-benefits of well-designed transport mitigation strategies are as important in developing countries as in developed countries, along with their potential to reduce emissions or prevent future emissions increases.

Some indicative ranges of CO₂-eq emissions by travel mode in developing countries are noted in Table 3. Actual emissions per passenger kilometre are strongly influenced by the age and type of vehicle, by urban and rural driving conditions, and by type and quality of fuel used. Actual emissions also are highly dependent on occupancy rates and, in the case of electric trams or rail, electricity generation methods. However, the table illustrates that, when operating at full or near-full capacity, rail and bus modes typically emit less greenhouse gasses as well as other types of local emissions (per passenger kilometre of travel) than private motorised travel. Walking and cycling emit no pollution at all.

Table 3: GHG emissions from vehicles and transport modes in developing countries

	Load factor (average occupancy)	CO ₂ -eq emissions per passenger-km (full energy cycle)
Car (gasoline)	2.5	130 – 170
Car (diesel)	2.5	85 – 120
Car (natural gas)	2.5	100 – 135
Car (electric) ^a	2.0	30 – 100
Scooter (two-stroke)	1.5	60 – 90
Scooter (four-stroke)	1.5	40 – 60
Minibus (gasoline)	12.0	50 – 70
Minibus (diesel)	12.0	40 – 60
Bus (diesel)	40.0	20 – 30
Bus (natural gas)	40.0	25 – 35
Bus (hydrogen fuel cell) ^b	40.0	15 – 25
Rail transit ^c	75 % full	20 – 50

Note: All numbers in this table are estimates and approximations and are best treated as illustrative.

a) Ranges are due largely to varying mixes of carbon and non-carbon energy sources (ranging from about 20–80% coal), and also to the assumption that battery electric vehicles tend to be smaller than conventional cars.

b) Hydrogen is assumed to be made from natural gas.

c) Assumes heavy urban rail technology (“metro”) powered by electricity generated from a mix of coal, natural gas and hydropower, with high passenger use (75% of seats filled on average).

Source: Kahn et al., 2007, Table 5.4.

SUTP Climate Change Module

Detailed information on instruments available to achieve GHG emission reductions in the transport sector can be found in SUTP Module 5e (Transport and Climate Change) at <http://www.sutp.org>.

2.1.6 Land use, access, social well-being and other factors

Land use change is one of the profound impacts of transport, which in turn affects health directly and indirectly. Directly, expansion of road systems tends to stimulate more energy intensive modes of travel, as compared to rail or exclusive bus corridors, and thus stimulates more pollution of air and water. Indirectly, road-oriented expansion in and around the urban periphery, as well as in between major cities reinforces car dependence.

This is because cars and the roads they travel on are intensive consumers of space. Compared with active travel or public transport, road-oriented development increases the amount of land needed for car access and parking in, around and between key commercial, office and residential destinations. This, in turn, makes walking, cycling and even public transport far less efficient. It also reduces the land available for other uses such as green spaces. Urban sprawl

typically results from this expansion of roads and highways in cities or on the periphery, or between destinations.

By influencing these broader land use patterns, transport also impacts profoundly on a wide range of health determinants (WHO 2010). When road-oriented development occurs, a “vicious cycle” of increased dependence on vehicle transport emerges, leading to less active transport, more sedentary lifestyles – and related diseases.

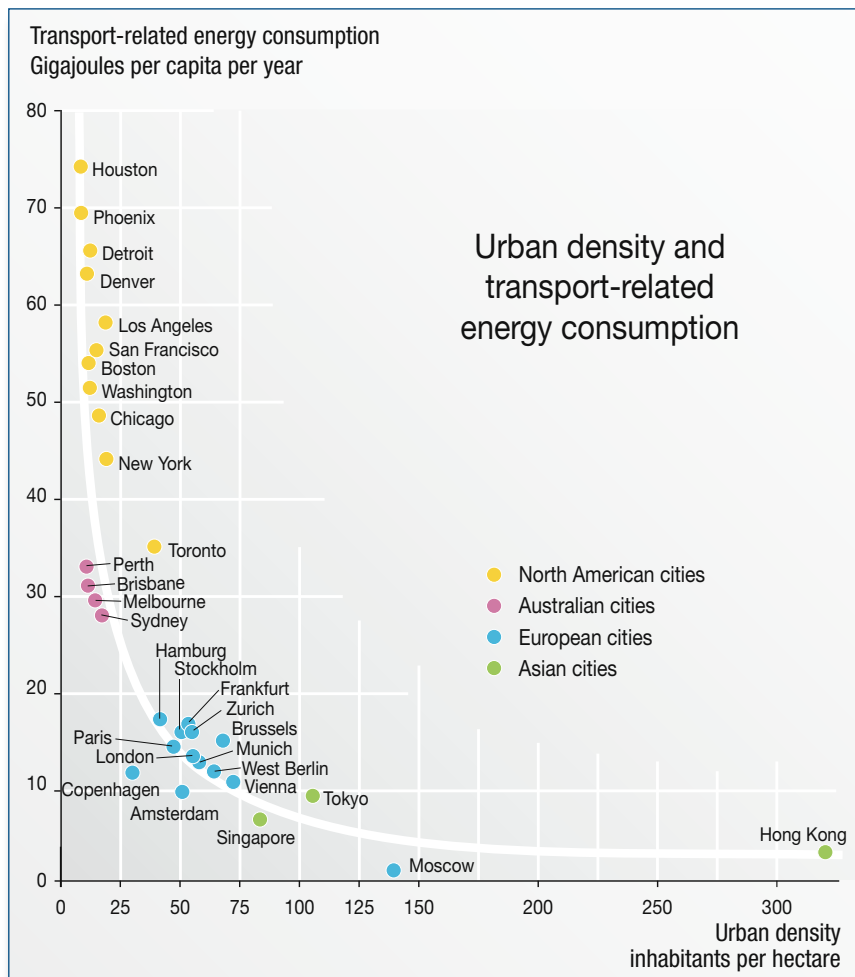
Land use planning can be seen as a process to ‘facilitate allocation of land to the uses that provide the greatest sustainable benefits’ (United Nations 1992). By trying to improve the proximity of people to their potential destinations, land use planning can reduce the distance that needs to be travelled by motorised transport and improve the feasibility of using non-motorised transport (Frank *et al.*, 2010). Another important task for smart land use planning is to increase the land available for green space. Access to green spaces is associated with longer life expectancy (Takano *et al.*, 2002). For instance, green spaces appear to buffer people’s mental health during stressful life events (van den Berg *et al.*, 2010), and may also help ameliorate the “heat island” effect of cities, promoting resilience to the effects of climate change (Lafortezza *et al.*, 2009).

Patterns of land use also influence the geographic proximity of homes and businesses to transport hazards such as air pollution, noise and pedestrian injury. The negative health impacts of transport tend to be concentrated along busy roads and in inner-city areas with high traffic density so people living and working in such areas are naturally more exposed, unless mitigating measures are adopted (Dora and Phillips 2000). Cities with higher road capacity appear more hazardous to health, with higher air pollutant levels and more road traffic injuries. These cities also have much higher transport-related greenhouse gas emissions per capita (Kenworthy and Laube 2002).

Land use factors also are associated with child and youth obesity and, in some studies, with adult obesity (Dunton *et al.*, 2009). Conversely, more compact and mixed land use can be a policy tool promoting better health in terms of

Figure 11
Urban density and transport-related energy consumption.

Source: Newman & Kenworthy 1989, via UNEP



more physical activity. This issue is explored further in Section 3.

Travel in and of itself can be stressful, and heart attacks have been associated with exposure to traffic (Peters *et al.*, 2004). While it makes sense that driving in congested traffic is stressful, long commutes by rail can also lead to stress (Evans and Wener 2006). Reducing public transport travel times, such as by running buses on exclusive rights-of-way rather than in mixed traffic (VTPI 2010c), as well as other public transport improvements, may help reduce commuting stress, particularly for the poor who often face long commutes, but also for the more affluent. Land use planning that increases proximity and reduces public transit commuting times, not only facilitates active travel and improves access, but also can help reduce stress levels.

There is some research to show that neighbourhoods based around active transport also are more socially cohesive. Residents on low-traffic streets are more connected to their neighbours (Appleyard and Lintell 1972) and more “walkable” communities have stronger social capital (Leyden 2003). As well as representing social well-being, more social networks and social capital are associated with better health (Kawachi and Berkman 2001, Kawachi *et al.*, 1999).

Active transport can be encouraged or deterred by levels of street crime (Seedat *et al.*, 2006), and patterns of land use and active transport may also influence crime rates. Rates of street crime are typically lower in locations with mixed land use and appropriate design treatments (Cozens *et al.*, 2003, Jacobs 1961, Mohan 2007). In the United States, where patterns of sprawl are very pronounced, higher residential densities are associated with both fewer homicides and also fewer road traffic deaths – this is despite the common perception that cities are more dangerous than suburbs as places to live (Lucy 2003).

Rapid horizontal growth of cities in developing countries has coincided with very considerable slum expansion on the urban periphery. Nearly 40% of the world's urban growth is occurring in slums (UN Habitat 2006). These are largely unplanned and lack basic infrastructure and accessibility to key services (WHO 2010). Horizontal urban growth, if unrestrained, can



outpace the ability of cities to provide infrastructure. While residents of slums may benefit from low housing costs and relative proximity to employment opportunities, living conditions are otherwise poor. Healthy cities need to be inclusive, and strive to ensure that people from all income groups have access to adequate housing, water and sanitation, decent employment opportunities and other basic human needs.

It is increasingly recognised that employment, education, income, health care, public services and other social factors are all important influences on health. Collectively, these are referred to as social determinants of health (WHO 2008a). Transport systems and land use patterns strongly influence whether access to these opportunities is available to all people, or only to those with a car. For example, lack of geographical accessibility of employment opportunities was associated with a high risk of unemployment in a US study, as was lack of car ownership (Cervero *et al.*, 1999). Ensuring non-motorised access to goods, services and other health needs can also reduce greenhouse gas emissions as well as impacting on the social determinants of health.

2.2 Groups at higher risk of health impacts from transport

Major social differences in health exist within cities (Kahn *et al.*, 2007). And the benefits and hazards from transport systems are often distributed unevenly between disadvantaged and

Figure 12

Long commuting times in crowded trains may lead to increased stress levels.

Photo by Andreas Rau, Hong Kong, 2007

privileged social groups. Additionally, certain population groups are particularly vulnerable to the health risks of transport. As already noted, children, the elderly, and disabled people are at higher risk of traffic injury. Walkers and cyclists also have higher injury rates than car occupants (Peden *et al.*, 2004).

In the case of air pollution, people exposed to higher levels of air pollution tend to be of lower socioeconomic status compared with the urban population as a whole (WHO 2006a). Deprived communities tend to suffer disproportionately from pedestrian deaths from crashes, and from social isolation due to the effects of busy roads dividing communities (SEU 2002). These same vehicle-related hazards are created disproportionately by high-income groups, among whom car ownership is higher.

Active transport (walking and cycling) is generally free or low-cost, while motorised transport, especially private car use, is typically much more expensive (UNEP/WHO 2009). According to economic theory and the income elasticity of demand, high prices disproportionately reduce consumption for low-income groups; thus financial barriers to motorised transport are relatively higher for low-income populations. Cities that require private motorised transport to access essential goods, services and other health needs implicitly favour high-income groups. Investment in roads disproportionately benefits the well-off, while active, non-motorised transport and low-cost public transport are more evenly accessible across social groups.

Social inequities also exist at global scale. Many new transport technologies will be more expensive than existing technologies (Kahn *et al.*, 2007). Thus newer, cleaner vehicles are likely to be adopted first in high-income settings, with poorer communities the last to benefit from technology-related vehicle pollution reductions. Older, more polluting vehicles that are exported from developed to developing countries pose particular health risks. Resale of such vehicles at low prices has facilitated their mass export to low-income countries and cities that lack infrastructure and capacity for adequate vehicle maintenance as well as control of fuel quality (Davis and Kahn 2010). This contributes to high air pollution exposures and injury rates

among residents of developing countries. Some African countries also continue to use leaded gasoline (UNEP/WHO 2009). Thus, without appropriate policies, low- and middle-income countries risk being “pollution havens” for older and dirtier but also cheaper vehicles and fuels.

2.3 Regional overview of health impacts from transport

Trends in travel are important determinants of the future progression of the global NCD epidemic in developed as well as developing countries. NCDs are already the leading cause of death in most developed countries, although in absolute terms, 80 % of NCD deaths are now occurring in low- and middle-income countries, which are experiencing a surge in NCDs as well (Beaglehole *et al.*, 2011). By 2030, NCDs are expected to cause over three-quarters of all deaths globally (WHO 2008e).

As noted previously, transport is closely associated with the development of many NCDs, including cardiovascular conditions caused by air pollution and traffic injury. Additionally, transport-related physical – from walking, cycling or accessing public transport – helps prevent many NCDs, including coronary heart disease, stroke, type 2 diabetes and some cancers (U.S. Department of Health and Human Services 2008). Globally, growth in transport sector energy use is higher than any other end-use sector making it a major contributor to climate change. This section examines a few key aspects of travel trends in developed as compared to developing countries, with an eye to how those trends impact key transport-related NCDs and health.

2.3.1 Organisation of Economic Co-operation and Development (OECD) countries

In general, higher gross domestic product (GDP) per capita is strongly associated with increased vehicle use and ownership, whether of cars, two-wheelers or small commercial vehicles.

However, there remains a wide variance in levels of car use among OECD countries. Only about 50 % of total trips are made by automobile in Western Europe as compared with 90 % in the United States (Kahn *et al.*, 2007). Additionally,

urban walking and cycling may comprise as much as 25–30 % of travel in many western European cities (e.g. Amsterdam, Copenhagen, and Zurich).

Thirty years of experience with air quality regulations, improvements in vehicle and fuel technologies, and improved transport demand management, including investment in rail, bus, pedestrian and cycle systems, have all contributed to stable, and in some cases, reduced pollutant emissions in European countries. Emissions of particulate matter decreased by 30 % in European Economic Area (EEA) member countries from 1990–2007, considered to be largely due to the increasing prevalence of catalytic converters and other technological improvements (EEA 2010b). However, certain gains from technological improvements were offset by increases in private vehicle travel in many European countries. For example, European transport sector greenhouse gas emissions grew by 28 % from 1990–2007; this was attributed to overall traffic growth despite improvements

in the energy efficiency of vehicles (EEA 2010a). The relationship between traffic volumes, air pollution and other health risks such as road traffic injuries means that, all else being equal, increases in motorised traffic still are likely to adversely affect health.

In addition, emissions of health-damaging small particles (PM₁₀, PM_{2.5}) per unit of travel have increased over the last decade as a result of market shifts from gasoline- to diesel-powered engines. This is considered to be a cause of stable (rather than lower) PM₁₀ levels in European cities in the last decade and thus no decline in the health impacts of urban air pollution – despite diesel technologies becoming cleaner.

In European conditions, where new diesel technologies are used, buses may even rival electric rail modes for their low emissions of PM₁₀ and other air pollutants (e.g. CO₂) – particularly in medium distance journeys of 10–250 km. In short journeys under 10 km, however, electric rail modes appear, on average, to be the least polluting per passenger kilometre of travel.

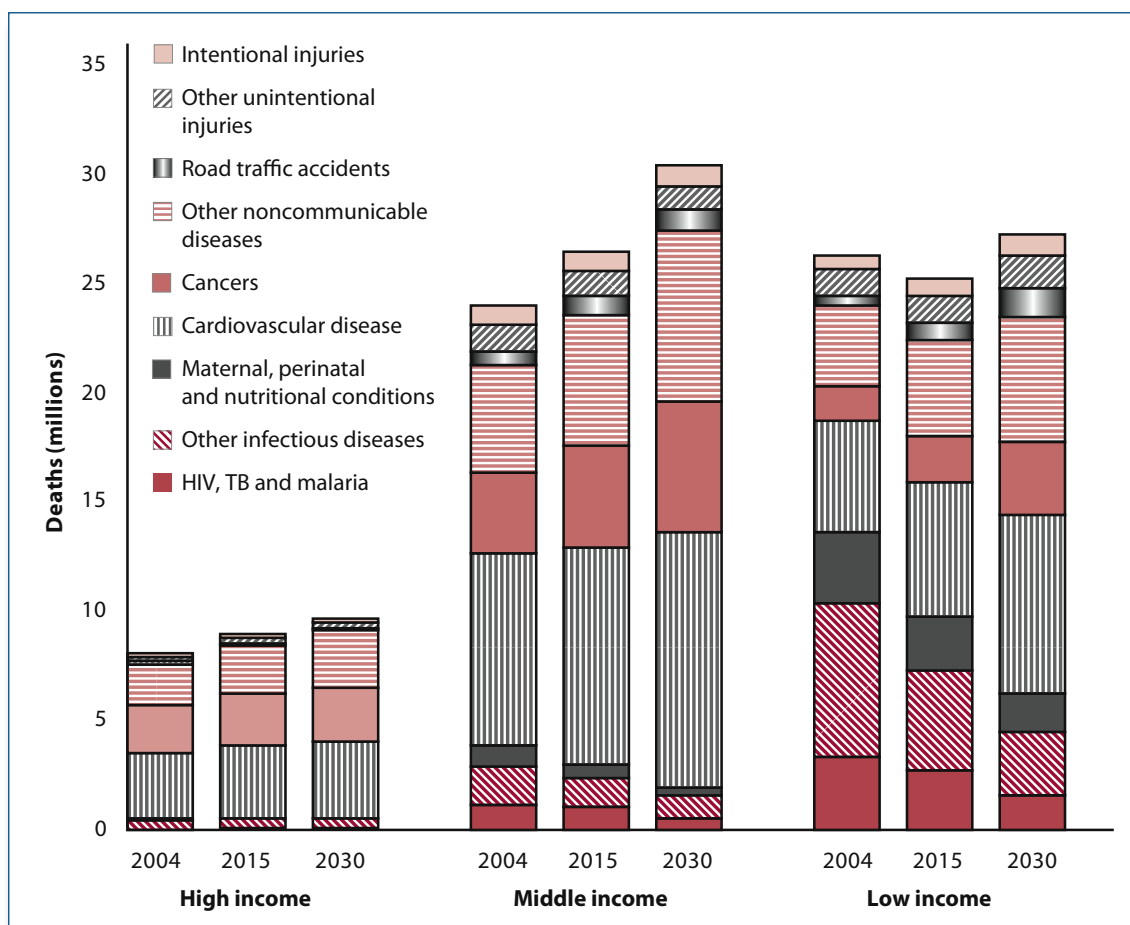


Figure 13
Projected deaths by cause for high-, middle- and low-income countries. Most deaths are due to cardiovascular disease, cancers and other non-communicable diseases (NCDs)

Source: WHO 2008e

2.3.2 Developing countries

In developing countries, automobile travel accounts for only 15–30% of total urban trips made, much less than in OECD countries. Non-urban vehicle travel is also much lower in non-OECD compared with OECD countries (OECD 2009). By 2030, however, under “business as usual” scenarios, the number of vehicles in developing nations is projected to exceed the number in developed countries (Wright and Fulton 2005). The number of light-duty vehicles is projected to triple between 2000 and 2050, with developing country demand as the major driver (Kahn *et al.*, 2007). Such increases in motorisation have generally been associated with increased emissions of urban air pollutants and climate change gases, increased road traffic injury and lower rates of physical activity.

Soaring growth in vehicle traffic is already a major factor in high developing city air pollution concentrations. Growth in motorised travel is also becoming an increasingly important factor in developing country greenhouse gas emissions. Although these problems can be offset to some extent by improvements in vehicle and road design, vehicles exported to developing countries are often older and more polluting (Davis and Kahn 2010).

In developing countries, diesel vehicles are an even more significant source of vehicle-related particulate emissions. This is particularly the case for older trucks and buses which may be poorly-maintained. Motorcycles and three-wheeled vehicles powered by old fashioned two-stroke engines also represent a disproportionate share of particulate emissions due to lower fuel efficiency, as compared with conventional four-stroke engines. However, modern three-wheeled vehicles using four-stroke engines with catalytic

converters can be as clean as cars. In Dhaka, Bangladesh, a significant decline was observed in airborne concentrations of fine particulates at two experimental monitoring sites following new government policies that removed two-stroke engines from the road and began to upgrade or convert diesel trucks and buses to cleaner fuels, *e.g.* compressed natural gas (CNG) (UNDP/World Bank-ESMAP 2004).

Urban population growth, due to rural-urban migration, is another key driver of trends in developing cities. Most of the world’s projected population growth between 2000 and 2030 will occur in low and middle income cities (de Jong 2002, Tudor-Locke *et al.*, 2003). As noted in the land use section, much of this growth is horizontal, low-density, which stimulates car use (Frumkin 2002, Begum *et al.*, 2006) and transport-related energy consumption (Figure 11) (Newman and Kenworthy 1989). Population growth also contributes to numbers of people exposed to traffic-related risks. In developing countries, other drivers of increases in motorisation may include marketing of motor vehicles, the role of cars as indicators of high social status, and aspirations to affluent lifestyles (of which car use is regarded as a component).

Surges in private motorised travel are often responsible for displacing other, healthier modes of travel. Walkers and cyclists, particularly those in ‘mixed’ traffic where motor vehicles are also present, are often put at risk by increases in traffic volumes and insufficient infrastructure providing for safe walking and cycling. The dearth of clean, safe, rapid and efficient bus or rail transit in many cities may give residents no choice but to use motor vehicles – if they can afford it. The alternative is long and difficult commutes on foot, bicycle, and crowded trains or buses, involving significant risks to health and safety. Urban policies and investments that favour private motor vehicles over other modes thus impose a “triple health penalty” on the carless – increasing their risks of air pollution and injury exposure as well as barriers to mobility/access.

Monitoring of transport-related health risks in developing countries can be impeded by a lack of data and basic information systems. Current travel mode share data is limited in these

Table 4: Growth in transport in developed and developing countries

Indicator	OECD (1980-1995)	OECD (1995-2010)	Non-OECD (1995-2010)
Population	+13 %	+ 8 %	+24 %
GDP	+44 %	+35 %	+123 %
Vehicle stock	+50 %	+33 %	+76 %
Vehicle kilometres travelled (VKT)	+65 %	+42 %	+70 %
Road fuel	+37 %	+21 %	+55 %

Source: OECD 2001; IPCC 2000a; ICAO 2005. Includes historical and projected figures.

countries, and may not capture all relevant forms of transport. For example, public transport counts may include only publicly-provided transport, whereas informal modes such as privately-owned buses, minibuses and converted pick-up trucks are frequently used by poorer populations due to their affordability and relative convenience, despite the lack of safety precautions associated with these modes (Peden *et al.*, 2004).

The experience in the 2008 Beijing Olympics provides a vivid case study of the contribution of traffic to urban air pollution exposures, and health impacts in developing megacities. During the Games, stringent restrictions on motor vehicle use were imposed to improve air quality. Compared with the period where there were no measures to improve air quality, asthma outpatient visits were almost halved (Li *et al.*, 2010), and PM₁₀ concentrations were reduced by between 9% and 27% (Wang *et al.*, 2009).

3. Instruments: tackling the problem

3.1 Policies for healthy transport

3.1.1 Improving land use planning

There is a large body of research examining potential links between land use planning and health. These links have been summarised in key reviews in the following ways:

- Urban form characteristics most associated with physical activity: 1) mixed land use and density; 2) footpaths, cycleways and facilities for physical activity; 3) street connectivity and design; 4) and transport infrastructure that links residential, commercial and business areas (NSW Centre for Overweight and Obesity 2005).
- Community- and street-scale urban design and land-use policies and practices effective at promoting physical activity (Heath *et al.*, 2006).
- A wider range of physical activity and/or walking determinants including: physical activity facilities, access to destinations, high residential density, land use, and urban 'walkability' scores (National Institute of Health and Clinical Excellence 2007).

Overall, it can be concluded that land use planning that promotes good health tends to involve 1) higher density of residents and amenities, 2) mixed residential and commercial land use planning, and 3) good street design that



Figure 14

Smart land use planning fosters infrastructure for cyclists and pedestrians, which in turn encourages healthy modes of travel and physical activity for leisure: Urban dwellers along the shoreline in Rio de Janeiro.

Photo by Carlos F. Pardo, Rio de Janeiro, Brazil, 2007

maximises connectivity for walkers and cyclists. These categories are sometimes known as “the 3Ds of urban design”.

Good urban land use planning for physical activity can synergistically address other transport-related health risks, generating double or triple health benefits. As illustrated by Figure 11, higher urban densities are also strongly associated with reduced transport-related energy use, primarily from private motor vehicle travel. Traffic volumes are also one of the most important influences on emissions of air pollutants, road traffic injuries and community noise levels. Thus, cities and communities that are designed to enable access to important destinations without the use of private motor vehicles can reduce air pollution and injuries as well as improving physical activity levels.

In the absence of clean and efficient public transport and traffic-calming measures, however, higher urban densities may also increase exposures and risks from air pollution, noise and road traffic injury, due to greater concentrations of traffic. This has been dubbed the ‘paradox of intensification’, and suggests that to optimise health, residential intensification needs to be accompanied by effective measures to constrain car use in intensifying areas (Melia *et al.*, 2011).

Two other land use factors are also consistently associated with health. The presence of more green and open spaces, parks and sports grounds is associated with a range of improved health outcomes in a large number of studies. Likewise, the presence of more green spaces and better aesthetic features in neighbourhoods is associated with higher levels of physical activity (Melia *et al.*, 2011, Kaczynski 2010, King *et al.*, 2006, Lee and Moudon 2008, Troped *et al.*, 2003) and active travel generally (Ishii *et al.*, 2010, Kerr *et al.*, 2006, Larsen *et al.*, 2009, Titze *et al.*, 2010).

One land use strategy for reducing the health impacts of air pollution is to reduce the proximity of motor vehicles to people (Krzyzanowski *et al.*, 2005). This can be done by limiting traffic in areas of high population density, or where vulnerable road users are present. Since heavy traffic also tends to discourage walking and cycling due to safety concerns, separation of motor vehicles may indirectly facilitate a shift

from car use towards walking and cycling, by making residential areas safer.

SUTP Land Use Module

The relationships between land-use structures and transport are examined in more detail in SUTP Module 2a (Land Use Planning and Urban Transport), available at <http://www.sutp.org>.

3.1.2 Facilitating healthy transport modes

Different transport modes have different patterns of health risks. As already noted, a large number of studies show that non-motorised travel (walking and cycling) is associated with more physical activity, reduced obesity and, in the case of cycle commuting, significantly lower overall rates of average annual mortality. Public transport use is also associated with more physical activity and less obesity, since public transport services are often accessed by walking and cycling.

Public transport users also have the lowest, on average, risk of injury, as compared to other modes of travel. However, while walkers and cyclists generate few risks to other road users, they are exposed to higher risks of traffic injury than motor vehicle passengers. These injury risks vary considerably depending on the design of the city, volume of cycle/pedestrian traffic, and the quality of cycle and pedestrian networks.

In contrast, car use is associated with less physical activity and more obesity. Increased motor vehicle travel increases emissions of air pollutants, as well as risks of injury to other road users. In contrast, walkers and cyclists do not emit air pollutants, and pose minimal risk of injury to other road users.

In well-designed cities, the available evidence suggests a hierarchy of travel modes with respect to their net health impacts, with non-motorised transport (walking and cycling) as the most beneficial, public transport intermediate; and private motorised transport the most harmful to health. The same ordering applies to greenhouse emissions, with private motorised transport having the highest emissions, and non-motorised transport having essentially zero



emissions. This relative desirability of different travel modes should thus be a cornerstone of transport policy for both health and climate change reasons, accompanied by land use planning that preferentially enables access for users of the most desirable travel modes. An example of this in practice is the development of a hierarchy of transport users to guide planning decisions, such as used by York in the United Kingdom (WHO 2006b).

SUTP Non-Motorised Transport Module

How to foster cycling and walking and increasing their share in the modal split is discussed in SUTP Module 3d (Preserving and Expanding the Role of Non-Motorised Transport), available at <http://www.sutp.org>.

3.1.3 Improving vehicles and fuels

Improved vehicle efficiency, and other technologies that reduce pollutant emissions, can improve population health. In the United States, the Clean Air Act of 1970 has been credited with reducing the proportion of cancers and cardiovascular diseases attributable to air pollution emissions from energy combustion; improved vehicle and fuel technologies were an important means of achieving those emissions reductions (Gallagher *et al.*, 2009, 2010).

A few decades later, emerging electric vehicle technologies offer the promise of even more substantial pollution and greenhouse gas emission (GHG) reductions at tailpipe, as compared with conventionally-fuelled vehicles (Kahn *et*

al., 2007). In other words, separating emission sources from people can improve health.

However, total emissions attributable to electric vehicles will nonetheless vary, depending on the source of electricity generation. For instance, vehicles powered by fossil fuel electricity from a coal-fired power plant would be less beneficial to health and to climate than vehicles powered by electricity from cleaner power sources, such as natural-gas. And vehicles powered primarily by rechargeable solar batteries would generate the lowest levels both of greenhouse gases and urban air pollution emissions. Also, emissions from fuel combustion alone also do not consider the life-cycle impacts of electric car manufacture on GHGs, which are considerable, when compared to those of bicycle manufacture, for example.

Biofuels are increasingly being encouraged as a way to reduce transport-related greenhouse gas emissions. However, the effects of different biofuels on different air pollutants remain unclear. A comparison of cellulosic and corn ethanol with gasoline found that while cellulosic ethanol could reduce PM_{2.5} and greenhouse gas emissions, corn ethanol may increase PM_{2.5} emissions without reducing greenhouse gas emissions (Hill *et al.*, 2009). Indirect impacts of biofuel production on health are also potentially important, especially if land is diverted from food production to fuel production, which could potentially reduce global food availability, increase food insecurity and prices, and increase global malnutrition (FAO 2008).

Figure 15a/b
Public transportation and non-motorised transport are most beneficial with regard to health impacts.

Photo by Carlos F. Pardo, Pereira, Brazil, 2007 (left) and Andrea Broaddus, Amsterdam, Netherlands, 2010 (right)

It has previously been suggested that while shifting from gasoline to diesel-powered vehicles could improve fuel economy and reduce GHG emissions insofar as diesel fuel tends to generate less GHGs per unit of travel than gasoline. However, per unit of travel, diesel fuel also is a proportionately greater contributor to health-harming air particulate pollution (Walsh and Walsh 2008). As noted in Section 2, higher average urban air concentrations of small particulates (PM₁₀ and PM_{2.5}) are associated in long-term studies with higher premature mortality as well as higher levels of hospital admissions and daily morbidity/mortality, primarily from cardiovascular conditions. Diesel exhaust has also been identified as a probable carcinogen (cancer-causing agent) (IARC 1989), although the evidence supporting this is still contested by some (Bunn *et al.*, 2004). There is less evidence to suggest that gasoline exhaust is carcinogenic. Among studies that separately assess the effects of diesel and gasoline exhaust on health, some find no difference in the effects of diesel and gasoline exhaust (Guo *et al.*, 2004a, b,) but at least one study has found lung cancer to be associated with exposure to diesel exhaust but not gasoline exhaust (Parent *et al.*, 2007).

Some researchers have attempted to quantify the likely air quality impacts of a shift to diesel vehicles. One study modelled the effect on photochemical smog of converting the US gasoline-powered fleet to modern diesel vehicles, and concluded that such an approach may increase smog (Jacobson *et al.*, 2004). Another study modelled the air quality impacts of UK consumers switching from gasoline to diesel cars, and estimated that this would increase air pollution deaths related to particulate matter (Mazzi and Dowlatabadi 2007).

Whether shifting from gasoline to diesel will worsen health very significantly is likely to be strongly dependent on the strength of the environmental standards applied to diesel vehicles, especially with respect to the quality of diesel fuel produced by refineries (especially sulphur content) and the quality of particulate filters on vehicles (Walsh and Walsh 2008). However, as already noted, large shifts of the vehicle fleet from gasoline to diesel fuels in European cities in the last decade are considered to be a cause

of stable (instead of lower) PM₁₀ levels and no decline in the health impacts of air pollution – despite the introduction of progressively more stringent standards for both fuel production and vehicle particulate filters. (Krzyzanowski *et al.*, 2005).

Finally, while low-emission motor vehicles may reduce air pollution-related health impacts, they are unlikely to reduce other important health risks such as road traffic injuries or lack of physical activity.

3.1.4 Comparison of policy options

While all of the three policy options discussed here appear likely to improve health, improving land use, increasing non-motorised transport, and shifts from private motorised travel to public transport appear to have the greatest combined potential for generating health benefits. Modifying vehicles and fuels may lead to additional reductions in air pollution, but is unlikely to reduce other health risks.

Growth in motorised travel may continue to offset many of the per-vehicle reductions in pollutant and carbon emissions from improved vehicles or fuels (Krzyzanowski *et al.*, 2005, EEA 2010a). First, vehicles that consume less fuel have lower running costs, which could incentivise motorised travel (a “rebound effect”) (VTPI 2010d). Additionally, as already noted, the growth in motor vehicle traffic tends to generate demands for even more motor vehicle travel, and more use of urban budgets and space on road and parking infrastructure to accommodate growing traffic. This, in turn, can make other modes comparatively less effective to use, as well as weakening the relative impact of investments in rail/bus and walking/cycling modes. Indirectly, then, an exclusive emphasis on improved vehicle and fuel technologies can even have a net negative health impacts. In one modelling study examining the health impacts of different transport development scenarios in Delhi, India and London, United Kingdom, the level of health benefit obtained by mode shifts from motorised to non-motorised travel was thus estimated to be higher overall, than the health benefit obtained from shifting to lower-emissions vehicles alone. Health benefits for a mode shift scenario were seven times higher for

Delhi, and over 40 times higher for London. A combined scenario using both policy strategies yielded almost double the reduction in greenhouse gas emissions, but only slightly increased health benefits compared with the mode shift scenario alone. This analysis took into account health effects from air pollution, physical activity and road traffic injury (Woodcock *et al.*, 2009).

In summary, a combination of policies, with the greatest emphasis on land use planning and facilitating healthy transport modes, appears likely to have the most beneficial effects for urban health in the short term. Improved vehicle and fuel technologies remain, however, an important component of measures to reduce GHGs and the climate-change related health impacts of transport.

3.2 Tools for assessing the health impacts of transport systems

3.2.1 Introduction

While previous sections in this report identified the best strategies and goals for health- and climate-friendly transport policy, this section identifies tools that can help select the right strategies to be implemented in a given setting,

and to assess progress towards identified transport and health goals. It outlines how transport modelling can incorporate health issues alongside other important outcomes such as environment and climate change effects. The main focus here is on examples of validated and non-commercial tools that can be used to quantify the expected health effects of different policy options. References with more detailed information are also provided for readers considering using these tools.

3.2.2 Types of assessment tools

There is a wide variety of tools that can be used to assess the health effects of transport policy options; these can be classified in a number of broad categories (Figure 16):

- 1) **Planning/procedural tools.** The key tool used is health impact assessment (HIA) which can be conducted on its own, or in association with other forms of impact assessment, such as environmental impact assessment (EIA) or strategic environmental/impact assessment (SEA/SIA), to determine the potential health impacts of policy options and to propose improvements.

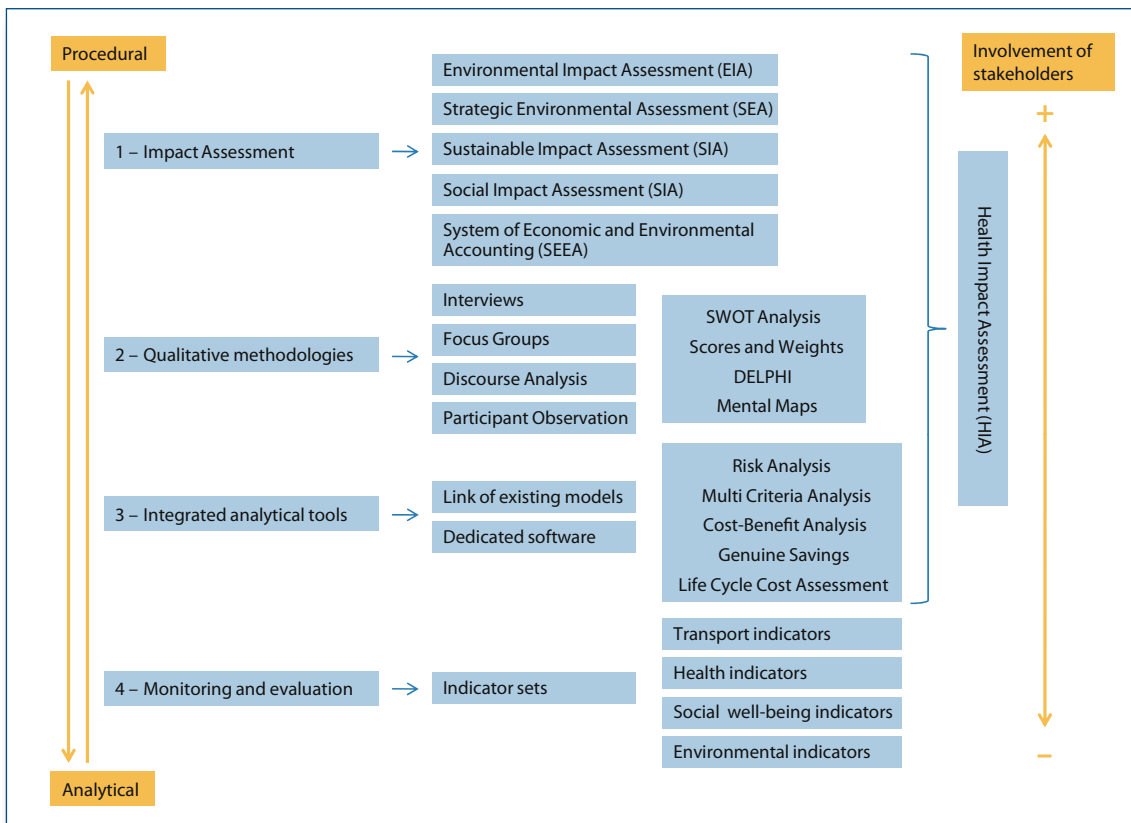


Figure 16
Tools to assess potential health impacts of transport policies.

- 2) **Qualitative tools** (e.g. interviews, focus groups, stakeholder discussions) can be used to support both planning or evaluation processes, supplementing hard data with local knowledge, feedback and perceptions.
- 3) **Integrative analytical tools** quantify and model actual or expected health outcomes. These include methods such as burden of disease analysis, quantitative risk assessment, and modelling, often used in combination. Economic modelling (e.g. cost-benefit analysis and cost-effectiveness analysis) can further be used to translate transport's health-related external costs, including deaths, illness and lost productivity, into economic terms. This is discussed briefly here and in more detail in Section 3.3.
- 4) **Monitoring and evaluation tools** often include the use of indicators to track progress against goals. Qualitative approaches may also be important here, however, particularly when there is a dearth of hard data, e.g. on issues such as pedestrian connectivity. HIA processes are also sometimes used retrospectively for monitoring and evaluation.

Impact assessment

Environmental impact assessment (EIA) was the first widely-used impact assessment process; it has been defined as “the process of identifying, predicting, evaluating and mitigating the

biophysical, social, and other relevant effects of development proposals prior to major decisions being taken and commitments made (IAIA, 1999).

In many countries, EIA is supported by legally-binding frameworks, which require impact assessment for many major forms of development, including transport infrastructure. Health is considered part of the environment and of the EIA processes, however the health assessment are implemented only partially (using a few environment risks to health) or, more frequently not implemented at all.

Health impact assessment

Health Impact Assessment (HIA) has been defined as “a means of assessing the health impacts of policies, plans and projects in diverse economic sectors using quantitative, qualitative and participatory techniques”. (WHO Regional Office for Europe, 1999). The HIA process is described in Figure 17.

While health impact assessment (HIA) is generally not legally mandated, it can be integrated with other impact assessments to predict the health impacts of different policy scenarios or projects. The underlying principles of HIA include sustainable development, equity (i.e. the distribution of health effects) and the ethical use of evidence (Joffe 2002, European Centre

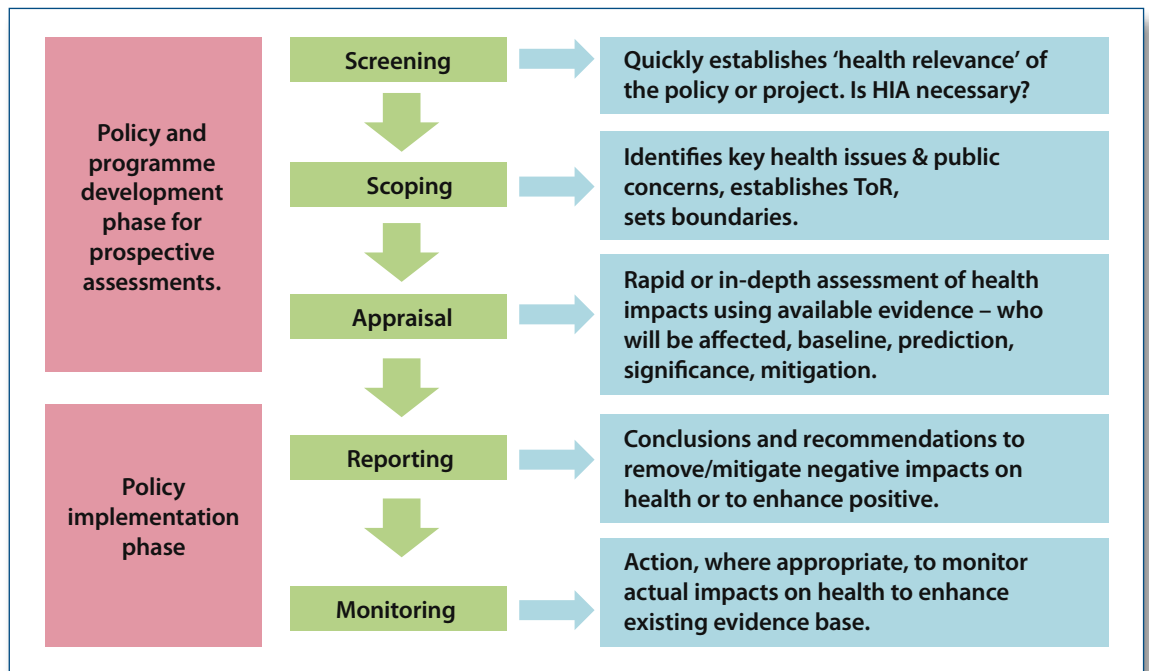


Figure 17
The health impact assessment (HIA) process.

Source: Based on WHO <http://www.who.int/hia/tools/en>

for Health Policy 1999). A particular emphasis of HIA is that views and concerns of diverse stakeholder groups are incorporated into the assessment process (Ness *et al.*, 2007).

In recent years, the integration of health impact assessment (HIA) into transport assessment has advanced, particularly in Europe (Dora and Racioppi 2003) and more recently in the USA (National Academy of Sciences 2011). For example, large infrastructure changes and highways were assessed by means of HIA in different contexts (*e.g.* East End Quality of Life Initiative 2001, Public Health Advisory Committee 2002). In the Netherlands two simulations were conducted that considered the impacts of 1) reduced speed limits and 2) a traffic diversion project to move traffic away from a very dense area to a lower-density one by building a new highway. Dannenberg *et al.*, (2008) have compiled a list of 27 US case studies. Websites maintained by the Transport, Health and Environment Pan-European Programme (<http://www.thepep.org>), co-sponsored by the World Health Organization and the United Nations Economic Commission for Europe (UNECE), as well as the WHO Health Impact Assessment gateway (<http://www.who.int/hia/en>) provide other general examples and guidance.

Qualitative tools

These tools include a set of very diverse methodologies that rely largely upon qualitative, descriptive evidence, rather than quantitative, statistical analysis. Evidence is gathered from: interviews, focus groups, field notes, videos and audio recordings, pictures and analysis of documents, and other forms of stakeholder testimony. In practice, qualitative tools are used where it is important to convey to policy-makers the perceptions, expectations and experiences of individuals, groups and organisations that may be affected by policies (Fitzpatrick and Boulton 1994).

Qualitative research can investigate the question of how evidence is turned into practice, and it can pursue systematically research questions that are not easily explored using quantitative tools or experimental methods (Green and Britten 1998). In recent years, qualitative assessment has increasingly challenged the dominance of

quantitative methods (Love *et al.*, 2005). Critics claim that over-reliance on quantitative impact assessment “may encourage policy-makers and others to attach more importance to those impacts that are easier to quantify but which do not necessarily have the greatest associated burden” (O’Connell and Hurley 2009). Essentially, both qualitative and quantitative methods provide useful information for assessment processes such as HIA.

Integrated analytical tools

Integrated tools connect different quantitative assessment methods (*e.g.* spatial models of dispersion of pollutants and epidemiological estimation of health impacts) within a modelling framework, in order to provide a more comprehensive and definitive measure of impacts. These tools represent a further refinement, and integration, of quantitative tools discussed at length elsewhere in the health and environment literature (see <http://www.who.int/heli>). These include burden of disease estimates, spatial measurements of pollutants and cost-benefit analysis. For example, an air pollution model might apply traffic modelling for different policy scenarios, with results passed through pollutant emission and dispersion models. This can yield estimates of population exposure and health impacts not only from average urban

Box 2: Geographical information systems

A geographical information system (GIS) is a procedure for linking together geographical information, such as the coordinates of a set of individuals in a defined area, to some data about events or characteristics linked to that location, such as the number of people killed in floods or hospitalised for respiratory outcomes in that area in a given period. Using GIS enables the different kinds of information for each time and place to be linked. Trends in exposure, modifying factors and disease outcomes in space and time can be mapped, and the linked data can be exported in a format that allows appropriate statistical analysis. This ensures that any correlations between the exposure data and the outcome data are drawn from the same place at the same time (Campbell-Lendrum *et al.*, 2003).

air pollution concentrations but also from exposures of particular population groups or particular neighbourhoods to that pollution as per its pattern of dispersion in the atmosphere (*e.g.* close to residential areas, close to transport routes). On the transport side, models using Geographical Information Systems (GIS) are often a key component of such integrated analytical tools. On the health side, epidemiological data, as represented by “years of life lost” analysis is important (see Box 2 and 3).

Much work is being done globally to assess the health impacts from different transport scenarios using integrated analytical tools. This may require several stages, or modelling layers,

whereby outputs from the first model comprise the inputs for the next stage. Construction of software tailored to the scenario in question may also be required.

Several challenges must be faced when integrating models. One challenge is ensuring that conventional transport models provide sufficient input data for the air pollution, physical activity and injury risk/exposure models to which they may be linked.

The problem is that conventional traffic simulation models generally represent only a limited part of a city’s street geography and travel. For instance car travel is fully represented in a traffic model, but travel by public transport may be incompletely represented, and pedestrian/cycle travel is often missing altogether. This means significant groups of “users” are invisible in the assessment. Integrating motor vehicle models with models of public transport travel (bus, tramway, metro and train networks) as well as models of pedestrian and bicyclist networks is critical, however, for comprehensive exposure assessment. Ensuring technical compatibility of the outputs of one model with inputs into the next model provides additional challenges.

Monitoring and evaluation – retrospective assessment

While most “impact assessment”, as such, is prospective, retrospective assessment can play an important role in transport and health assessment. Monitoring and evaluation tools support retrospective assessment by analyzing trends in transport and correlating those with environment and health trends and outcomes. Retrospective assessment may involve processes such as health impact assessment, and a range of quantitative and qualitative tools. However, routine and rigorous monitoring and evaluation can often be performed most efficiently through the use of standard indicators and indices (Ness *et al.*, 2007).

In the case of transport and health, progress towards healthy transport goals can be readily monitored and evaluated by collecting data on key transport and health indicators and analyzing patterns with respect to geographic locale, populations, and time sequences. Many transport trends (*e.g.* number of vehicles, paved

Box 3: The concept of Years of Life Lost (YLL)

Rationale for use

Years of life are lost (YLL) take into account the age at which deaths occur by giving greater weight to deaths at younger age and lower weight to deaths at older age.

Definition

YLL are calculated from the number of deaths multiplied by a standard life expectancy at the age at which death occurs. The standard life expectancy used for YLL at each age is the same for deaths in all regions of the world and is the same as that used for the calculation of Disability Adjusted Life Years (DALY). Additionally 3% time discounting and non-uniform age weights which give less weight to years lived at young and older ages were used as for the DALY. With nonuniform age weights and 3% discounting, a death in infancy corresponds to 33 YLL, and deaths at ages 5 to 20 to around 36 YLL.

Associated terms

The Disability Adjusted Life Year or DALY is a health gap measure that extends the concept of potential years of life lost due to premature death (PYLL) to include equivalent years of ‘healthy’ life lost by virtue of being in states of poor health or disability. DALYs for a disease or health condition are calculated as the sum of the years of life lost due to premature mortality (YLL) in the population and the years lost due to disability (YLD) for incident cases of the health condition.

Source: WHO

road surface) are carefully monitored at global, country and urban levels, making this a rich field of exploration. However, indicators of key transport-linked health and social well-being factors are often incomplete or missing from conventional reporting of key transport indicators by governments, industry and international agencies or banks (Litman 2007). Without those critical indicators, it may often be difficult to assess progress towards healthy transport goals.

For example, while vehicle traffic volumes are usually recorded and reported systematically, similar data on volumes of pedestrians/cyclists using the transport system is often not routinely collected by Transport Ministries. Similarly, data on vehicle crashes may be routinely collected by police, less so data on pedestrians injured or killed by vehicles. Infrastructure ministries may report upon kilometres of road paved annually; similar indicators for sidewalks or bike paths are slim to nonexistent in most developing countries and much of the developed world. Nor is data routinely collected on social well-being factors such as pedestrian traffic in correlation to crime or measures of neighbourhood cohesiveness. Consideration of health requires that essential data on transport-related human health and social factors, and not only vehicle data, be collected and monitored in a balanced transport indicator set (TRB 2008). Collecting and reporting indicator data allows public assessment of whether transport systems are moving in the right direction, whether progress is rapid enough and thus whether the right policy settings are in place.

Given the evidence that socioeconomically disadvantaged groups typically bear more of the burden of transport hazards and also have poorer access to current transport systems, the social distribution of transport effects should also be monitored as part of such health-oriented analysis.

One example of a formalised transport and environment indicator set is the Transport and Environment Reporting Mechanism (TERM) (EEA 2010a). The most recent TERM report assesses progress towards reducing greenhouse gas emissions, and finds that although vehicle efficiency is improving, growth in travel means

that total transport-related greenhouse gas emissions continue to rise. However, while TERM assesses progress on environmental outcomes including greenhouse gas emissions, air quality and noise, other important health outcomes such as road traffic injury and physical activity are not considered.

While a number of transport and health indicator sets have been developed or proposed by individual agencies, researchers or institutions, these are usually quite large, often including more than 30 indicators; and no single set has been systematically implemented. To achieve this, there is a need to identify briefer, more manageable sets of core indicators (Borken 2003).

While TERM provides a promising example of transport and environment system monitoring for Europe, low- and middle-income countries require different monitoring approaches due to their differing levels of resources available for data collection. One possible solution would be to implement a standard set of surveys collecting information on a limited set of the most key factors, *e.g.* modal split, pedestrian/cycle injuries, and other health risks and outcomes, for statistically significant samples in key urban areas and/or for different population groups. This would help monitor key transport and health links, and enrich analysis of actual and expected impacts of policy changes on public health.

SUTP Technical Document Nr. 7 – Review of Sustainable Transport Evaluation

On behalf of the Federal Ministry for Environment, Nature Conservation and Nuclear Safety (BMU), GIZ has reviewed existing assessment and indicator schemes for sustainability in the transport sector to determine which are most appropriate for sustainable transport planning and policy purposes on an international level. The study outlines options for choosing appropriate indicators and evaluation tools, encompassing environmental, social, economic and governance-related dimensions. It also summarises the benefits of an evaluation scheme not only for national and local governments, but also for donors and the scientific community. The document is available for download at <http://www.sutp.org>.

3.2.3 Applying qualitative and quantitative tools – case studies and examples

This section provides further case study examples in the application of various tools. Many different applications are possible, ranging from simple to very complex exercises, and ranging from urban to international levels. Particular emphasis is given to case studies of integrative analytical tools, which are summarised in Table 5; examples of qualitative tool use are also provided. As noted previously, both types of tools can contribute to a successful health impact assessment process.

Integrative analytical and quantitative tools

HEARTS

The WHO project entitled Health Effects and Risks of Transport Systems (HEARTS) (WHO – Regional Office for Europe 2006) is a project that includes three case studies to test models for quantitatively assessing effects of different urban land use and transport policies on human health.

One of the three case studies was undertaken in Florence, Italy. This assessed the effects of a new transport plan, which included new tram lines, parking facilities at the terminus of tram lines, use of railways for urban transport, rearrangement of the urban bus network, new connecting roads within the metropolitan area, a new ring road to the north and increased highway traffic capacity. In addition, the consequences of changing the fleet composition (*i.e.* improved vehicle technology) were considered.

Scenarios were constructed for the existing transport network compared with the new transport network, for the existing vehicle fleet compared with the improved vehicle fleet, and for combined changes in both transport network and vehicle fleet. Based on geo-coded traffic modelling results, a chain of different models was implemented, including a noise pollution model, an emission model for traffic air pollutants and air dispersion and exposure models. Air pollution modelling was undertaken using AirQ, a simple software tool designed to assess health impacts of air pollution in a specified population using a methodology developed

by WHO. A similar tool is the Fast Environmental Regulatory Evaluation Tool (FERET) developed by Carnegie-Mellon University and the University of Washington, which includes a cost-benefit analysis component (Farrow *et al.*, 2001).

Emission scenarios for the HEARTS simulation identified improvements in the transport network and the vehicle fleet, compared with the 2003 reference scenario, and estimated a reduction of 129 deaths, 596 acute bronchitis cases (aged <15 years), 5 869 restricted-activity days (aged 15–64 years) and 1 400 years of life lost per year.

Health Economic Assessment Tool (HEAT)

The Health Economic Assessment Tool (HEAT) for cycling developed by WHO estimates the economic value of reduced mortality from cycling. For further details about the tool see Box 5 in Section 3.3.1.

Urban Outdoor Air Pollution Database

The Urban Outdoor Air Pollution Database, developed by WHO, is the most comprehensive compilation of air pollution levels measured in particulate matter (PM₁₀ and PM_{2.5}). The database contains measured data for more than 1 000 cities representing more than one third of the world's urban population. The database aims to be representative for human exposure, and therefore primarily captures measurements from monitoring stations located in urban background, urban traffic, residential, commercial and mixed areas (WHO 2011b). This database is also underlying the latest estimates of disease burden caused by urban outdoor air pollution.

Estimates of disease burden from urban outdoor air pollution

The air pollution data of the WHO Urban Outdoor Air Pollution Database was linked to validated epidemiological models that reflect excess mortality due to increased concentrations of small particulate exposure in urban areas. All in all, the WHO exercise found that an estimated 800 000 premature deaths in the year 2000 and 1.3 million premature deaths in the year 2008 were due to excessive particulate air-pollution related exposures. The findings, in cities of over

100 000 people, include about 5 % of mortality attributable to cardiopulmonary disease in adults, about 9 % of mortality attributable to cancers of the trachea, bronchus and lung, and about 1 % of mortality attributable to acute respiratory infections (WHO 2009a; Cohen *et al.*, 2004).

Box 4: Netherlands: Scenario modelling of the health benefits of modal shift from car to bicycle

Hypothetical scenarios based on national statistics can offer interesting insights into the expected health impacts of modal shift to active travel (de Hartog *et al.*, 2010). For the individuals who shift from car to bicycle, it was estimated that beneficial effects of increased physical activity are substantially larger (with estimates ranging from

3 to 14 months of life gained) than the potential mortality effect of increased inhaled air pollution doses (0.8 to 40 days lost) and the increase in traffic crashes (5 to 9 days lost). Societal benefits were even larger due to a modest reduction in air pollution and greenhouse gas emissions and traffic crashes.



Figure 18a/b
Evidence from the Netherlands points at the potential benefits of increased physical activities: Cycleways in Amsterdam (left) and Nijmegen (right).

Photos by Andrea Broaddus, Amsterdam, Netherlands, 2007 (left) and Jeroen Buis, Nijmegen, Netherlands, 2007 (right)

Table 5: Summary of case studies applying integrative analytical tools

Area (study)	Description of case study	Scale and/or parameters	Population	Policy and scenarios modelled	Tool	Outcomes
Florence urban planning impacts (HEARTS)	Integrated modelling within a geographical information system (GIS) of exposures to PM _{2.5} . Measures and elemental analysis of PM _{2.5} samples.	Urban: the Florence municipality	Whole adult population in observed area (about 190 000).	Application to the existing and planned transport scenarios by the Florence municipality in 2010.	Integrated modelling system by loose-coupling the various models within a GIS.	<ul style="list-style-type: none"> ■ Mortality (aged ≥30 years, excluding accidental causes) long-term. ■ Acute bronchitis (aged <15 years). ■ Restricted-activity days (aged 15–64 years). ■ Years of life lost.
Netherlands modal shift	Study of health effects of modal shift from car to bicycle in terms of decreased air pollution emissions, greenhouse gas emissions and increased levels of physical activity; and risk of traffic injury.	National	Modelled population of 500 000 people (18–64 years of age).	Hypothetical scenario, based on Netherlands statistics, involving shift from car to bicycle for short trips on a daily basis in the Netherlands.	Integration of the literature for air pollution, traffic accidents and physical activity using systematic reviews supplemented with recent key studies.	<ul style="list-style-type: none"> ■ Quantification of the impact on all-cause mortality in terms of life years gained or lost, using life table calculations.
New Zealand modal shift (HEAT)	The University of Auckland, New Zealand, used HEAT for cycling to estimate changes in mortality associated with 1000 additional adult (ages 20–64) regular urban commuter cyclists.	National	Adults	What if 1000 additional adult (ages 20–64) become regular urban commuter cyclists.	HEAT	<ul style="list-style-type: none"> ■ A reduction in mortality of 17.5 % estimated. Annual savings of NZD 765 000.

Area (study)	Description of case study	Scale and/or parameters	Population	Policy and scenarios modelled	Tool	Outcomes
Europe emissions impacts (CAFE)	Quantification and economic valuation of the health impacts of ozone and particulate matter for cost-benefit analysis (CBA) being undertaken as part of the Clean Air For Europe (CAFE) program. Results are based on modelling a uniform relative reduction in emissions of each pollutant within each country. As such, they represent something of an average of damages between rural and urban emissions.	Continental (EU 25) and national	Whole population, approx. 450 million.	The analysis takes as its starting point pollution data generated by the EMEP and RAINS models for baseline conditions, and uses the CAFE CBA methods. It assesses the state of the environment in 2000 and 2020, and looks at benefits of current policies over this period.	Use of values in terms of the value of a statistical life (VSL) and, either directly or through computational analysis, the value of a life year (VOLY). The CAFE CBA methodology is only applicable for assessing the changes between scenarios, i.e. marginal policy changes.	<ul style="list-style-type: none"> ■ Chronic mortality from PM among those aged over 30 ■ Infant mortality from PM ■ Acute mortality from ozone in the general population ■ Morbidity from PM and ozone ■ Valuation of mortality among adults and in the general population ■ Valuation of infant mortality ■ Valuation of morbidity impacts ■ VSL ■ VOLY
Global urban air pollution (GMAPS)	Application of the Global Model of Ambient Particulates (GMAPS) designed to obtain the best city-level prediction of concentrations of PM for a wide range of cities on the basis of the limited amount of data from monitoring available. Model-based estimates used to estimate burden of disease.	Global and sub-continental	Data were modelled for 3 211 national capitals and cities with populations of >100 000 (around 559 million, or about 28 % of the global urban population).	Ten scenarios were built, including a base-case scenario.	If no data are available for the cities or countries under study, it is possible to model estimates of annual PM ₁₀ and PM _{2.5} concentrations using: <ol style="list-style-type: none"> 1) energy consumption, 2) atmospheric and geographical factors, 3) city and national population density, 4) local urban population density, 5) local intensity of economic activity, 6) national income per capita, 7) time trends, 8) binary variable for each country. 	<ul style="list-style-type: none"> ■ Numbers of attributable deaths ■ Years of life lost (YLL) for adults and children (aged 0–4 years)

Source: Kahmeier et al., 2010; Dannenberg et al., 2008; de Hartog et al., 2010

Qualitative tools

Examples of the use of qualitative tools in the appraisal of transport projects are summarised in Table 6, and include SWOT (strengths, weaknesses, opportunities and threats) analysis, scores and weights, and DELPHI (EU 2009b).

Table 6: Examples of qualitative tools used for transport projects

Case	Tool
Strategic overview of transport issues for the Republic of Ireland	SWOT
“Corridor Ranking Framework” in Greece, Ireland and Portugal	Scores and weights
Forecasting the development of transport telematics technologies (in the year 2015 in medium-size European cities)	DELPHI
Appraisal of central Asian transport projects	Small sample surveys of road users

Source and further information: http://ec.europa.eu/regional_policy/sources/docgener/evaluation/evalsed/sourcebooks/themes_policy/policy/transport/approaches_en.htm.

3.2.4 Modelling greenhouse gas emissions and health

Emissions modelling tools that have been developed to assist transport decision-makers can simultaneously address health and climate change impacts. For example, models that employ “back-casting” methods enable policy-makers to estimate the scale of the measures required to reach a given emission reduction target, to assess the relative impacts of different components of policy “packages”, and clearly indicate whether or not targets will be met based on existing policy settings.

A 2009 study used models to estimate in more detail the health outcomes related to physical activity, air pollution and road traffic injury from different mitigation policies for the transport sector. This allowed emissions and health impacts to be concurrently estimated, and indicated that emissions reductions from vehicle fuel efficiency measures were associated with smaller health gains than emissions reductions from modal shift towards active transport. This finding held for very different settings such as London and Delhi (Woodcock *et al.*, 2009).

Health and emissions outcomes were concurrently examined by a study that examined a scenario of United Kingdom consumers switching from petrol to diesel cars. Although this switch was estimated to reduce carbon dioxide emissions by 7Mt, adverse effects on air quality

(from increased emissions of small particles associated with diesel fuel) were predicted to result in 90 additional deaths annually (range 20–300) (Mazzi and Dowlatabadi 2007).

To date, researchers have gained more experience modelling the health impacts of transport in European and North American settings. However, these models can also be adapted for developing countries, as illustrated by the study of Delhi in Woodcock *et al.*, (2009). While lack of data may be a particular barrier in some developing countries, useful effect estimates may still be generated either by initiating new data collection where needed or by making assumptions based on the data available. Incomplete data are also a common problem in developed-country settings. Ensuring that sufficient modelling skills are available in developing countries could require workforce development as well as building international partnerships with centres with established modelling expertise.

Increasing the extent to which health outcomes are robustly incorporated alongside emissions in the outputs of transport models is thus a useful strategy for promoting healthy transport and land use policies. Given the wide range of available methods for estimating the health impacts of transport, many of which have been discussed here, transport scenarios should routinely be assessed for both health and emissions

outcomes. Doing so would help ensure that mitigation strategies with the greatest co-benefits are preferentially selected by policy-makers.

3.3 Economic mechanisms

3.3.1 Health in the economic evaluation of transport systems

Economic evaluation, particularly cost-benefit assessment (CBA), is commonly used to inform transport investment decisions by governments. However, most CBA applications in the transport sector remain focused on economic evaluation of proposed road projects, without reference to alternative modes of development. Such CBAs assessments typically analyse factors such as savings in vehicle operating costs (VOCs) and economic savings resulting from reduced travel times on particular road segments. They often underestimate, or fail to consider, the full range of health impacts that may emerge from road development over time, particularly in comparison to alternatives that emphasise more investment in mixed modes and modal shift to rail/bus modes, cycling and walking.

There are a number of standardised cost-benefit assessment tools used by a wide range of international development agencies to guide international transport investment decisions. One example is the HDM-4 (Highway Development and Management-4), which is sponsored by the World Bank, the UK Overseas Development Administration/Department for International Development (ODA/DFID), Asian Development Bank, Swedish National Road Administration, along with the World Road Association and the Inter-American Federation of Cement Producers (World Bank, 2011). Recent versions of this tool have been adapted to consider limited environmental and health (*e.g.* accident) impacts. However the full spectrum of changes in land use and transport mode choices are yet to be fully considered by any single standardised transport modelling tool, particularly with respect to health costs/benefits in terms of injuries, air pollution, access, physical activity, non-motorised travel, etc.

For instance, expanding road capacity may reduce traffic congestion in the first years of the road's operation, saving time and vehicle operating costs. However, in doing so, it also

stimulates additional vehicle travel, known as induced travel. Induced travel can lead to future indirect health impacts that are not fully measured, such as increased pollution over time, increased reliance upon private car travel, reduced efficiency of public transport systems, barriers to walking and cycling, and reductions in physical activity.

The land use impacts of transport development also have health impacts that require consideration in economic assessment. Per passenger-km of travel, roads require far more urban space than transit. Land used by roads will not be available for other health-promoting uses such as green spaces or public services. Over time, road and car-oriented investments also tend to reduce urban densities, reduce mixed-use development and promote street design that discourages walking and cycling, and thus physical activity.

In contrast, investments in public transport infrastructure can free up more space for parks and walking/cycle infrastructure and support more compact, accessible cities. These land use effects on health are not typically considered in the evaluation of transport projects, though some methods for incorporating these effects in transport planning do exist (VTPI 2010a). CBA that does not fully account for induced travel and the land use impacts of transport projects tends to ignore many important transport-related health impacts, and to favour car-oriented transport planning over non-motorised travel. This is a major gap in policy assessment, with far-reaching implications for transport investments, requiring greater attention by national ministries, development agencies and multi-lateral development banks.

Recognising these challenges, the World Bank recently developed initial guidance for more inclusive, multi-modal assessment of urban transport investments (World Bank, 2008). However such guidance recognises the continuing barriers to investment decisions based on economic evaluation using standard tools: “Because funding for strategic roads and rapid transit systems tends to come through different institutional channels, evaluation studies most often look at uni-modal sets of options”. (World Bank, 2008)

Also, the report notes, public transport infrastructures, particularly rail, typically are much more complex and costly public sector undertakings, as compared to roads. Rail and transit infrastructures require a larger dimension of continuing public sector involvement in their operation, as well as public subsidy of capital and operating costs not covered by ticket fares. Such support for public transit's operation can be readily generated through a "virtuous" tax cycle of dedicated vehicle fuel and parking taxes – but that requires policymaker recognition of

the full range of benefits from a transit investment (see also Section 3.3.2).

A full-cost accounting of health costs of transport alternatives can help ensure that transit projects are reviewed in light of their true economic rate of return over time. Along with the urban transport issues discussed here, multi-modal assessment of rural and interurban transport options in developing countries also needs closer consideration. Here, too, the split between road and rail passenger and freight travel may have far-reaching impacts on rural

Box 5: Health Economic Assessment Tool (HEAT) for cycling

Investments in road transport infrastructure are traditionally assessed in terms of vehicle operating costs and time saved in vehicle travel. However, the health factor as noted in Chapter 3.2 is often neglected. Recently, a number of validated models have been developed that quantify, monitor and evaluate the financial return of investments in cycling infrastructure, in terms of health benefits obtained. The Health Economic Assessment Tools (HEAT) for walking and cycling is one such tool, offering transport planners an easy-to-use tool means of assessing economic benefits from reduced mortality due to increased physical activity from walking and cycling. This tool, consisting of a user-friendly spreadsheet (Figure 19), can be used to evaluate current levels of walking and

cycling or to assess the impact of a transport intervention that is expected to change current levels. What is needed is mainstream integration of such tools into standard CBA processes for transport evaluation.

One HEAT case study in New Zealand has been included in Table 5. Another example of HEAT application from Austria estimated that the 412 lives are saved due to current levels of cycling, which has a modal share of 5% of all travel. This is due to mortality reductions associated with increased physical activity, and is equivalent to EUR 405 million in monetary terms. Achieving the national goal of 10% cycling share would increase lives saved to 824 annually, for an annual benefit of EUR 812 million (Kahlmeier *et al.*, 2010).

Health Economic Assessment Tool for Cycling

Fill in the two fields in Step 1 with your values and read the corresponding results in Step 3. You can use the default parameters supplied in Step 2 or adjust them according to your needs. The population parameters used to calculate the results are displayed at the bottom of the sheet.

Step 1: enter your data (all users must fill in the red fields)

Number of trips per day	300,000
Mean trip length (km)	3.2

Step 2: check the parameters

Mean number of days cycled per year	124
Proportion of trips that are one part of a return journey (or 'round trip')	0.9
Proportion undertaken by people who would not otherwise cycle	0.5
Mean proportion of working age population who die each year	0.005847
Value of life (in Euros)	EUR 1,509,000
Discount rate	5.0%

Step 3: read the economic savings resulting from reduced mortality

Maximum annual benefit	EUR 101,015,000
Savings per km cycled per individual cyclist per year	EUR 0.81
Savings per individual cyclist per year	EUR 612
Savings per trip	EUR 2.72
Mean annual benefit:	EUR 75,256,000
Present value of mean annual benefit:	EUR 54,801,000

Based on:
 5% discount rate
 5 year build-up of benefit and 1 year build-up of uptake, averaged over 10 years

Population parameters used to calculate results

Population that stands to benefit	82500
Mean proportion of working age population who die each year	0.005847
Expected deaths in the local population	482.35
Protective benefit, according to actual distance traveled	0.14
Lives saved	67.34

Notes on how to use this tool. For additional instructions, hold the mouse over any red triangle.

How many trips are observed (or are estimated) on the specific route; across a city; or on a network, in any direction?

What is the mean trip length (estimated or measured)?

The default parameters in green are based on best available evidence and are to be changed only if local data available.

The estimated number of days per year that people cycle

What proportion of these observed cyclists do you expect will also be making a return trip later in the day?

Proportion of these cyclists that are new users DIRECTLY as a result of the new infrastructure or policy

See local parameters page for explanation.

What is the standard value of a statistical life used in the country of study?

Discount rate used for future benefits. This is only used for the 'Present value of mean annual benefits'; see step 3.

Click here to change local parameters

Click here to view underlying study parameters

Total value of lives saved (mortality only) assuming 'steady state' of health benefits achieved

This value takes the likely build up of benefit into account (see below)

This value uses the discount rate from section two to calculate the present value, taking inflation into account

Click here to change the timeframe used in calculation

Click here to view full calculation, graphs and adjust error

Reset all default values

Based on number of individual cyclists calculated from data in steps 1 and 2

This reflects the relative risk of all cause mortality in the age groups that are most likely to cycle

Yearly deaths expected among the population of cyclists (assuming they are aged 25-64)

Relative risk of death among cyclists, adjusted for the actual distance cycled (assuming regular trips per year)

Reduction in number of deaths expected due to the modelled increase in cycling

Figure 19
 Health Economic Assessment Tool (HEAT) for cycling.
 More information:
<http://www.euro.who.int/HEAT>

development and health, rural sprawl, equity, pollution and greenhouse gas emissions. It is thus critical that conventional economic assessment of road development generally be integrated with the best available models for health assessment of transport to account more inclusively for the economic costs and benefits of the full range of health impacts emerging from different transport modes and development scenarios (VTPI 2011a).

3.3.2 Transport pricing measures

There is a large body of literature discussing both the environmental and the travel impacts of fuel and congestion pricing (*e.g.* Goodwin *et al.*, 2004, Sterner 2007, Kim *et al.*, 2011, Seik 1997, World Transport Policy and Practice 1999, ADVA Center 1999, Royal Commission on Environmental Pollution 1994). Reviews of the direct impacts of pricing strategies on health are more limited. However, in cities at comparable stages of development, higher fuel prices are typically associated with comparatively less motor vehicle travel and more travel by alternative public transport, walking/cycling modes (Rashad 2009; World Transport Policy and Practice 1999; Royal Commission on Environmental Pollution 1994).

In one study, a 20% increase in fuel prices was estimated to lead to reductions in mortality

from road traffic injury and air pollution (Leigh and Geraghty 2008). In another study, it was estimated that 'optimum' transport pricing would reduce road traffic injury mortality by about half (VTPI 2011b). Lower levels of obesity have also been associated with higher fuel prices (Rabin *et al.*, 2007). In general, pricing policies that provide incentives for travel by modes other than motor vehicles are regarded as having the potential to both reduce health risks as well as greenhouse gas emissions (Pew Center on Global Climate Change 2003).

Fuel taxes as a pricing tool are often both politically lucrative and controversial. In rapidly motorising developing countries fuel taxes may represent a considerable source of government revenue. Fuel taxes may also quickly become the object of populist protest if fuel prices rise sharply and unexpectedly. Nonetheless, dedicating a significant proportion of fuel tax income to sustainable transport modes, including public transport, walking and cycling infrastructure, has been described as one of the most effective ways for developing countries to self-finance healthy and sustainable transport improvements (World Bank, 2008). Doing so recognises the "polluter pays" principle of sustainability, and promotes equity by investing taxes on alternative travel modes that benefit society widely as well as improving the health and mobility of groups least able to afford motor vehicles.

Downtown and highway congestion charging is another common measure used to manage traffic more sustainably. Studies of congestion charging have concluded with mixed results. One study of congestion charging effects in London and Stockholm concluded that there had been relatively small city-wide reductions in air pollution-related mortality that were greatest inside the charging zone (Tonne *et al.*, 2008, Eliasson *et al.*, 2009).

Another pricing approach provides incentives for the use of improved vehicles and fuels. This will reduce air pollution, but will not likely influence other transport-related health risks such as physical inactivity. In some cases, incentives for improved vehicles and fuels could, even increase motorised travel, whereas raising the price of undesirable vehicles or fuels would, in principle, be more likely to decrease overall motorised travel.

Box 6: Clean Air for Europe (CAFE)

The CAFE program is an example of a region-wide assessment of the economic costs and benefits, including health benefits, of potential measures for improving air quality in Europe (for EU-25 countries). In the year 2000, CAFE estimates found that the annual impacts of air pollution amounted to 3.7 million years of life lost (YLL) each year, equivalent to 348 000 premature deaths. Particulate matter (PM) exposure was also responsible for 700 infant deaths per year. These estimated health damages for 2000 were estimated to correspond to 3% to 10% of EU-25 GDP (based on low and high damage estimates). The estimated health benefits of implementing current European air quality legislation up to 2020 were valued at between EUR 87–181 billion per year, which translated into an average benefit of between EUR 191 and EUR 397 per person per year (EU 2005).

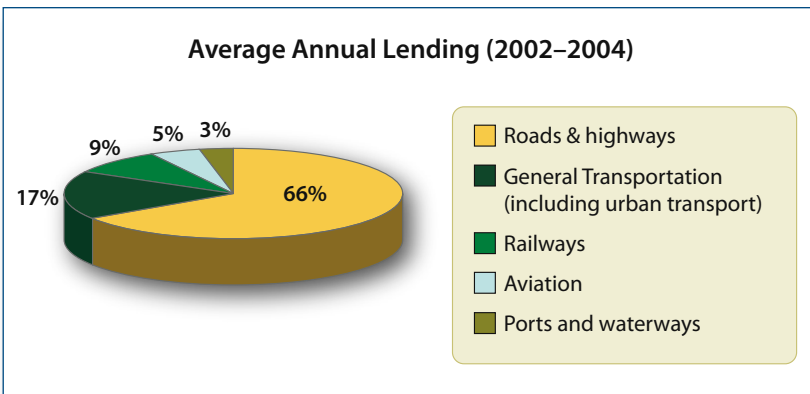
In summary, the health effects of a pricing strategy are likely to be strongly dependent on the way the pricing strategy is designed, what aspect of the system it targets for taxation and what aspect for incentivisation.

3.3.3 International financial mechanisms

The availability of international finance for different types of transport projects has an important influence on trends in infrastructure development globally, especially in developing countries. Such finance, while it may be supplementary or “packaged” with private and national financial backing, can make the difference between a feasible or unfeasible project, and also sends an important market signal in terms of trends in lending for new infrastructure development overall.

Figure 20
World Bank transport lending by type, 2002–2004.

Source: World Bank 2005a



This section examines the extent to which health co-benefits are considered in the financing of transport projects, and the methods used for that purpose, in two types of International financing mechanisms: the clean development mechanism (CDM) available via the United Nations Framework Convention on Climate Change (UNFCCC); and financing available through international development finance institutions (in this case, the World Bank). Further in-depth consideration of financing mechanisms is considered by the UNEP Green Economy report (UNEP 2010).

International development funding

Many international development financial mechanisms are available for transport infrastructure lending. For example, lending from the World Bank has historically focused on road infrastructure that served primarily transport by truck freight and private motorised vehicles (Figure 20). Low-carbon transport modes, in particular rail and urban transport schemes with mixed bus rapid transit (BRT)/rail/bus and walking/cycling systems that have greater health co-benefits have received far less emphasis.

More recently, the World Bank has created policy frameworks and guidance that emphasise urban transport design of healthier and more sustainable modes, including modal shifts to walking/cycling and public transport (World Bank, 2008). However, the extent to which these new guidelines will shift overall funding priorities is yet to be determined.

The most recent available data (Figure 21) reflects an increase in World Bank lending for “general transport” projects. This category typically includes, but is not limited to, urban transport projects such as bus rapid transit, light rail, and active transport.

More explicit and precise reporting on transport lending by modal type, particularly for urban and interurban rail, BRT and walking/cycling would allow better evaluation of key trends in international finance for transport, and how

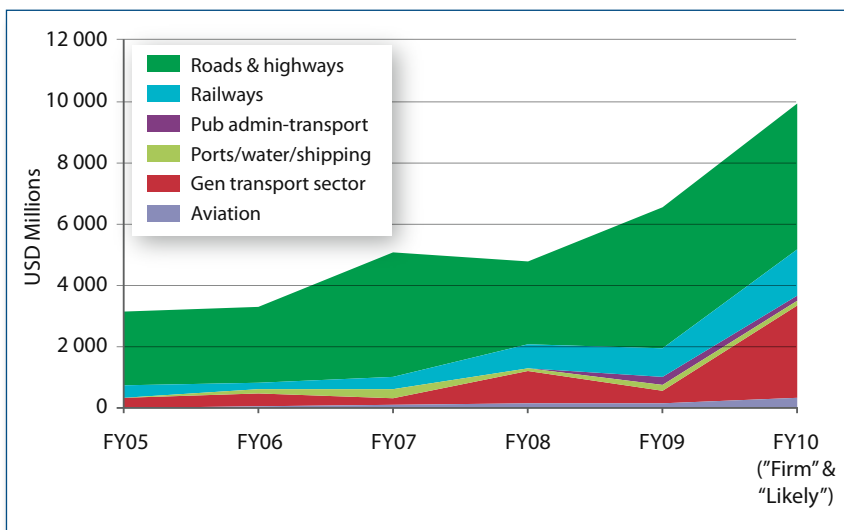


Figure 21
World Bank transport lending trends, 2005–2010. FY: fiscal year.

Source: World Bank, 2011

those trends are contributing to health, sustainability and carbon footprints.

Clean Development Mechanism

The Clean Development Mechanism (CDM) is a financial mechanism that allows high-income countries that have committed under the Kyoto Protocol to reduce GHG emissions, to do so through investing in projects that reduce emissions in low- and middle-income countries. This is intended to allow emission reductions to occur where they are less costly.

One example has been the TransMilenio system in Bogotá, which has been registered as a CDM project by the UNFCCC, and as a result is expected to receive as much as USD 350 million from the sale of emission credits by the year 2026 (Grütter 2007). This example demonstrates how CDM can facilitate the implementation of projects such as mass transit systems that can reduce emissions and improve health by making them more financially attractive. Encouraging greater application of CDM for such projects could be one useful strategy to foster transport systems that reduce GHG emissions and increase health co-benefits.

While many CDM projects may improve health, the presence or absence of health co-benefits does not currently affect CDM qualification criteria or subsequent revenues, which are calculated solely on greenhouse gas emissions. In the

case of transport, this is a particular gap in the CDM process, given the great opportunities for health co-benefits.

Paradoxically, projects that involve shifts to less “travel-intensive” forms of land use together with shifts to carbon-neutral, active transport may be highly efficient mitigation measures with important health co-benefits, but may be less attractive as CDM projects since “compliance” and “outputs” may be difficult to measure in currently accepted frameworks.

Revision of CDM protocols to estimate such health co-benefits from transport mitigation, and to consider them in the project qualification and financing process, would increase incentives for healthy transport initiatives.

3.4 Governance frameworks and mechanisms for transport, environment and health

This section describes some of the processes and mechanisms that may be used to support healthy and sustainable transport policies. The experience of Europe, which has a long record of policy action on sustainable transport, is used here as illustration.

Beginning in the mid-1980s, growing awareness in Europe about health and environment led to the convening of the First European Ministerial Conference on Environment and Health (in

Figure 22a/b
One of the first transport projects to be registered under the CDM mechanism is the TransMilenio BRT system in Bogotá.

Photos by GIZ, Bogotá, Colombia, 2007



1989). Out of the first Ministerial conference, a *European Environment and Health Committee* was created to support and facilitate what is still an ongoing European environment and health process, including regular ministerial meetings every five years. The *EEHC* is a multi-stakeholder committee including health and environment ministries, WHO, European Commission, UNEP, OECD and UNECE.

The European Environment and Health Committee's first activity was a state of the art review of environment, development and health issues in Europe. The review, *Concern for Europe's Tomorrow* (WHO 1994), clarified how different sectors of the economy, including transport, were key affecting health and environment, and identified effective interventions.

This review led to a series of regional meetings and discussions culminating in a *European Charter on Transport, Environment and Health*, which was adopted at the Third Ministerial Conference on Environment and Health in London in 1999. The Charter described the costs of unsustainable transport to health and environment, reviewed actions so far, and proposed a way forward for more integrated policies that included:

- 1) A framework of principles and approaches for transport sustainable for health and environment, including the “polluter pays” principle, “integrated decision making across the sectors”, “public participation”; “access to information”, and “precaution and prevention”.
- 2) Policies that would be pursued, including a reduction of the need for motorised transport, a shift towards healthy and clean modes of transport.
- 3) Tools for selecting transport policies with best results, including the use of health and environment impact assessments, of indicators and monitoring.
- 4) Environmental health targets for transport, including a reduction in diseases and deaths attributed to transport-related air pollution, road traffic injuries, noise and lack of physical activity.

The three sectors cooperated through a working group and identified ways to implement the Charter objectives, through a series of discussions involving governments, NGOs and

international organisations. It was agreed to implement a program of joint action. This joint program became known as the *Transport Health and Environment Pan European Programme* (The PEP).

The Transport Health and Environment Pan European Programme (The PEP)

The Transport Health and Environment Pan European Programme (THE PEP) was established in 2002 at the Second High Level Meeting of Ministers of Transport, Health and Environment. It pools capacities and skills from Europe, Caucasus, Central Asia and North America, translating national policy into local action. It offers a unique tri-partite platform for countries to share information and know-how and benefit from experience. It has the support from the World Health Organization Regional Office for Europe and the United Nations Economic Commission for Europe, which facilitate effective use of resources and coordination at the national and international levels. THE PEP provides a policy framework around four priorities:

- Investment in environment- and health-friendly transport;
- Sustainable mobility and more efficient transport systems;
- Reduction of emissions of transport-related greenhouse gases, air pollutants and noise; and
- Promotion of policies and actions conducive to healthy and safe modes of transport.

THE PEP promotes the development of more comprehensive approaches to consider the health and environment implications of transport policies and interventions. Support is given to countries, regions and cities through the provision of expertise and joint projects from across the region (THE PEP Partnership), exchange of experience and good practice (THE PEP Toolbox and THE PEP Clearing House) and national and local workshops on policy integration and healthy and safe urban walking and cycling (THE PEP relay race). Special attention is given to the needs of the eastern, south-eastern European and central Asian countries, as well as to particularly environmentally sensitive areas.

Although THE PEP is not legally-binding and depends entirely on voluntary donations it has been successful in bringing together the three sectors at the international, national and local level and continues to raise the awareness of the issues. It has proven to be a useful framework for implementing international commitments at national as well as local levels. For more information: <http://www.thepep.org>.

Box 7: THE PEP tools and activities

THE PEP Toolbox

The Healthy Transport website (THE PEP-toolbox) was developed to help policymakers and local professionals solve transport problems that affect health and the environment. In addition to tools and promising practices, it contains policy briefs on selected topics and provides access to information from relevant sources. It also provides guidance on transport-related health impacts and sustainable solutions with a focus on issues such as road-traffic injuries, air pollution, noise, climate change and physical activity. More information: <http://www.healthytransport.com>

THE PEP relay race

THE PEP organises regular workshops on integrating health and environment in transport policy making at national, regional and local level and on promoting safe and healthy walking and cycling in urban areas. As such, these workshops encourage cooperation between authorities, industry and civil society and pay special attention to national or local conditions. Experience from neighbouring countries and cities from across the region inform these workshops and help introduce long-term changes. Recent workshops included Prohunice (Czech Republic), Skopje (The former Yugoslav Republic of Macedonia) and Batumi (Georgia).

4. Good practices

4.1 Principles of healthy transport

The literature discussed earlier in this report suggests that higher density and diversity of land use in urban areas is associated with positive outcomes including more active transport, more physical activity and reduced obesity. Promotion of walking, cycling and public transport, such as by providing better infrastructure for these modes, is also associated with more active transport and physical activity. Conversely, car use is not only less active but also poses hazards to other travellers, and moderating these hazards is especially important in cities with high population density and more vulnerable road users such as walkers and cyclists. These strategies, which aim to concurrently achieve health, transport and climate goals, are summarised in Table 7.

Several of these strategies act through the pathway of reducing vehicle kilometres travelled (VKT). Reducing VKT can lower emissions of air pollutants and of noise. Lower VKT is also associated with fewer road traffic injuries, although mode shift from car use to walking and cycling needs to be accompanied by measures to improve safety for users of these vulnerable modes.

Improving access by walking, cycling and public transport can reduce greenhouse gas emissions associated with people accessing essential goods, services and other requirements for health and well-being. Travel by these modes is also more physically active, and provides more opportunities for social interaction than car use. Enabling access by these modes is more equitable, especially for low-income groups who lack access to a car.

Increased residential density has the potential to increase proximity to potential destinations, and thus improve access while reducing the need for private motorised transport. However, to maximise benefits, densification of housing needs to be matched by increased density of key destinations such as health and social services, education and employment opportunities, transit nodes and green spaces. Densification can also bring people in closer proximity to

the hazards of motorised transport, making it important that dense cities adopt measures to moderate these hazards. These include reducing speed, increasing the separation of vehicles from walkers and cyclists, and improving vehicle technology to reduce the emissions of air pollutants and noise per vehicle. Reducing these hazards can also remove safety barriers to walking and cycling – facilitating a shift to these healthy, climate-friendly modes.

While there is increasing evidence that better land use planning, increasing walking and cycling, and mode shift from cars to public transportation are all likely to lead to improvements in some domains of health, the most effective strategies for achieving these goals are not always clear. For example, a systematic

review of strategies to promote active travel to work and school found that the evidence that the selected strategies were effective at achieving mode shift was very limited (Hosking *et al.*, 2010). Effective strategies for reorganising land use may be even more challenging to identify. However, the effectiveness of some other relevant measures, such as 30 km/h zones and traffic calming for reducing vehicle speeds and injuries, is much clearer (Bunn *et al.*, 2003, Grundy *et al.*, 2009). A systematic review has also identified some effective interventions to promote cycling, including infrastructure improvements (Yang *et al.*, 2010). Economic measures such as fuel pricing, parking charges and pay-as-you-drive pricing may also help encourage mode shift (VTPI 2010d).

Table 7: 'Win-win' transport strategies to maximise health and climate gains

Strategy	Key pathways
1. Land use systems that increase density and diversity of uses;	<ul style="list-style-type: none"> ■ Increases proximity of destinations, reducing need for car travel and reducing VKT; ■ Improves access by walking, cycling and rapid transit/public transport;
2. Investment in and provision of transport network space for pedestrian and cycle infrastructure;	<ul style="list-style-type: none"> ■ Improves access by walking and cycling; ■ Encourages shift from car use to walking and cycling, reducing VKT;
3. Investment in and provision of transport network space for rapid transit/public transport infrastructure;	<ul style="list-style-type: none"> ■ Improves access by rapid transit/public transport; ■ Encourages shift from car use to rapid transit/public transport, reducing VKT;
4. Engineering and speed reduction measures to moderate the leading hazards of motorised transport;	<ul style="list-style-type: none"> ■ Reducing speed improves safety of walking and cycling; ■ Increasing separation of vehicles from walkers and cyclists improves safety of walking and cycling; ■ Encourages walking and cycling by reducing safety barriers; ■ Technological improvements reduce production of hazards per vehicle (greenhouse gases, pollutants, noise);

VKT: vehicle kilometres travelled

Box 8: Health Paths in Koprivnica, Croatia

To increase the number of people walking for everyday trips, a network of safe, pleasant, barrier-free, well lit and maintained walking paths were designed and implemented in Koprivnica.



Background & Objectives

The need to improve walking conditions was perceived as an important requirement for increasing the number of daily walking trips for local people in Koprivnica. However, in order to attract more people to walk the quality of walking areas must meet the needs of their most vulnerable users, while the attractiveness of the scenery should also motivate more citizens to walk for health and recreation purposes. To achieve these goals, members of the Active Access project team (consisting of health professionals, health and sports clubs representatives as well as town planners and tourist officers) were in charge of the design of new improvement of existing walking routes. By studying examples of similar walking paths networks in Europe (especially Walk 4 Life), they conducted a detailed walking audit and designed the new walking path network.

Implementation

Prior to their implementation, the potential Health Paths network was audited by various user groups, including walking and health clubs, and school children. Suggested improvements included pavement repairs, improved crossings, curbs removal, new benches and fountains with safe drinking water. Following these audits, improvements were made by the City of Koprivnica and Municipal utility company. The new network contains 4 walking paths of 1 km, 2 km, 3 km and 3.5 km respectively, and was opened in June 2010. They were named according to their position in the city, important landmarks or their sponsors. Sponsors of the paths are organisations responsible for further promotional events or activities.

Maps detailing the Health Paths were printed in the form of tear-out pads and delivered to health professionals and pharmacies alongside the paths, and also the local tourist information office to distribute to potential users. The reverse side of the map contains motivational text written by members of City hospital's Active Access team. Seven signposts were placed at central points of the network which contain enlarged printed maps of the network and a number of information pointers indicating the distance to town landmarks expressed in the average walking times.

Results and conclusions

There have been several promotion campaigns for the Koprivnica Health Paths and evaluation of the new paths revealed the following results:

- The health paths network has stimulated organized walking for health amongst local residents.
- Promotion via medical professionals has increased the usage of health paths. According to the medical team's report, about 12 % of patients, who have been advised to walk for health, have been using the Health paths regularly.
- The percentage of schoolchildren walking to school has risen by 2 % in a year, due to the increased safety of the walking paths network.
- There has been interest for the introduction of new walking paths to the existing network, especially among formal and informal walking clubs.
- As a knock on effect to the success of the walking paths, improvements of pedestrian facilities in the town centre have also begun.

Source: Helena Hecimovic, ELTIS Case Study, <http://www.eltis.org>

4.2 Co-benefits of healthy transport systems

Investments in walking, cycling and rapid transit/public transport can assist the transport sector to achieve its own objectives by reducing congestion and the need to fund costly road infrastructure (Mohan 2010). Motorised transport has been estimated to lead to social costs in Beijing of 7.5–15 % of the city's GDP, with congestion, along with health and climate costs, a major component of this. Internalising these external costs of motorised transport could thus lead to congestion, climate and health benefits (Creutzig and He 2009). Other economic benefits arising from reduced motor vehicle use include reduced parking costs and reduced costs to consumers (VTPI 2010d). Transport systems with strong walking, cycling and public transport provisions are also less vulnerable to future interruptions in supply of oil or other fuels.

Investments in rapid transit/public transport may also stimulate transit-oriented development, in which urban densification occurs adjacent to transit nodes, increasing the extent to which potential destinations are accessible without use of private motorised vehicles. Thus, public transport may not only transfer current trips from car to public transport, it may also have additional land use effects that further reduce car use, an effect sometimes known as 'transit leverage'. While designing robust studies to accurately measure the magnitude of transit leverage is challenging, existing evaluations suggest that long-term reductions in car travel may be several times higher than the initial increase in public transport travel. Similar effects may also exist for walking and cycling infrastructure (VTPI 2010b, FTA 2010).

4.3 Barriers to progress on healthy transport

While this module suggests that land use changes and mode shift are the most promising strategies for health, as well as other outcomes such as climate change, many existing recommendations for transport systems (such as those from the Intergovernmental Panel on Climate Change) give greater emphasis to improved vehicles and fuels. One reason for this is that improving vehicles and fuels can

reduce emissions while preserving current travel behaviours, which avoids the need for substantial behaviour change and which may be more politically attractive. Entrenched travel behaviours are thus an important transitional barrier to be overcome if large mode shifts are to be achieved in developed countries. In developing countries that are undergoing rapid motorisation, there may be particular opportunities to act to restrain growth in car travel before these travel behaviours become entrenched.

An important feature of land use and transport planning is that decisions relating to these areas are often made at the local level. This stands in contrast to improved vehicle and fuel technologies, which may be more strongly influenced by decisions at national or global levels. The local nature of land use and transport planning may make it difficult to ensure that good policies are consistently implemented for all urban areas. Local decision-makers are thus likely to require strong guidance and support from national and global levels. This may include making local decision-makers accountable to national government for progress on measures to improve health, as well as technical support to ensure that the rationale for such measures is fully recognised.

Globally, there is still insufficient emphasis on the promotion of alternatives to private motorised travel. A WHO survey found that less than a third of countries had national or local policies that promoted walking and cycling as an alternative to motorised transport, and many also lacked policies to encourage public transport (WHO 2009b). Transport data and indicators often focus disproportionately on car use to the exclusion of walking and cycling, as reflected in a recent European Union report (EU 2009a). Improvements in these areas are likely to be an important part of global efforts to shift travel behaviours.

Box 9: Measuring public health for a sustainable transport project in Arequipa, Peru

The city of Arequipa, Peru, has been reorganising its transport system to include a new 23 km Bus Rapid Transit (BRT) corridor running through the city centre, and including modernised fleet and feeder lines and bicycle and walking infrastructure.

The project's goals include reducing greenhouse gas emissions from transport sources, enlivening public spaces and creating a vibrant transit system, alleviating the cost of travel and increasing economic competitiveness. Another major goal is to address key public health issues that arise from traffic-generated air pollution, injuries and barriers to healthy physical activity.

In 2010, the Pan American Health Organization (PAHO), working with EMBARQ, the Center for Sustainable Transport at the World Resources Institute, helped fund a baseline assessment of traffic safety, physical activity and air pollution before implementation of the transport system changes. PAHO also helped fund a road safety audit, which outlined specific recommendations for improvement of the future BRT corridor. The baseline assessment was a data-driven, field-based review. An international expert in road safety provided analysis of traffic fatalities and injuries. A public health expert measured levels of biking and walking activity among city residents, among other factors. Lastly, measurements were taken along the future BRT corridor for two weeks of ambient air concentrations of $PM_{2.5}$, the vehicle-related pollutant most directly associated with excess mortality. A follow-up study, measuring the same factors, is planned after implementation. The results of the baseline assessment confirmed anecdotal evidence of substantial transport-related health impacts, including the following:

Traffic fatalities and injuries: From 2007 to 2009, there were 2288 crashes involving 5128 people, 320 deaths and 1081 serious injuries in the city as a whole. Pedestrians are the major injury victims. Although pedestrians are involved in only 30% of all traffic accidents, they constitute 59% of injury-related fatalities, and 51% of seriously injured victims.

Along the future trunk BRT corridor, there were 350 traffic accidents and a total of 321 fatalities and injuries from 2007–2009. Pedestrians were involved in 26% of the total crashes, nearly double the rate found in northwestern Europe. A large number of these incidents occurred when pedestrians crossed the main road in areas between intersections – where no pedestrian facilities exist.

Physical activity: In the baseline study, only 9.9% of residents citywide were found to regularly walk as a

means of transport for at least 150 minutes per week. Only 3% walked 150 minutes per week for leisure, and only 3% of residents cycled 150 minutes per week for transport, suggesting that only a small minority of residents were getting enough physical activity to meet recommended levels through walking and cycling. Therefore, the results showed that the transport system was not promoting a healthy lifestyle among a large majority of Arequipa residents.

Personal exposure to $PM_{2.5}$: Average outdoor $PM_{2.5}$ concentrations of $164 \mu\text{g}/\text{m}^3$ (24 hours mean) were found at bus stops along the future BRT corridor, well above the WHO guideline value of $25 \mu\text{g}/\text{m}^3$. Inside the buses themselves, where passengers were exposed to trapped bus fumes, $PM_{2.5}$ concentrations were even higher at $222 \mu\text{g}/\text{m}^3$. The very high concentrations found in the buses and their immediate vicinity suggested that introducing low-emission buses as part of the BRT implementation could potentially lead to direct and immediate reductions in $PM_{2.5}$ exposures for those riding the buses, as well as for people driving and walking along the corridor, while also contributing to air pollution mitigation in the city as a whole.

As part of the reorganisation of the transport system, the public transportation fleet will be renewed and optimised over a four-year period, and will be improved to meet at least Euro 3 standards. The fleet will also use cleaner fuels, including liquefied petroleum gas and ultra-low sulphur diesel. While currently there are no bike lanes in Arequipa, the project includes 70 km of bike lanes and 4 km of new pedestrian paths.

To date, the Provincial Municipality of Arequipa has built 1.6 km of the trunk corridor infrastructure (Bolivar-Sucre). Road safety audit recommendations are being incorporated into BRT infrastructure designs, and the remaining works are expected to begin in July 2011, with the integrated transport system to begin operation in early 2013.

A follow-up evaluation will be conducted in 2015, and will measure public health indicators including air pollution exposure, road safety and physical activity, enabling comparison with the baseline study in 2010. The follow-up evaluation will allow policymakers to assess and improve upon decisions, and guide costs and benefits for future actions.

While much attention has been given to congestion and carbon emissions from transport, a public health baseline can add a public health element to any assessment of a sustainable transport project. This can improve not only the environment and urban economy, but help save lives and create a more livable and lovable city.

Source: Claudia Adriaola, Salvador Herrera, Alejandra Acosta

5. Summary

Some transport measures are much better for health than others. A rich body of evidence accumulated over the past 30 years indicates that reduced private motorised travel, increased active transport and public transport, and improved land use planning have much greater health co-benefits than policies that focus on improving vehicles and fuels alone. These strategies are complementary, and should be pursued concurrently, but much greater emphasis is needed on improving land use and travel mode shift. Targets for reducing private motorised travel need to be more ambitious, and achieving these targets will carry substantial health co-benefits.

There are a range of factors that have historically favoured private motorised travel over alternatives. Transport funding, such as through international development mechanisms, has emphasised road infrastructure over public and active transport. Evaluation of transport projects has often neglected or underestimated the health and climate change effects of transport, while transport indicators have often given more attention to car-focused measures such as roadway level of service than to measures applicable to public transport and active transport. While data on the relative use of different travel modes is incomplete globally, data quality for active travel, including injuries to walkers and cyclists, has often been especially poor. Changes are underway in some of these areas, but will need to be expanded if the goal of healthy transport systems is to be fully realised.

Historically, much of the original focus around transport policy and health has been air pollution abatement – largely through vehicle improvements. To obtain greater health co-benefits, transport strategies should place greater emphasis on land use planning that makes

cities more accessible by walking, cycling and improved rapid transit/public transport, based on evidence available that these make a difference to several domains of health. This module has summarised this evidence on the health benefits and risks of different transport strategies.

This module suggests that the goal of healthy transport can be achieved via four main strategies:

1. Land use systems that increase density and diversity of uses;
2. Investment in and provision of transport network space for pedestrian and bicycle infrastructure;
3. Investment in and provision of transport network space for rapid transit/public transport;
4. Engineering and speed reduction measures to moderate the leading hazards of motorised transport.

Several policy-support instruments are available to promote healthy transport, including technical methods for predicting the health impacts of transport policies and projects, such as health impact assessment (<http://www.who.int/hia>); economic and financial instruments for promoting healthy transport; and governance mechanisms that can enable a shift in strategic direction towards healthy transport policies.

Healthy transport systems can not only improve population health and wellbeing within cities and countries, they can also help address key transport challenges such as congestion and reduce transport-related greenhouse gas emissions.

The barriers to achieving better land use planning and greater shifts to walking, cycling and transit are primarily political rather than technological. With greater understanding of their immediate health benefits, as well as other benefits such as their longer-range climate change mitigation potential, political interest and will can be bolstered. The sooner such measures are implemented, the better for health.

Figure 23a/b/c
Increased active transport and public transport, and improved land use planning offer the greatest health co-benefits.

Photos by Carlos F. Pardo, Bogota, Colombia/Utrecht, Netherlands, 2007 (left and middle) and Dominik Schmid, Belfast, 2011 (right)



Related GTZ/GIZ sourcebook modules and other publications

- **Fletcher J** (2011) GTZ SUTP Sourcebook Module 5e: Urban Road Safety (revised version). Eschborn.
- **Grütter J** (2007) GTZ SUTP Sourcebook Module 5d: The CDM in the Transport Sector. Eschborn.
- **Xie, Q & Alter, C** (2010) Urban Transport and Health: Recommended Reading and Links. Literature list available for download at <http://www.sutp.org>.

References

- **ADVA Center** (1999) Road transport, environment and equity in Israel. Tel Aviv.
- **Andersen LB *et al.***, (2000) All-cause mortality associated with physical activity during leisure time, work, sports, and cycling to work. In: *Arch Intern Med*, 160(11):1621-8.
- **Appleyard D & Lintell M** (1972) The Environmental Quality of City Streets: The Residents' Viewpoint. In: *Journal of the American Planning Association*, 38(2):84-101.
- **Asian Development Bank (ADB)** (2002a) Indonesian multi-sectoral action plan group on vehicle emissions reduction. Integrated vehicle emission reduction strategy; Greater Jakarta, Indonesia. Reducing vehicle emissions in Asia (RETA5937).
- **Asian Development Bank (ADB)** (2002b) Multi-sectoral action plan group: integrated action plan to reduce vehicle emission, Vietnam. Reducing Vehicle Emissions in Asia RETA5937.
- **Asian Development Bank (ADB)** (2010) Applicability of post 2012 climate instruments to the transport sector: final consultants report. Manila.
- **Babisch W** (2008) Road traffic noise and cardiovascular risk. In: *Noise Health*, 10(38):27-33.
- **Bassett DR, Jr *et al.***, (2008) Walking, cycling, and obesity rates in Europe, North America, and Australia. In: *J Phys Act Health*, 5(6):795-814.
- **Beaglehole R *et al.***, (2011) Priority actions for the non-communicable disease crisis. In: *The Lancet*, 2011.
- **Beck LF, Dellinger AM & O'Neil ME** (2007) Motor vehicle crash injury rates by mode of travel, United States: using exposure-based methods to quantify differences. In: *Am J Epidemiol*, 166(2):212-8.
- **Begum BA, Biswas SK & Hopke PK** (2006) Temporal variations and spatial distribution of ambient PM_{2.2} and PM₁₀ concentrations in Dhaka, Bangladesh. In: *Science of the Total Environment*, 358(1-3):36-45.
- **Benkhelifa F, Quang Cu T & Le Truong N** (2002) Air pollution and traffic in Ho Chi Minh City: the ETAP approach. In: *Transport Planning, Demand Management and Air Quality*, Manila, Philippines, 26–27 February, 2002.

- **Berglund B, Lindvall T & Schwela DH** (Eds) (1999) Guidelines for community noise. Geneva: World Health Organization.
- **Bhatia R & Wier M** (2011) "Safety in Numbers" re-examined: Can we make valid or practical inferences from available evidence? In: *Accident Analysis & Prevention*, 43(1):235-240.
- **Boone-Heinonen J et al.**, (2009) Walking for prevention of cardiovascular disease in men and women: a systematic review of observational studies. *Obesity Reviews*, 10(2):204-217.
- **Borken J** (2003) Indicators for sustainable mobility – a policy oriented approach. In: *Journard R (ed) "1st International Symposium Environment & Transport"*, Avignon: INRETS.
- **Branca F, Nikogosian H & Lobstein T**, (Eds) (2007) The challenge of obesity in the WHO European Region and the strategies for response. Copenhagen: World Health Organization.
- **Brugge D, Durant JL & Rioux C** (2007) Near-highway pollutants in motor vehicle exhaust: a review of epidemiologic evidence of cardiac and pulmonary health risks. In: *Environ Health*, 6 (23).
- **Bunn F et al.**, (2003) Area-wide traffic calming for preventing traffic related injuries. *Cochrane Database Syst Rev*, 2003(1):CD003110.
- **Bunn WB, 3rd et al.**, (2004) A reevaluation of the literature regarding the health assessment of diesel engine exhaust. In: *Inhalation Toxicology*, 2004, 16(14):889-900.
- **Campbell-Lendrum DH, Corvalán CF & Prüss-Ustün A** (2003) How much disease could climate change cause? In: *McMichael AJ, ed. Climate change and human health: risks and responses*. Geneva: WHO, WMO, UNEP.
- **Cavill N, Kahlmeier S & Racioppi F**, (Eds) (2006) Physical activity and health in Europe: evidence for action. Copenhagen: World Health Organization.
- **Centers for Disease Control and Prevention** (2000) How land use and transportation systems impact public health: a literature review of the relationship between physical activity and built form. Atlanta.
- **Cervero R et al.**, (2009) Influences of Built Environments on Walking and Cycling: Lessons from Bogotá. *International Journal of Sustainable Transportation*, 3(4):203 - 226.
- **Cervero R, Rood T & Appleyard B** (1999) Tracking accessibility: employment and housing opportunities in the San Francisco Bay Area. In: *Environment and Planning A*, 31(7):1259-1278.
- **Cohen AJ et al.**, (2004) Urban air pollution. In: *Ezzati M et al.*, (Eds) *Comparative Quantification of Health Risks: Global and Regional Burden of Disease Due to Selected Major Risk Factors*. Geneva: World Health Organization, 2004(2):1353-1433.
- **Costello A et al.**, (2009) Managing the health effects of climate change: Lancet and University College London Institute for Global Health Commission. In: *Lancet*, 373(9676):1693-733.
- **Cozens P et al.**, (2003) Managing crime and the fear of crime at railway stations - a case study in South Wales (UK). In: *International Journal of Transport Management*, 1(3):121-132.
- **Creutzig F & He D** (2009) Climate change mitigation and co-benefits of feasible transport demand policies in Beijing. In: *Transportation Research Part D: Transport and Environment*, 14(2):120-131.
- **Dannenberg AL et al.**, (2008) Use of health impact assessment in the U.S.: 27 case studies, 1999–2007. In: *Am J Prev Med*, 34(3):241-56.
- **Davis LW & Kahn ME** (2010) International Trade in Used Vehicles: The Environmental Consequences of NAFTA. In: *American Economic Journal: Economic Policy*, 2(4):58-82.
- **de Hartog JJ et al.**, (2010) Do the Health Benefits of Cycling Outweigh the Risks? In: *Environmental Health Perspectives*, 118(8):1109-1116.
- **de Jong R** (2002) The environmental impact of cities. *Habitat debate; UN-Habitat, United Nations Human Settlements Programme*, 8(2):5.
- **Dijkema MBA et al.**, (2008) Air quality effects of an urban highway speed limit reduction. In: *Atmospheric Environment*, 42(40):9098-9105.
- **Dora C & Racioppi F** (2003) Including health in transport policy agendas: the role of health impact assessment analyses and procedures in the European experience. In: *Bull World Health Organ*, 81(6):399-403.
- **Dora C and Phillips M** (2000) Transport, environment and health. Copenhagen: World Health Organization.

- **Dunton GF *et al.***, (2009) Physical environmental correlates of childhood obesity: a systematic review. In: *Obesity Reviews*, 10(4):393-402.
- **East End Quality of Life Initiative** (2001) Health Impact Assessment of the Rotherham Sheffield Motorway Corridor Planning Study. Sheffield
- **EEA** (2010a) Towards a resource-efficient transport system. TERM 2009: indicators tracking transport and environment in the European Union. Copenhagen.
- **EEA** (2010b) Transport emissions of air pollutants (TERM 003) - Assessment published Sep 2010. Copenhagen. Available online at <http://www.eea.europa.eu/data-and-maps/indicators/transport-emissions-of-air-pollutants/transport-emissions-of-air-pollutants-2>
- **Eliasson J *et al.***, (2009) The Stockholm congestion - charging trial 2006: Overview of effects. *Transportation Research Part A: Policy and Practice*, 43(3):240-250.
- **Elvik R & Mysen AB** (1999) Incomplete Accident Reporting: Meta-Analysis of Studies Made in 13 Countries. In: *Transportation Research Record*, 1665:133-140
- **Elvik R** (2009) The non-linearity of risk and the promotion of environmentally sustainable transport. *Accident Analysis & Prevention*, 41(4):849-855.
- **EU** (2005) CAFE CBA: Baseline Analysis 2000 to 2020. Baseline Scenarios for service contract for carrying out cost-benefit analysis of air quality related issues, in particular in the clean air for Europe (CAFE) programme. Brussels.
- **EU** (2009a) EU energy and transport in figures: Statistical pocketbook 2009. Luxembourg.
- **EU** (2009b) Possible approaches, methods and tools for evaluation. Brussels. Available online at http://ec.europa.eu/regional_policy/sources/docgener/evaluation/evalsed/source-books/themes_policy/policy/transport/approaches_en.htm
- **EU** (2010) TREMOVE: an EU-wide transport model. Brussels. Available online at <http://ec.europa.eu/environment/air/pollutants/models/tremove.htm>
- **European Centre for Health Policy** (1999) Health impact assessment: main concepts and suggested approach. Gothenburg consensus paper. Brussels.
- **Evans GW & Wener RE** (2006) Rail commuting duration and passenger stress. In: *Health Psychology*, 25(3):408-412.
- **FAO** (2008) Impact of climate change and bio-energy on nutrition. FAO High Level Conference on Food Security and the Challenges of Climate Change and Bioenergy. Rome
- **Farrow RS *et al.***, (2001) Facilitating regulatory design and stakeholder participation: the FERET template with an application to the Clean Air Act. In: Fischbeck PS & Farrow RS, Eds. *Improving Regulation*. Washington, D.C., 429-442.
- **Federal Transit Administration (FTA)** (2010) Public Transportation's Role in Responding to Climate Change. Updated January 2010. Washington, D.C.
- **Fitzpatrick R & Boulton M** (1994) Qualitative methods for assessing health care. In: *Qual Health Care*, 3(2):107-113.
- **Fletcher E** (1999) Road Transport, Environment and Social Equity in Israel in the New Millennium. *World Transport Policy & Practice* 5/4: 8-17
- **Frank LD *et al.***, (2010) Carbonless footprints: promoting health and climate stabilization through active transportation. In: *Prev Med*, 50 Suppl 1:S99-105.
- **Friedman MS *et al.***, (2001) Impact of changes in transportation and commuting behaviors during the 1996 Summer Olympic Games in Atlanta on air quality and childhood asthma. In: *JAMA*, 285(7):897-905.
- **Frumkin H** (2002) Urban sprawl and public health. In: *Public Health Rep*, 117(3):201-17.
- **Gallagher P *et al.***, (2009) Cancer-risk benefits of clean fuel technology and policy: A statistical analysis. In: *Energy Policy*, 37(12):5113-5124
- **Gallagher P *et al.***, (2010) Cardiovascular disease-risk benefits of clean fuel technology and policy: A statistical analysis. In: *Energy Policy*, 38(2):1210-1222. Goodwin P, Dargay J & Hanly M. (2004) Elasticities of road traffic and fuel consumption with respect to price and income: a review. *Transport Reviews*, 24(3):275-292.
- **Green J & Britten N** (1998) Qualitative research and evidence based medicine. In: *BMJ*, 316(7139):1230-1232.
- **Grundy C *et al.***, (2009) Effect of 20 mph traffic speed zones on road injuries in London, 1986–2006: controlled interrupted time series analysis. *BMJ*, 2009, 339:b4469.

- **Grütter J** (2007) GTZ SUTP Sourcebook Module 5d: The CDM in the Transport Sector. Eschborn.
- **Guo J et al.**, (2004a) Occupational exposure to diesel and gasoline engine exhausts and risk of lung cancer among Finnish workers. In: American Journal of Industrial Medicine, 45(6):483-90.
- **Guo J et al.**, (2004b) Risk of esophageal, ovarian, testicular, kidney and bladder cancers and leukemia among Finnish workers exposed to diesel or gasoline engine exhaust. In: International Journal of Cancer, 111(2):286-92.
- **Haines MM et al.**, (2001) A follow-up study of effects of chronic aircraft noise exposure on child stress responses and cognition. In: Int J Epidemiol, 30(4):839-45.
- **Haq G et al.**, (2002) Benchmarking urban air quality management and practice in major and mega cities of Asia, Stage 1. Seoul, Korea, Air Pollution in the Megacities of Asia (APMA) Project c/o Korea Environment Institute
- **Health Effects Institute** (2010a) Impact of improved air quality during the 1996 summer olympic games in Atlanta on multiple cardiovascular and respiratory outcomes. HEI research report 148. Boston.
- **Health Effects Institute** (2010b) Traffic-related air pollution: A critical review of the literature on emissions, exposure, and health effects. HEI special report 17. Boston.
- **Health Scotland** (2007) Health impact assessment of transport initiatives: a guide. Edinburgh.
- **Heath GW et al.**, (2006) The effectiveness of urban design and land use and transport policies and practices to increase physical activity: a systematic review. In: Journal of Physical Activity and Health, 3 Suppl 1:S55-76.
- **Hill J et al.**, (2009) Climate change and health costs of air emissions from biofuels and gasoline. In: Proceedings of the National Academy of Sciences of the United States of America, 106(6):2077-82.
- **Hillman M, Adams J, Whitelegg J** (1990) One false move: a study of children's independent mobility. London.
- **Hosking J et al.**, (2010) Organisational travel plans for improving health. In: Cochrane Database Syst Rev, 2010(3):CD005575.
- **Hu G et al.**, (2005) Physical Activity, Cardiovascular Risk Factors, and Mortality Among Finnish Adults With Diabetes. In: Diabetes Care, 28(4):799-805.
- **ICAO** (2005) International civil aviation organization. 1996–2005. Available online at <http://www.icao.int>.
- **IGES** (Ed) (2006) Transportation, energy use and emissions in Indian cities. International Workshop on Policy Integration Towards Sustainable Energy Use for Asian Cities: Integrating Local Air Pollution and GHG Emissions Concerns, 28–30 January 2004. Hayama, Japan, Institute for Global Environmental Studies (IGES), http://www.iges.or.jp/kitakyushu/megacity_workshop/bose.pdf, accessed 30 March, 2006.
- **IMPACT** (2008) Handbook on estimation of external costs in the transport sector. Produced within the study Internalisation Measures and Policies for All external Cost of Transport (IMPACT). Version 1.1. Delft.
- **International Association of Impact Assessment** (1999) Principles of Environmental Impact Assessment Best Practice, January, 1999. Available at: <http://www.iaia.org/publicdocuments>
- **International Agency for Research on Cancer** (IARC) (1989) Diesel and gasoline engine exhausts and some nitroarenes. IARC monographs on the evaluation of carcinogenic risks to humans, Volume 46. Lyon.
- **International Institute for Sustainable Development** (IISD) (2005) Getting on Track: Finding a Path for Transportation in the CDM. Winnipeg.
- **IPCC** (2000a) Methodological and technological issues in technology transfer. Geneva.
- **IPCC** (2000b) IPCC special report: emissions scenarios. Geneva.
- **Ishii K et al.**, (2010) Association of built environment and active commuting among Japanese adults. In: Japanese Journal of Physical Fitness and Sports Medicine, 59(2):215-224.
- **Jacobs J** (1961) The death and life of great American cities. New York.
- **Jacobsen PL** (2003) Safety in numbers: more walkers and bicyclists, safer walking and bicycling. In: Injury Prevention, 9(3):205-9.

- **Jacobson MZ *et al.***, (2004) The effect on photochemical smog of converting the U.S. fleet of gasoline vehicles to modern diesel vehicles. In: *Geophys. Res. Lett.*, 31(2):L02116.
- **Joffe M & Mindell J** (2002) A framework for the evidence base to support Health Impact Assessment. *J Epidemiol Community Health*, 56(2):132-8.
- **Kaczynski AT** (2010) Neighborhood Walkability Perceptions: Associations With Amount of Neighborhood-Based Physical Activity by Intensity and Purpose. In: *Journal of Physical Activity & Health*, 7(1):3-10.
- **Kahlmeier S *et al.***, (2010) "Health in All Policies" in practice: guidance and tools to quantifying the health effects of cycling and walking. In: *Journal of Physical Activity and Health*, 7(Suppl 1):S120-S125.
- **Kahn Ribeiro S *et al.***, (2007) Transport and its infrastructure. In: Metz B *et al.*, (Eds.) *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge & New York.
- **Kawachi I & Berkman LF** (2001) Social ties and mental health. In: *J Urban Health*, 78(3):458-67.
- **Kawachi I, Kennedy BP & Glass R** (1999) Social capital and self-rated health: a contextual analysis. In: *Am J Public Health*, 89(8):1187-93.
- **Kebin H *et al.***, (1996) Status and development of vehicular pollution in China (in chinese). In: *Environmental Science*, 1996, 17(4):80-83.
- **Kenworthy J & Laube F** (2002) Travel Demand Management: The potential for enhancing urban rail opportunities and reducing automobile dependence in cities. In: *World Transport Policy & Practice*, 2002, 8(3):20-36.
- **Kerr J *et al.***, (2006) Active commuting to school: Associations with environment and parental concerns. In: *Medicine and Science in Sports and Exercise*, 38(4):787-794.
- **Keuken MP *et al.***, (2010) reduced NO_x and PM10 emissions on urban motorways in The Netherlands by 80 km/h speed management. *Science of the Total Environment*, 408(12):2517-2526.
- **Kim Y-D, Han H-O & Moon Y-S** (2011) The empirical effects of a gasoline tax on CO₂ emissions reductions from transportation sector in Korea. In: *Energy Policy*, 39(2):981-989.
- **King AC *et al.***, (2006) Perceived environments as physical activity correlates and moderators of intervention in five studies. In: *American Journal of Health Promotion*, 21(1):24-35.
- **Krzyzanowski M, Kuna-Dibbert B & Schneider J, (Eds.)** (2005) *Health effects of transport-related air pollution*. Copenhagen: WHO.
- **Lafortezza R *et al.***, (2009) Benefits and well-being perceived by people visiting green spaces in periods of heat stress. In: *Urban Forestry & Urban Greening*, 8(2):97-108.
- **Landa RT** (2001) *Mobile source pollution in Mexico City and market based instruments. The Cato review of business and government*, 2001.
- **Larsen K *et al.***, (2009) The Influence of the Physical Environment and Sociodemographic Characteristics on Children's Mode of Travel to and From School. *American Journal of Public Health*, 99(3):520-526.
- **Lee C & Moudon AV** (2008) Neighbourhood design and physical activity. In: *Building Research and Information*, 36(5):395-411.
- **Leigh JP & Geraghty EM** (2008) High gasoline prices and mortality from motor vehicle crashes and air pollution. *Journal of Occupational & Environmental Medicine*, 50(3):249-54.
- **Leyden KM** (2003) Social capital and the built environment: the importance of walkable neighborhoods. In: *Am J Public Health*, 93(9):1546-51.
- **Li Y *et al.***, (2010) Air quality and outpatient visits for asthma in adults during the 2008 Summer Olympic Games in Beijing. In: *Science of the Total Environment*, 408(5):1226-7.
- **Lindsay G, Macmillan A & Woodward A** (2011) Moving urban trips from cars to bicycles: impact on health and emissions. In: *Australian and New Zealand Journal of Public Health*, 35(1):54-60.
- **Litman TA** (2007) Developing Indicators for Comprehensive and Sustainable Transport Planning. In: *Transportation Research Record: Journal of the Transportation Research Board*, 2017:10-15.
- **Litman TA & Fitzroy S** (2011) *Safe Travels - Evaluating Mobility Management Traffic Safety Impacts*. Available online at <http://www.vtpi.org/safetrav.pdf>

- **Ljung R, Sorqvist P & Hygge S** (2009) Effects of road traffic noise and irrelevant speech on children's reading and mathematical performance. In: *Noise and Health*, 2009, 11:194-198.
- **Love K et al.**, (2005) Qualitative and quantitative approaches to health impact assessment: an analysis of the political and philosophical milieu of the multi-method approach. In: *Critical Public Health*, 15(3):275-289.
- **Lovegrove, GR & Litman T** (2007) Using macro-level collision prediction models to evaluate the road safety effects of mobility management strategies: new empirical tools to promote sustainable development. Available online at http://www.vtpi.org/lovegrove_litman.pdf
- **Lucy WH** (2003) Mortality risk associated with leaving home: recognizing the relevance of the built environment. In: *Am J Public Health*, 93(9):1564-9.
- **Matthews CE et al.**, (2007) Influence of exercise, walking, cycling, and overall nonexercise physical activity on mortality in Chinese women. *Am J Epidemiol*, 165(12):1343-50.
- **Mazzi EA & Dowlatabadi H** (2007) Air Quality Impacts of Climate Mitigation: UK Policy and Passenger Vehicle Choice. In: *Environmental Science & Technology*, (2):387-392.
- **Melia S, Parkhurst G & Barton H** (2011) The paradox of intensification. In: *Transport Policy*, 18(1):46-52.
- **Mohan D** (2007) Traffic safety as a pre-requisite for sustainable urban transport: an international analysis. In: *Journal of the Eastern Asia Society for Transportation Studies*, 7:2907-2917.
- **Mohan D** (2010) Urban transport and climate change: issues and concerns in the Indian context. In: 3iNetwork, ed. *India infrastructure report 2010: infrastructure development in a low carbon economy*. New Delhi.
- **Moudon AV** (2009) Real noise from the urban environment: how ambient community noise affects health and what can be done about it. In: *Am J Prev Med*, 37(2):167-71.
- **National Academy of Sciences** (2011) *Improving Health in the United States: The Role of Health Impact Assessment*. Washington, D.C. Available online at <http://www.nap.edu>.
- **National Institute of Health and Clinical Excellence** (2007) *Environmental correlates of physical activity and walking in adults and children: a review of reviews*. London.
- **Ness B et al.**, (2007) Categorising tools for sustainability assessment. In: *Ecological Economics*, 60:489-508.
- **Newman & Kenworthy** (1989): *Urban density and transport-related energy consumption*. In: *Atlas Environnement du Monde Diplomatique 2007*. Available online at: <http://maps.grida.no/go/graphic/urban-density-and-transport-related-energy-consumption>
- **Nicholl JP, Freeman MR & Williams BT** (1987) Effects of subsidising bus travel on the occurrence of road traffic casualties. In: *Journal of Epidemiology & Community Health*, 41(1):50-4.
- **NSW Centre for Overweight and Obesity** (2005) *Creating healthy environments: a review of links between the physical environment, physical activity and obesity*. Sydney
- **O'Connell E & Hurley F** (2009) A review of the strengths and weaknesses of quantitative methods used in health impact assessment. In: *Public Health*, 24(4):306-10.
- **OECD** (2001) *OECD environmental outlook for the chemicals industry*. Paris.
- **OECD** (2009) *Transport, energy and CO₂: moving towards sustainability*. Paris.
- **Parent ME et al.**, (2007) Exposure to diesel and gasoline engine emissions and the risk of lung cancer. In: *American Journal of Epidemiology*, 165(1):53-62.
- **Pearce SH & Cheetham TD** (2010) Diagnosis and management of vitamin D deficiency. *BMJ*, 340:b5664.
- **Peden M et al.**, (Eds) (2004) *World report on road traffic injury prevention*. Geneva: World Health Organization
- **Peters A et al.**, (2004) Exposure to traffic and the onset of myocardial infarction. In: *New England Journal of Medicine*, 351(17):1721-30.
- **Pew Center on Global Climate Change** (2003) *Reducing Greenhouse Gas Emissions from U.S. Transportation*. Arlington.
- **Public Health Advisory Committee** (2002) *New Zealand evidence for health impacts of transport: a background paper prepared for the Public Health Advisory Committee*. Wellington.
- **Rabin BA, Boehmer TK & Brownson RC** (2007) Cross-national comparison of environmental and policy correlates of obesity in Europe. *European Journal of Public Health*, 17(1):53-61.

- **Rashad I** (2009) Associations of Cycling With Urban Sprawl and the Gasoline Price. In: *American Journal of Health Promotion*, 24(1):27-36.
- **Robinson DL** (2005) Safety in numbers in Australia: more walkers and bicyclists, safer walking and bicycling. In: *Health Promotion Journal of Australia*, 16:47-51
- **Rutter H** (2006). Mortality benefits of cycling in London. London: Transport for London.
- **Seedat M, MacKenzie S & Mohan D** (2006) The phenomenology of being a female pedestrian in an African and an Asian city: A qualitative investigation. In: *Transportation Research Part F: Traffic Psychology and Behaviour*, 9(2):139-153.
- **Seik FT** (1997) An effective demand management instrument in urban transport: the Area Licensing Scheme in Singapore. In: *Cities*, 14(3):155-164.
- **Social Exclusion Unit (SEU)** (2002) Making the connections: transport and social exclusion. London.
- **Sterner T** (2007) Fuel taxes: An important instrument for climate policy. *Energy Policy*, 35(6):3194-3202
- **Suksod J** (2001) Automotive emissions in Thailand. In: *Reduction of emissions from 2-3 wheelers, Hanoi, Asian Development Bank Regional Workshop*, 5-7 September, 2001.
- **Swedish Environmental Research Institute** (2008) External costs in the transport sector: a literature review. Stockholm.
- **Takano T, Nakamura K & Watanabe M** (2002) Urban residential environments and senior citizens' longevity in megacity areas: the importance of walkable green spaces. In: *Journal of Epidemiology and Community Health*, 56:913-918.
- **The Royal Commission on Environmental Pollution** (1994). *Transport and the Environment*, 18th reports. His Majesty's Publishing House, London, United Kingdom.
- **Titze S et al.**, (2010) Associations Between Intrapersonal and Neighborhood Environmental Characteristics and Cycling for Transport and Recreation in Adults: Baseline Results From the RESIDE Study. In: *Journal of Physical Activity & Health*, 7(4):423-431.
- **Tonne C et al.**, (2008) Air pollution and mortality benefits of the London Congestion Charge: spatial and socioeconomic inequalities. *Occupational and Environmental Medicine*, 65(9):620-627.
- **TRB** (2008) Sustainable transportation indicators: a recommended research program for developing sustainable transportation indicators and data.
- **Troped PJ et al.**, (2003) Correlates of recreational and transportation physical activity among adults in a New England community. In: *Preventive Medicine*, 37(4):304-310.
- **Tudor-Locke C et al.**, (2003) Objective physical activity of filipino youth stratified for commuting mode to school. In: *Medicine & Science in Sports & Exercise*, 35(3):465-71.
- **U.S. Department of Health and Human Services** (2008) *Physical Activity Guidelines Advisory Committee Report*. Washington, D.C.
- **UN Habitat** (2006) *State of the world's cities 2006/7*. Nairobi.
- **UNDP/WorldBank-ESMAP** (2004) *Towards cleaner urban air in South Asia, tackling transport pollution, understanding sources*. Washington D.C.
- **UNEP** (2010) *Towards a green economy: pathways to sustainable development and poverty eradication*. Nairobi
- **UNEP, ILO and WHO** (1999) *Carbon monoxide, environmental health criteria 213*. Geneva.
- **UNEP/WHO** (2009) *Healthy Transport in Developing Cities*. Geneva.
- **United Nations** (1992) *Agenda 21: earth summit. The United Nations programme of action from Rio*. New York.
- **van den Berg AE et al.**, (2010) Green space as a buffer between stressful life events and health. In: *Social Science & Medicine*, 70(8):1203-1210.
- **Victoria Transport Policy Institute (VTPI)** (2010a) *Evaluating transportation land use impacts: considering the impacts, benefits and costs of different land use development patterns*. Victoria.
- **Victoria Transport Policy Institute (VTPI)** (2010b) *Evaluating Non-Motorised Transportation Benefits and Costs*. Victoria.

- **Victoria Transport Policy Institute (VTPI)** (2010c) Safe travels: evaluating mobility management traffic safety impacts. Victoria.
- **Victoria Transport Policy Institute (VTPI)** (2010d) Win-Win Transportation Emission Reduction Strategies. Victoria.
- **Victoria Transport Policy Institute (VTPI)** (2011a) Generated traffic and induced travel: implications for transport planning. Victoria.
- **Victoria Transport Policy Institute (VTPI)** (2011b) Pricing for traffic safety: how efficient transport pricing can reduce roadway crash risk. Victoria.
- **Vincente de Assunção J** (2002) São Paulo metropolitan area air quality in perspective. In: International Seminar on Urban Air Quality Management, São Paulo, Brazil, International Union of Air Pollution Prevention & Environmental Protection Associations (IUAPPA) and Brazilian Association for Ecology and Water & Air Pollution Prevention (ABEPPOLAR) in association with the University of São Paulo, 21–23 October, 2002.
- **Walsh MP & Walsh MP** (2008) Ancillary benefits for climate change mitigation and air pollution control in the world's motor vehicle fleets. In: Annual Review of Public Health, 29:1-9.
- **Wang W et al.,** (2009) Atmospheric particulate matter pollution during the 2008 Beijing Olympics. In: Environmental Science & Technology, 43(14):5314-20.
- **World Bank** (2008) A framework for Urban Transport Projects, Operational Guidance for World Bank Staff. Transport Papers, TP-15, January 2008. Washington, DC.
- **World Bank** (2011) Highway Development and Management Model (HDM-4). Available at: http://www.worldbank.org/transport/roads/rd_tools/hdm4.htm
- **World Health Organization - Regional Office for Europe** (1999) European Centre for Health Policy, Gotenburg Consensus Paper.
- **World Health Organization - Regional Office for Europe** (2000) Air quality guidelines for Europe, 2nd edition. European Series, No. 91. Copenhagen.
- **World Health Organization - Regional Office for Europe** (2002) Health impact assessment of air pollution in the eight major Italian cities. Rome.
- **World Health Organization - Regional Office for Europe** (2004) Health aspects of air pollution: results from the systematic review of health aspects of air pollution in Europe. Copenhagen. (EUR/04/5046026)
- **World Health Organization - Regional Office for Europe** (2006) Health Effects and Risks of Transport Systems: the HEARTS project. Copenhagen
- **World Health Organization - Regional Office for Europe** (2011) Burden of disease from environmental noise: quantification of healthy life years lost in Europe. Copenhagen.
- **World Health Organization** (1994). Concern for Europe's Tomorrow. WHO Regional Publications, European Series, No. 53, 1994.
- **World Health Organization** (2004) Global strategy on diet, physical activity and health. Geneva.
- **World Health Organization** (2005) Effects of air pollution on children's health and development: a review of the evidence. Copenhagen.
- **World Health Organization** (2006a) Air quality guidelines: global update 2005. Geneva
- **World Health Organization** (2006b) Promoting physical activity and active living in urban environments: the role of local governments. Copenhagen.
- **World Health Organization** (2008a) Closing the gap in a generation: health equity through action on the social determinants of health. Final report of the Commission on Social Determinants of Health. Geneva.
- **World Health Organization** (2008b) Economic valuation of transport-related health effects: review of methods and development of practical approaches, with a special focus on children. Copenhagen.
- **World Health Organization** (2008c) The global burden of disease: 2004 update. Geneva.
- **World Health Organization** (2008d) Transport and health: health economic assessment tool (HEAT) for cycling. Geneva. Available online at <http://www.euro.who.int/HEAT>.
- **World Health Organization** (2008e) World Health Statistics 2008. Geneva.
- **World Health Organization** (2009a) Global health risks: mortality and burden of disease attributable to selected major risks. Geneva.

- **World Health Organization** (2009b) Global status report on road safety: time for action. Geneva.
- **World Health Organization** (2009c) Interventions on diet and physical activity: what works: summary report. Geneva.
- **World Health Organization** (2009d) Protecting health from climate change: connecting science, policy and people. Geneva.
- **World Health Organization** (2010) Urban health matters: World health day 2010. Geneva.
- **World Health Organization** (2011a) Burden of disease associated with urban outdoor air pollution for 2008. Geneva.
- **World Health Organization** (2011b) Urban Outdoor Air Pollution Database, Geneva. http://www.who.int/phe/health_topics/outdoorair/databases/en/index.html
- **Woodcock J et al.**, (2009) Public health benefits of strategies to reduce greenhouse-gas emissions: urban land transport. In: *Lancet*, 374(9705):1930-43.
- **World Bank** (2005a) World Bank lending for transport (2000–2002) and (2002–2004). Washington, D.C. Available online at <http://www.worldbank.org/transport/lending.htm>
- **World Bank** (2005b) World development indicators 2005. Washington, D.C.
- **World Bank** (2010a) Air Pollution in World Cities (PM10 Concentrations). Washington, D.C. Available online at <http://go.worldbank.org/3RDFO7T6M0>
- **World Bank** (2010b) World Bank Group Energy Sector Financing Update. Washington, D.C.
- **World Bank** (2011) Transport - projects. Washington, D.C. Available online at <http://go.worldbank.org/HIHM2APB70>
- **World Business Council for Sustainable Development** (2004) Mobility 2030: meeting the challenges to sustainability. The sustainable mobility project: full report. Geneva.
- **Wright L & Fulton L** (2005) Climate Change Mitigation and Transport in Developing Nations. In: *Transport Reviews*, 25(6):691-717.
- **Yang L et al.**, (2010) Interventions to promote cycling: systematic review. *BMJ*, 2010, 341.
- **Zhongan M et al.**, (2002) Traffic and urban air pollution: the case of Xi'an city, P.R. China (document 15C). In: *Transport Planning, Demand Management and Air Quality*, Manila, Asian Development Bank, 26–27 February.



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