Health co-benefits of climate change mitigation – Transport sector

Health in the green economy

World Health Organization

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Cover photo: Walking to school in Atteridgeville, South Africa, near Pretoria. A number of South African cities, supported by national Ministries of Health, Sport and Transport, are developing new pedestrian and bicycle initiatives to generate health, physical activity, energy and climate co-benefits. (Brett Eloff)

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Foreword

The threat climate change poses to health, equity, and development has been rigorously documented.[i,ii,iii,iv] However, in an era marked by economic crisis, regional conflicts, natural disasters and growing disparities between rich and poor, the joint global actions required to address climate change have been vigorously debated – and critical decisions postponed.

This document, part of WHO's *Health in the Green Economy* series, describes how many climate change measures can be "win-wins" for people and the planet.

These policies yield large, immediate public health benefits while reducing the upward trajectory of greenhouse gas emissions. Many of these policies can improve the health and equity of people in poor countries and assist developing countries in adapting to climate change that is already occurring, as evidenced by more extreme storms, flooding, drought and heatwaves.

Walking to school: Important to child health and to climate change mitigation. Here, pupils from Banareng Primary School, Atteridgeville, South Africa, stand on scholar patrol duty: Boitumelo Phalane (foreground). (Photo: Brett Eloff)

WHO's Department of Public Health and Environment launched the *Health in the Green Economy* initiative in 2010 to review potential health and equity "co-benefits" of proposed climate change measures – as well as relevant risks.

This review examines mitigation strategies discussed in the *Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Working Group III)*,[v] which constitutes the most broad-based global review of mitigation options by scientific experts.

The IPCC review covers transport, agriculture, commercial and residential buildings and energy, among other topics. Policies considered in the IPCC review of each sector are thus the primary focus of health-oriented review in this *Health in Green Economy* series. Each report in the series considers the likely health co-benefits of mitigation measures in a particular sector; this review addresses the *Transport Sector.*

WHO has undertaken considerable work on "healthy transport" measures such as active transport (walking and cycling) and better urban planning based upon low-emissions public transport systems. This document looks at how such healthy strategies can be implemented through mitigation policies. Mitigation strategies could not only reduce the

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i Chan M. Cutting carbon, improving health. *Lancet*, 2009, 374(9705):1870–1871 (http://www.thelancet.com/journals/lancet/article/PIIS0140-6736(09)61993-0/fulltext).

ii *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Geneva, 2007.

iii *Climate variability and change and their health effects in small island states: information for adaptation planning in the health sector.* World Health Organization. Geneva, 2006 (http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1764155/).

iv *Protecting health from climate change: connecting science, policy and people.* World Health Organization, Geneva, 2009 (http://extranet.who.int/iris/handle/123456789/866).

v Metz B et al. eds. *Climate Change 2007: Mitigation of Climate Change. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge & New York, Cambridge University Press, 2007.

risks of transport, but also promote health-enhancing environments that, for example, could facilitate healthy physical activity. Many such strategies can save considerably in health care costs, particularly in the costs of soaring noncommunicable diseases, including cardiovascular disease, hypertension, cancers and a range of obesity-related diseases.

Healthier lower-carbon transport strategies also are cost-efficient investments for individuals and societies. The infrastructure costs of better networks for walking and cycling, or of siting schools nearer to residential areas, are very modest compared with the costs of developing new vehicle technologies, however vital such technologies still may be. For households, and particularly the poor, more effective public transport and safer walking/cycling routes can yield significant savings in travel time and expense as well as preventing disease and promoting better health.

As the preamble to WHO's 1948 constitution states: "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity."

Mitigation measures that can produce better health outcomes are of vital interest to the health sector and health policy-makers. Local, national and international policies can protect the natural environment while also improving public health and health care services. Such policies serve WHO's goal of "attainment of the highest level of health for all." This document and this series outline opportunities where, for a minimal investment of health sector resources, big gains for public health can be leveraged.

Dr Maria Neira
Director of Public Health and Environment
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Contents

Executive summary

Key messages

Health co-benefits of transport-related climate change mitigation

- **A shift to active transport (walking and cycling) and rapid transit/public transport combined with improved land use** can yield much greater immediate health "co-benefits" than improving fuel and vehicle efficiencies. These strategies need more systematic study by the Intergovernmental Panel on Climate Change (IPCC)[i] in the assessment of transport mitigation measures.
- **Potential health gains of a shift from private motorized transport to walking, cycling and rapid transit/public transport include reduced** cardiovascular and respiratory disease from air pollution, less traffic injury and less noise-related stress. In addition, large benefits are expected from increased physical activity, which can prevent some cancers, type 2 diabetes, heart disease and other obesity-related risks. Improved mobility for women, children, elderly and the poor, who have less access to private vehicles, enhances health equity.
- **Shifting from gasoline to diesel vehicles could increase emissions of health-damaging small particulates (PM_{10}, $PM_{2.5}$).** IPCC's assessment finds diesel vehicles have potential to reduce transport's CO_2 emissions. However, diesel engines typically emit higher concentrations of small particulates – the vehicle pollutant most closely associated with health impacts. In Europe, large shifts to diesel vehicles over the last decade are regarded as a cause of stable (but not lower) urban PM_{10} levels – despite the introduction of cleaner diesel technologies.
- **Transport-related health risks now cause the deaths of millions of people annually.** For example, WHO estimates that urban air pollution (much of it transport-generated) kills some 1.3 million people annually.[ii] Additionally, traffic injuries kill another 1.3 million people every year, mostly in low- and middle-income countries. Some 3.2 million deaths annually are due to physical inactivity.[iii]

"Win-win" strategies for transport and health

- **IPCC should more systematically consider health co-benefits (and potential risks) of transport mitigation strategies** to highlight policies with the greatest overall gains for society. The *IPCC Fourth Assessment Report* gives little, if any, consideration to health impacts.
- **Improved active transport and rapid transit/public transport is not only healthy: it is cost effective.** Studies cited by IPCC of Latin American cities note the large greenhouse gas (GHG) mitigation potential (25%) and relatively low cost (US $30/tonne CO_2 reduced) for a package of bus-rapid transit (BRT), pedestrian upgrades and cycleways.[iv]

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i Kahn Ribeiro S et al. Transport and its infrastructure. In: Metz, B et al. eds. *Climate Change 2007: Mitigation of Climate Change. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge & New York, Cambridge University Press, 2007.

ii *Air quality and health.* Fact sheet. No. 313. Geneva, World Health Organization. September 2011 (http://www.who.int/mediacentre/factsheets/fs313/en/index.html).

iii *Global health risks: mortality and burden of disease attributable to selected major risks*. Geneva, World Health Organization, 2009.

iv Wright L, Fulton L. Climate change mitigation and transport in developing nations. *Transport Reviews,* 2005, 25(6):691–717.

- **More compact land use that integrates urban residential and commercial areas enhances the climate and health co-benefits of transport strategies.** Emphasis on "proximity planning" makes walking, cycling and public transport to jobs, schools and services more feasible. For example, one study of Santiago, Chile projected that relocating schools closer to homes could reduce GHGs by 12% over a 20-year period at a cost of only US$ 2 per tonne of CO_2 reduced.[v]
- **Cost-benefit assessment (CBA) commonly performed on transport projects, including by development banks, often fails to quantify the health and equity costs** that some road projects may generate – in terms of injury risks, pollution exposures, and barriers to travel by public transport or non-motorized modes. CBA tools need to provide more "multimodal" comparisons of the costs and benefits of various mixes of BRT/rail, non-motorized and road investments in terms of expected health gains, or losses.
- **Well-tested tools exist for considering health in transport and land-use policies,** including health impact assessment (www.who.int/hia). These tools can be applied more widely in developed and developing countries and cities.
- **Investments in active transport and rapid transit/public transport can assist budget-conscious ministries to achieve development objectives cost effectively** by reducing congestion and the need to fund costly road infrastructure. Transport systems with strong walking, cycling and rapid transit/public transport components also are less vulnerable to price shocks and interruptions in supply of oil or other fuels.

Closing the health equity gap

- **Low- and middle-income cities** may have the most to gain in health terms from low-carbon transport strategies. These cities are experiencing the most rapid urban population growth as well as traffic congestion, air pollution and traffic injury risks. The same cities face growing noncommunicable disease risks from more sedentary lifestyles. Healthier transport strategies can help address these risks.
- **Healthier transport strategies** will yield a wide range of health benefits for the majority of the world's population, and large equity benefits for vulnerable groups. Women, older adults, children, people with disabilities, and lower income groups generally have less access to private vehicles, and this creates barriers to accessing economic and social opportunities. These groups also are more directly exposed to certain transport-related health risks. As pedestrians, men are more often the victims of traffic injury in some countries. So almost everyone benefits somehow from public and non-motorized transport that improves their mobility, safety, and independent access to key destinations.
- **Biofuel production** for transport mitigation may pose a threat to food security when diversion of food croplands to fuel production decreases access to nutritious and affordable foods. This also compromises the right to food.
- **Export of older, more polluting vehicles** to developing regions poses health risks for the latter. As developed countries shift to lower-emissions vehicles, older vehicles are resold at low prices to developing country markets where regulatory controls on fuels and vehicle maintenance may be less strict. This can exacerbate traffic congestion, air pollution and injury risks – particularly when public transit systems are weak and inefficient.

[v] Barias JL et al. *Getting on track: finding a path for transportation in the CDM*. Winnipeg, International Institute for Sustainable Development, 2005.

Background and rationale

Transport has powerful impacts on health. Well-designed transport policies and infrastructure investment priorities can lead to far-reaching reductions in traffic-related health risks from air and noise pollution and injury. Cycling and walking, on their own or as part of a public transport journey, can greatly enhance physical activity levels and help prevent a range of chronic diseases including heart disease, some cancers and type 2 diabetes.

The transport sector is also a major source of GHG emissions, and thus an important focus of climate change mitigation. To optimize the social and economic benefits that can be derived from mitigation, transport mitigation strategies need to be examined in light of expected health impacts – both co-benefits and potential risks. Additionally, strategies may be examined in light of their potential to achieve greater health equity by improving the access of diverse groups to social, educational and economic opportunities. In light of this need, WHO undertook a review of potential health co-benefits (and risks where relevant) of transport mitigation strategies.

Box 1. The climate footprint of transport

Transport emissions accounted for about 23% of global energy-related CO_2 emissions in 2008, with land transport accounting for the largest share (about 16.5% of the global total). In addition to CO_2 emissions, diesel particles also contain black carbon, a short-lived climate change pollutant – although biomass combustion is a more important source.[vi,vii] Growth in energy use is higher for the transport sector than for any other end-use sector with emissions rapidly rising in absolute terms.

About 80% of transport energy use is due to land transport, with most of this due to light-duty vehicles (LDVs) including cars, followed by freight transport (see Chapter 1, Fig. 2). Globally, the number of cars and other LDVs is projected to triple between 2000 and 2050; by 2030, the number of vehicles in developing nations is expected to exceed those in developed countries.[viii] Since land transport leads to more immediate health impacts than shipping and air travel, and also accounts for a greater share of emissions, this report focuses on land transport.

[vi] *Health risks of particulate matter from long-range transboundary air pollution.* Copenhagen, World Health Organization, 2006.

[vii] Novakov T et al. Large historical changes of fossil-fuel black carbon aerosols. *Geophysical Research Letters*, 2003, 30(6):1324

[viii] Wright L, Fulton L. Climate change mitigation and transport in developing nations. *Transport Reviews,* 2005, 25(6):691–717.

Scope and methods

This report reviews potential health impacts of mitigation strategies considered by the Intergovernmental Panel on Climate Change in the *Fourth Assessment Report – Working Group III* (also referred to here as the IPCC review). [ix] It draws on an extensive review of nearly 300 peer-reviewed and health-relevant scientific articles and reports. The focus was on studies of the health impacts of mitigation strategies implemented in real-life settings, as well as evidence on transport-related risk factors. Existing tools for assessing health impacts of transport decisions were illustrated as well as case studies of climate- and health-friendly transport policies. The review was limited to land transport, which has the greatest impacts on health as well as the largest share of transport's GHG emissions. Passenger transport, rather than freight, was the key focus.

In the appraisal, key literature on known transport-related risk factors (e.g. air pollution exposures and traffic injuries) and health impacts (e.g. cardiovascular disease), as well as health equity impacts, was first reviewed and summarized. A targeted literature search was then conducted for available knowledge about the expected impacts of IPCC-reviewed mitigation measures. The search strategy drew upon keywords related to the IPCC assessment to identify studies on health impacts of:

1. modified vehicles and fuels
2. transport pricing strategies
3. transport and land-use policies that promote shifts to non-motorized transport (also described as active transport), public transport and to more compact land use.

Based on a synthesis of these findings, the likely health effects of a given mitigation strategy or package of strategies are described and classified from " -- " (strongly negative for health) to "++" (strongly positive for health). The strength of the evidence was also assessed, assigning a rating from "0" (no evidence) through weak (small number of observational studies only, or good theoretical or indirect rationale for an effect) to moderate (large number of observational studies, or observational studies plus clear theoretical rationale). Evidence on health equity effects of each factor was difficult to quantify with these methods and was described qualitatively. These classifications, presented in the "Appraisal of health implications of IPCC-assessed mitigation strategies" (Table 1), should be regarded as indicative rather than definitive.

Summary of findings

The major focus of the IPCC mitigation review is improved fuels and vehicle technologies. To obtain greater health co-benefits, transport mitigation strategies should place greater emphasis on land-use planning that makes cities more accessible by walking, cycling and improved rapid transit/public transport. Greater emphasis on land use and mode shift may also enhance the mitigation potential of transport strategies. Also needed are land-use strategies that reduce the need for motorized travel, particularly by private modes, while promoting better access, particularly for vulnerable groups. A

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ix Kahn Ribeiro S et al. Transport and its infrastructure. In: Metz, B et al. eds. *Climate change 2007: mitigation of climate change. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge & New York, Cambridge University Press, 2007.

systematic evaluation of potential health impacts should be included in the next evaluation of transport-related mitigation strategies to ensure win-win outcomes for health, the environment, and people's mobility and access.

Overarching goals of healthy transport include: (a) reduced deaths and disease generally from transport-generated air, noise, and water pollution; (b) reduced exposures of disadvantaged groups to excessive transport-related injuries and health risks; (c) safer and more efficient access, especially for vulnerable groups, to jobs, schools, services and social opportunities; (d) increased physical activity, including through safe walking and bicycling; (e) reduced climate change emissions from transport that contribute to future, as well as present-day, health impacts.

These goals can be achieved via four main strategies:

1. Compact land-use systems that increase density and diversity of uses.
2. Investments in, and prioritization of, transport networks for pedestrians and cyclists.
3. Investments in, and prioritization of, transport networks for rapid transit/public transport.
4. Transport engineering and traffic-calming measures that protect vulnerable road users from motorized transport's hazards.

Tested policy tools can support health-oriented strategies, such as the following.

- Health impact assessment that identifies and addresses health co-benefits and risks at the planning stage, as well as measures to improve health and reduce health inequities.
- Strengthened land-use/transport planning, codes and enforcement; for example, ensuring universal access to safe cycling and pedestrian routes and to rapid transit/public transport for basic routines.
- Development and monitoring of healthy transport performance criteria and indicators, including better indicators for active travel/physical activity; use of non-motorized modes and public transport; air/noise pollution exposures; pedestrian injuries; and mobility/access.
- Economic evaluation and assessment methods that fully account for the health co-benefits of walking, cycling and rapid transit/public transport use.

Table 1. Appraisal of health implications of IPCC-assessed mitigation strategies

Mitigation strategy	Potential to reduce emissions (illustrative example)	Likely reduction of health risk factors			Additional effects, limitations and comments
		Size and direction of effect		Strength of evidence	
IPCCa Modified vehicles and fuels	21% reduction in CO_2 emissions of light-duty vehicles by 2030 under a high-efficiency vehicle scenario, almost all at costs less than US$ 100/tonneCO_2.	Air pollution	- to ++	Moderate	Increasing fuel efficiency could lower travel costs and thus promote more motorized transport. Alternatively, improved vehicles may be more expensive, reducing their use in low-income settings. Particulate emissions may be higher from diesel engines than from equivalent gasoline engines per unit of travel, which could worsen health. Air quality impacts of biofuels remain unclear. Significant concern exists regarding biofuels' production impacts on food security and nutrition for the poor.
		Physical activity	0	Weak	
		Road traffic injury	0	Weak	
		Noise	0	Weak	
		Social effects	0	Weak	
		Land use	0	Weak	
IPCCb Pricing policies regarding vehicle and fuel use, and pricing of travel to urban centres or by different modes (e.g. congestion pricing)	Depends on whether target is pricing of modified vehicles and fuels (IPCCa) or land-use changes and alternatives to private motorized transport (IPCCc). Congestion charges have reduced emissions by 13–30%, while a subsidy for low-carbon fuel has been estimated to reduce emissions by 6%.	Air pollution	- to ++	Weak	Pricing policies to encourage vehicle/fuel improvements are likely to lead to health benefits similar to IPCCa, but not to reduce travel. Pricing to encourage use of non-motorized transport and public transport is likely to lead to health benefits similar to IPCCc. Policies would have different effects on health equity depending on mode targeted, e.g. public transport or private, and type of pricing tool, e.g. taxes or subsidies.
		Physical activity	0 to ++	Weak	
		Road traffic injury	0 to ++	Weak	
		Noise	0 to ++	Weak	
		Social effects	0 to ++	Weak	
		Land use	0 to ++	Weak	
IPCCc Land-use changes and alternatives to private motorized transport	Package of walkways, cycleways and bus rapid transit could reduce emissions by 25% at a cost of US$ 30/ tonneCO_2.[x] Improved land use could reduce emissions by 21% over a 20-year period at a cost of US$ 91/tonneCO_2.[xi]	Air pollution	++	Moderate	Can help ensure equity of access for people without cars. Can make walking and cycling safer for vulnerable groups, e.g. children, older adults and people without cars. Increases in walking and cycling need to be accompanied by improvements in the safety of the walking and cycling environment.
		Physical activity	++	Moderate	
		Road traffic injury	++	Moderate	
		Noise	++	Weak	
		Social effects	++	Weak	
		Land use	Not applicable		

See Chapter 3 for complete references to potential to reduce emissions.

Note: Size and direction of likely health effects were rated from "--" (strongly negative effects) to "++" (strongly positive effects), with the midpoint "0" representing no significant effects.

Strength of evidence was rated from 0 (no evidence) through weak (small number of observational studies only, or good (theoretical or indirect rationale for an effect) to moderate (large number of observational studies, or observational studies plus clear theoretical rationale).

[x] Wright L, Fulton L. Climate change mitigation and transport in developing nations. *Transport Reviews*, 2005, 25(6):691-717.

[xi] Barias JL et al. *Getting on track: finding a path for transportation in the CDM*. Winnipeg, International Institute for Sustainable Development, 2005.

Notes

HardRain

Road building in Mexico. Emissions impacts of infrastructure construction and vehicle production also need to be considered for a complete assessment of health and mitigation impacts of alternative transport strategies involving roads, rail, transit, and non-motorized modes.

Introduction

Background and rationale

Transport has powerful impacts on health; well-designed transport policies and infrastructure can lead to far-reaching reductions in health risks related to air and noise pollution exposures and traffic injuries. Daily travel by bicycle, on foot, or via rapid transit/public transport can significantly increase routine physical activity, helping to prevent chronic diseases such as heart disease, some cancers, and type 2 diabetes.

In addition to the health impacts, the transport sector is a major source of greenhouse gas emissions, and thus an important focus of climate change mitigation. To optimize the social and economic benefits of mitigation actions, transport strategies need to be examined in light of expected health impacts – both risks and co-benefits. This can help identify those mitigation strategies that are most effective in reducing the immediate health risks from transport in terms of pollution, injuries, and barriers to physical activity and related costs to individuals and societies in terms of death, illness, health-care costs and lost productivity. To address such issues, WHO undertook a review of potential health co-benefits and risks of transport mitigation strategies. The review focuses on mitigation measures reviewed by the Intergovernmental Panel on Climate Change in the *Contribution of Working Group III to the Fourth Assessment Report* (also referred to here as the IPCC review).[1] Along with assessment of health impacts per se, strategies are examined in light of their potential to achieve greater health equity by reducing the burden of transport-related disease and injury that falls disproportionately on disadvantaged groups, who also enjoy less mobility and access to social and economic opportunities.

Outline

This report begins with an overview of the transport sector's contributions to climate and environmental change, followed by discussion of key pathways by which transport can affect health. This is followed by a comprehensive review of the health co-benefits, or risks, of key transport mitigation strategies, focusing on the IPCC's three main categories of transport mitigation strategies. Strategies that appear to have the best potential to achieve win-win outcomes for both health and climate are summarized and tools for assessing, planning and financing healthy, low-emission transport systems are reviewed. The report concludes by describing case studies of transport strategies that pursue both health and climate objectives.

Scope and methods for analysis

Scope

Relevant literature was identified from searches of electronic databases, web searches, references of other relevant reports and reviews, and communication with experts in the field. The review focuses on peer-reviewed articles, supplemented by other sources, (e.g. government, development agency, civil society) where appropriate.

For the core analysis of health co-benefits, or risks, from mitigation measures (Chapter 3), a more structured review method was pursued. A literature search focused on three main IPCC-assessed transport mitigation strategies (Table 2), and searched for evidence of environmental health risks, disease impacts, and where identified, health equity. Given the topics' breadth, it was deemed impractical to conduct systematic reviews. However, the review was designed to summarize key findings in existing literature and to identify major gaps where applicable. The search strategy, in terms of data collection, eligibility criteria, and analysis are described further below and in Chapter 3.

For the core analysis of health co-benefits, or risks, from mitigation measures, a more structured review method was pursued. The review summarized key findings in existing literature, and identified major gaps.

Table 2. Selected transport sector policies, measures and instruments shown to be environmentally effective in multiple national cases, as summarized by IPCC

Category title (as used in this report)	Policies, measures and instruments shown to be environmentally effective	Key constraints or opportunities
Modified vehicles & fuels (IPCCa)	Mandatory fuel economy/CO_2 standards for road transport; shifts to lower-carbon fossil fuels, biofuels, CNG & hybrid/electric vehicles; other vehicle design modifications	Partial coverage of vehicle fleet may limit effectiveness
Modified pricing of vehicles, fuels, infrastructure (IPCCb)	Taxes on vehicle purchase, registration, use; taxes on motor fuels; road and parking pricing; congestion/area pricing	Effectiveness may decline with higher incomes
Land-use changes and/or mode shifts from private to public/transit and non-motorized modes (IPCCc)	Influence mobility needs through land-use design/regulations and infrastructure planning; prioritization of, and investment in, public transport and non-motorized transport infrastructure and amenities	Particularly appropriate for countries that are building their transportation systems; or cities undergoing rapid expansion

Source: adapted from IPCC Working Group III *Summary for Policymakers*[6] (Table SPM.7) and *Climate Change 2007: Synthesis Report*[7] (Table 4.2).

Eligibility criteria

Studies were included if they corresponded to any of the three IPCC categories identified above and were relevant for assessing health effects. The review focused on peer-reviewed journal articles reporting individual studies. Systematic reviews on related topics were used as a comparison for the findings of this review.

Search strategy

MEDLINE and Web of Science were searched using the following search concepts:

1. modified vehicles and fuels AND health
2. transport pricing strategies AND health
3. land use factors AND health
4. active/non-motorized transport or public transport AND health.

Data collection and analysis

Statistically significant findings of eligible studies were summarized in tables where appropriate. Studies were only reported to show a significant association if the association was found for the total population. Similarly, some studies found associations between transport factors and some outcome subcategories but no association with the broader outcome category as a whole, and in such cases this was not treated as a significant association. For example, Forsyth et al. found urban density was associated with transport-related walking but not overall walking levels, and this was not reported in this review as a significant association.[5]

Based on all the studies identified in each of these areas, Chapter 3 summarizes the evidence on health effects of each factor and relates this to pathways such as air pollution, physical activity and road traffic injury.

As this is a scoping exercise, data from all potentially relevant outcomes reported by each paper were not extracted. Instead, statistically significant findings, both positive and negative, were summarized. There was no attempt to routinely assess studies' risk of bias. Based on the body of evidence identified, the likely health effects of a given mitigation strategy or package of strategies are described and classified from " -- " (strongly negative effects) to "++" (strongly positive effects), with the midpoint "0" representing no significant effects. The strength of the evidence was also assessed, assigning a rating from 0 (no evidence) through weak (small number of observational studies only, or good theoretical or indirect rationale for an effect) to moderate (large number of observational studies, or observational studies plus clear theoretical rationale). Due to the lack of randomized trials in this area, a "strong" evidence rating was not used. Effects on health equity were challenging to quantify, so are addressed instead by way of comments. These classifications, presented in Table 13 in Chapter 3, should be regarded as indicative rather than definitive.

Locating schools closer to residential neighbourhoods is one way of reducing travel-related emissions and increasing physical activity, at comparatively low cost. (Photo: Bigstock)

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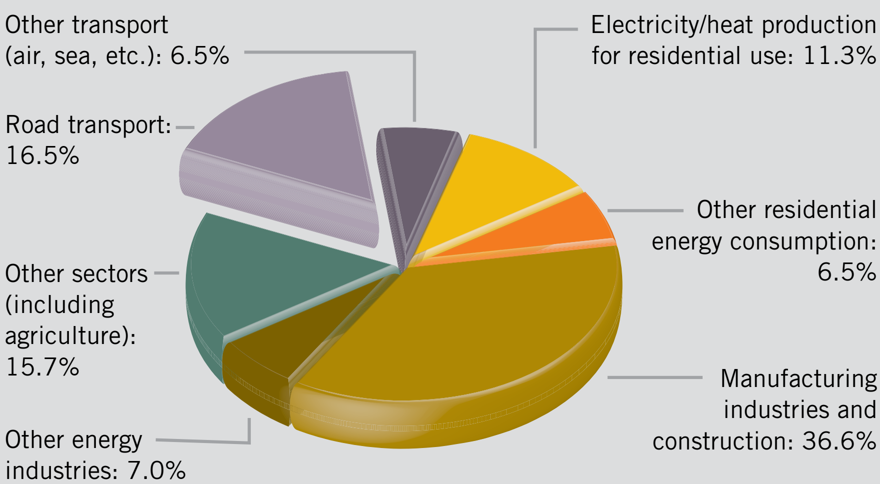
Freeway interchange in Asia. Globally, the number of cars and other light-duty vehicles is projected to triple between 2000 and 2050, with consequences for both climate change and health.

The transport sector, climate and environmental change

Transport is a leading contributor to greenhouse gas emissions (Fig. 1). As well as accounting for about 23% of global energy-related emissions, growth in energy use is higher for the transport sector than any other end-use sector.[1] About 80% of transport energy use is due to land transport, mostly light-duty vehicles (LDVs) including cars, followed by freight transport (Fig. 2).[1] 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.

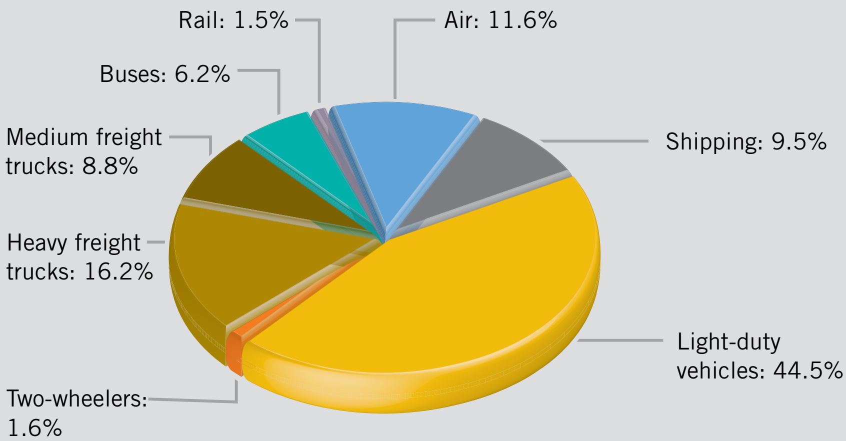
Under 'business as usual' or reference case scenarios, global transport energy use is projected to grow by about 80% between 2002 and 2030, with emissions rising in parallel. The primary drivers of this growth will be light-duty vehicles, freight trucks and air travel.[1] Globally, the number of cars and other LDVs is projected to triple between 2000 and 2050.[1]

Fig. 1. CO_2 emissions by sector, 2008



Source: International Energy Agency, 2010[2].
"Other transport" includes air and water transport; agriculture is included in "other sectors."

Fig. 2. World transport energy use in 2000, by mode



Source: Kahn Ribeiro et al., 2007[1]

1.1 Regional trends in travel and emissions

Higher gross domestic product (GDP) per capita is strongly associated with increased vehicle ownership.[1] Use of automobiles for daily travel, however, varies widely between countries and regions, representing 50% of travel in western Europe and 90% in the United States of America, as compared with 15–30% of trips in many developing countries.[1]

Developing countries are, however, undergoing rapid motorization (Fig. 3). Users are rapidly shifting from walking and cycling to motorcycles and other private vehicles – particularly in cities and regions where public transport systems are too weak to respond to mobility needs.

Urban sprawl and the weak response of public transport/transit systems to changing mobility needs are drivers of increased motor vehicle use in fast-growing economies.

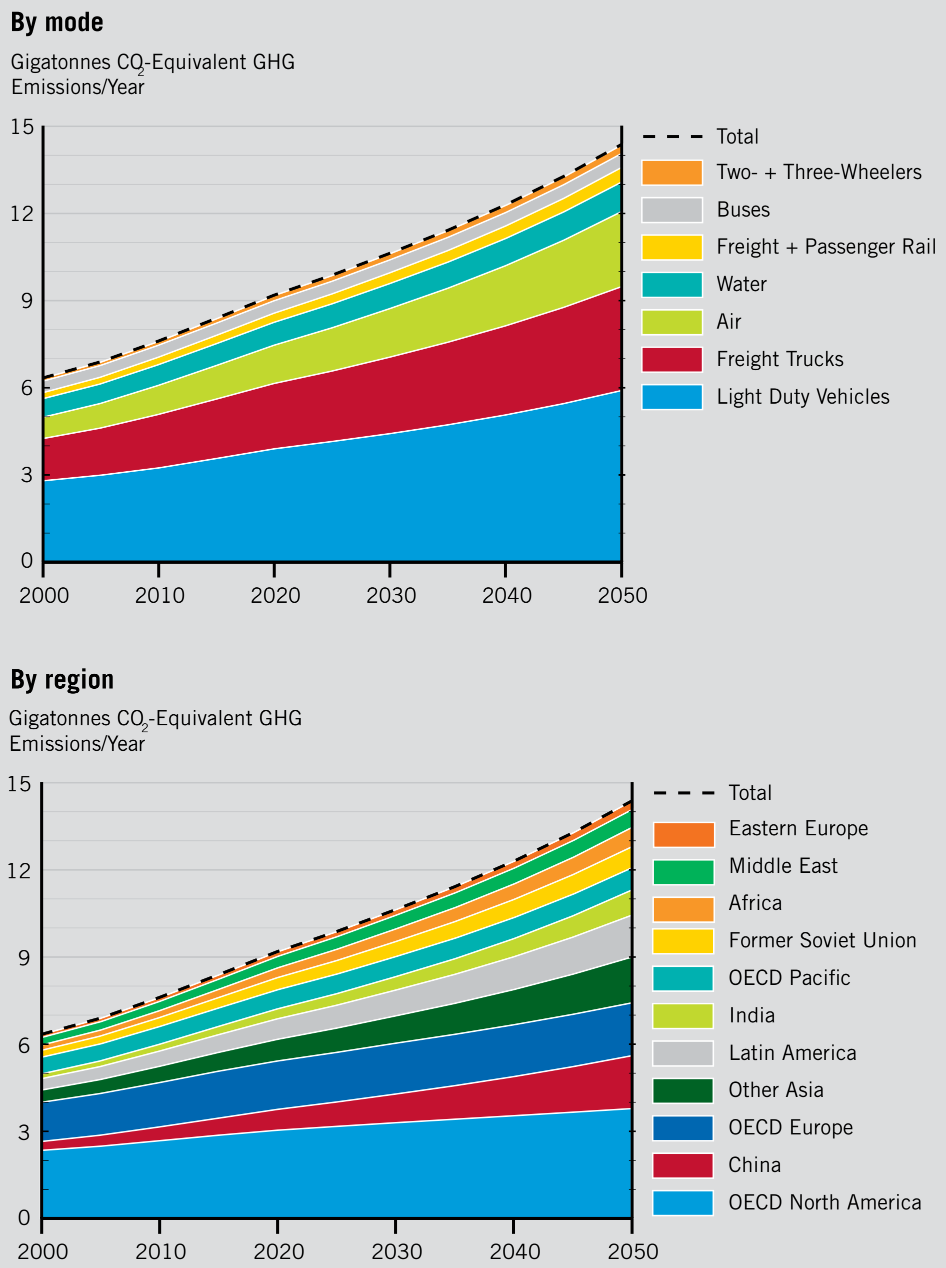
Further large increases in private vehicle travel are expected in coming decades if developing countries continue on the same trajectory. By 2030 the number of vehicles in developing nations is projected to exceed the number in developed countries.[3]

A range of factors are driving increased motor vehicle use, particularly in developing societies, including urbanization and urban sprawl, socio-economic changes, and popular perceptions of private vehicles as indicators of social status and affluence.

However, one key factor is the weak response of public transport/transit systems to changing mobility needs. Users who want to “move up” the mobility ladder often perceive no other choice than to shift from walking/cycling to motorcycles and other private vehicles – to access key destinations with greater efficiency and comfort.

Globally, the number of motorized two-wheeled vehicles has increased rapidly in recent years, nearly tripling between 1990 and 2005.[4] This trend is most pronounced in developing regions, where a motorcycle is more affordable than an automobile. In many Asian cities, motorized two- and three-wheeled vehicles comprise 50–80% of all vehicles, leading to the term “motorcycle cities”.[5] Motorcycles are also rapidly gaining ground in some countries outside Asia, with Uganda experiencing a doubling in motorcycle imports between 2003 and 2006.[5] Four-stroke motorcycles are more fuel-efficient and have lower emissions of GHGs and other pollutants compared with two-stroke motorcycles.[5] However, they are also more expensive. Despite this, cities such as Bangkok have reduced sales of two-stroke motorcycles by phasing in tighter emission standards.[6]

Fig. 3. Transport-related well-to-wheels CO_2 emissions, by mode and region



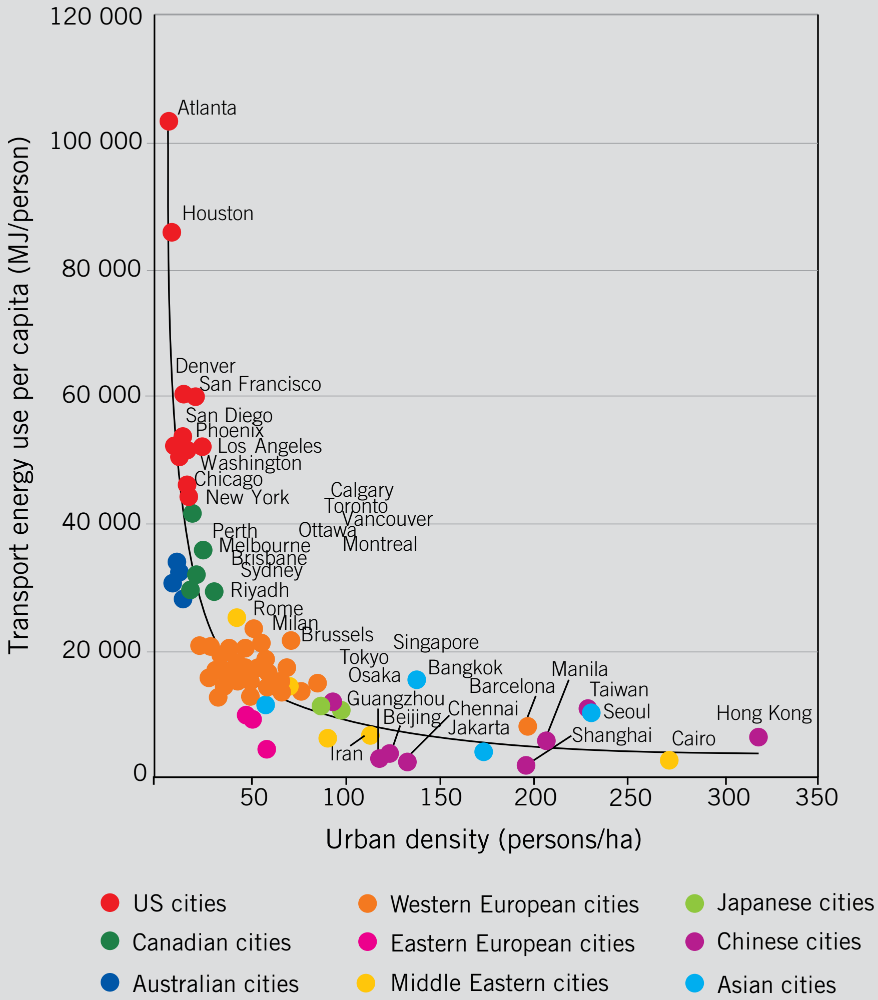
Source: WBCSD, 2004.[7]

Note: Values on y axis represent gigatonnes of CO_2-equivalent GHG emissions per year.

1.2 Urban and rural transport emissions

Although global data comparing urban with non-urban travel are limited, the International Energy Agency estimates that distances travelled by car are about evenly split between urban and non-urban travel, while bus travel is predominantly urban and rail travel is predominantly non-urban. However, non-urban travel is much lower in non-OECD compared with OECD countries.[4]

Fig. 4. Urban density and transport-related energy consumption



Source: International Association of Public Transport Providers, 2005[11]

Urban density is one of the most important determinants of car use[8,9] and transport-related energy consumption in cities (Fig. 4).[10]

1.3 Transport-related emissions by travel mode

Different travel modes and energy sources have very different greenhouse gas (GHG) emissions (Table 3). Notably, even conventionally powered bus and rail have GHG emissions per passenger- kilometre that are at or below the level of electric cars, and well below conventionally powered cars. In addition, walking and cycling (not listed in Table 3) have effectively zero emissions, making active transport and public transport highly desirable modes in terms of reducing GHGs. Negative changes in one factor can outweigh positive changes in other factors, as illustrated by the fact that European transport sector emissions grew by 28% from 1990 to 2007 due to growth in transport volume, despite improved vehicle energy efficiencies.[12] Generally, transport modes with higher GHG emissions also emit more health-harming air pollutants per passenger-kilometre of travel, an issue addressed more in Chapter 2. The exception is private diesel vehicles, which typically emit less CO_2, but more health-harming fine particulates, than comparable gasoline-powered vehicles.[13]

Table 3. GHG emissions from different travel modes and energy sources for developing countries

	Load factor (average occupancy)	CO_2-equivalent emissions grams/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)*	2	30–100
Scooter (two-stroke)	1.5	60–90
Scooter (four-stroke)	1.5	40–60
Minibus (gasoline)	12	50–70
Minibus (diesel)	12	40–60
Bus (diesel)	40	20–30
Bus (natural gas)	40	25–35
Bus (hydrogen fuel cell)**	40	15–25
Rail transit***	75% full	20–50

Source: Sperling and Salon, 2002.[14] Note: All numbers in this table are estimates and approximations.

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

** Hydrogen is assumed to be made from natural gas.

*** 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).

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1.4 Reducing transport-related GHG emissions

Most fundamentally, transport emissions can be seen as a function of three factors: vehicle kilometres travelled, vehicle fuel consumption and fuel carbon intensity (Table 4).[15] Accordingly, strategies to reduce transport emissions can target any of these components. Notably, active non-motorized transport involves no vehicle (e.g. walking) or no fuel consumption (e.g. cycling).

Table 4. Factors contributing to transport-related GHG emissions and potential mitigation strategies

Factor contributing to emissions		Potential mitigation strategy
1.	Vehicle kilometres travelled	Land-use measures to reduce need for travel; mode shift from cars to walking and cycling
2.	Vehicle fuel consumption	Improve vehicle fuel efficiency
3.	Fuel carbon intensity	Electric cars powered by renewable energy

Source: modified from Ewing et al. 2007.[15]

The current potential for GHG emissions reductions is greatest in high-income countries, which generate the largest per-capita transport emissions. But as developing countries are rapidly motorizing, mitigation is increasingly important in those settings, too.

The IPCC report reviews key transport mitigation strategies' potential to reduce emissions and the cost-effectiveness of each – although not their potential to affect health.[1]

As per-capita emissions are the largest in high-income countries, the potential for transport emission reductions is currently greatest in high-income countries. However, since many developing countries are undergoing rapid motorization, mitigation strategies will become increasingly important in those settings as well. In light of prevailing trends, preserving a significant mode share for walking, cycling and public transport will require substantial effort.

Additionally, effective implementation and monitoring of mitigation strategies in developing countries can be impeded by a lack of data and basic information systems. Current travel mode share data are limited in many developing economies, and often fail even to measure travel by non-motorized modes or by the informal public transport sector including privately-owned buses, minibuses and converted pickup trucks. These informal public sector modes are frequently used by low-income groups due to their affordability and relative convenience, although vehicles are often old, unsafe and poorly regulated.[16]

In light of this challenge, the health risks of carbon-intensive transport and the health co-benefits of well-designed transport mitigation strategies may be an important element in transport policy dialogue.

While there are some exceptions, many of the same transport modes that contribute to high GHG emissions also pose comparatively greater public health risks in terms of local air and noise pollution, and water pollution (from vehicle fuel depots and runoff). Motorized transport also indirectly leads to land-use changes that affect GHG emissions and health, and that reinforce car dependence. When compared to public transport, walking or cycling, road and parking infrastructures required by private motorized vehicles require many times more land.[17] This contributes to urban sprawl that further impedes walking and cycling, as well as being a factor in peri-urban land depletion, which leads to the loss of biodiversity and agricultural space. Vehicle waste disposal also creates environmental risks.[18] The ways in which the environmental risks of transport impact on health are discussed further in Chapter 2.

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2

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Motorcyclists stop at a traffic light in northern Nigeria, while a street trader wears and sells face masks to protect them from poor air quality.

Summary of health impacts of transport

Links between transport and health are well-described, and have been extensively reviewed elsewhere.[1–7] This chapter briefly summarizes these links, emphasizing those aspects most relevant to climate change and its mitigation.

Transport can affect health through the process or means of transport (i.e. the journey itself) as well as through the goal or ends of transport (i.e. providing access to destinations). Health effects from the journey may include both risks (e.g. air pollution emissions and noise from motorized vehicles, risks of road traffic injury) and benefits (e.g. the health benefits of physical activity from walking and cycling). Transport also impacts on patterns of access to services and social interaction, which in turn can affect social determinants of health (health equity) and mental health. Typically, transport and health literature has focused more on the health effects of the journey itself, as compared to the health or equity impacts of having good access to services, employment and social opportunities. An attempt is made to reflect the latter set of issues here, as well, framed in terms of social well-being and health equity.

2.1 Air pollution exposures

As well as being a leading source of greenhouse gas (GHG) emissions, the transport sector is responsible for a large proportion of urban air pollution. This has major health implications, with urban air pollution estimated by WHO to cause 1.3 million deaths per year.[8] The evidence regarding the health impacts of these pollutants is summarized below, and described in more detail in WHO air quality guidelines.[9]

2.1.1 Health impacts of key transport-related air pollutants

Transport-related air pollutants that most affect health include small particulate matter (PM_{10} and $PM_{2.5}$). Road transport is also an important source of carbon monoxide (CO), oxides of nitrogen (NO_x), ground-level ozone and benzene.[10]

Overall, higher urban air pollution concentrations increase the risk of cardiovascular and respiratory disease, cancer and adverse birth outcomes, and also are associated with higher death rates (Table 5).[10] Studies of populations with higher exposures to traffic-related air pollution, as indicated by living near a major road (within 200–500 metres), have found that exposed children experienced worse health and development patterns, while adults also had increased morbidity and death rates.[11–13]

Table 5. 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

Source: adapted from Krzyzanowski et al., 2005.[10]

Note: PM: particulate matter generally; $PM_{2.5}$: PM<2.5μm in diameter; VOCs: volatile organic compounds (including benzene); CAPs: concentrated ambient particles

The health impact of small particles is due both to their size and composition. Particles of less than 10 microns (μm) in diameter (PM_{10}) and less than 2.5 microns in diameter ($PM_{2.5}$) are able to penetrate deep into the respiratory system, bypassing usual defences against dust. They may comprise components including carbon or carbon compounds, heavy metals and sulfurs, and carcinogens such as benzene derivatives.

WHO air quality guidelines set health-based values of 20 micrograms per cubic meter (20 μg/m^3) for PM_{10} and 10 μg/m^3 for $PM_{2.5}$, for annual average ambient air pollution concentrations. However, progressively greater rates of morbidity and premature mortality have been observed from annual average air pollution concentrations as low as 8 μg/m^3 for $PM_{2.5}$, and 15 μg/m^3 for PM_{10}.[14] To date, most studies of the long-term health effects of these pollutants in large cities have been carried out in the United States of America and in Europe.[14–16]

Small particles emitted by vehicles are able to penetrate deep into the respiratory system, bypassing usual defences against dust. Particle size, along with composition (it may include heavy metals, sulfurs and carcinogens) explains the large impacts on health.

CO, another transport-related pollutant, may have cardiovascular effects such as exacerbating exercise-related angina, and impaired exercise performance.[17] NO_x exposure can be associated with reduced lung function and increased frequency of respiratory symptoms.[15] Lead emissions from motor vehicles, until recently, were a major source of environmental lead exposure. Lead is highly toxic, especially to children. Although most countries no longer use leaded fuels, in those countries that still do use lead, it remains an important transport-related hazard.

2.1.2 Trends in transport-related air pollution

The highest levels of air pollutants are found today in large developing cities, particularly in Asia, Africa and the Middle East. In these cities, estimated average pollutant concentrations far exceed those in cities of comparable size in developed countries (Fig. 5).

Although the precise contribution of transport to urban air pollution in different regions of the world has not been reviewed systematically, available data suggest that transport is a significant and growing contributor in the developing city context.

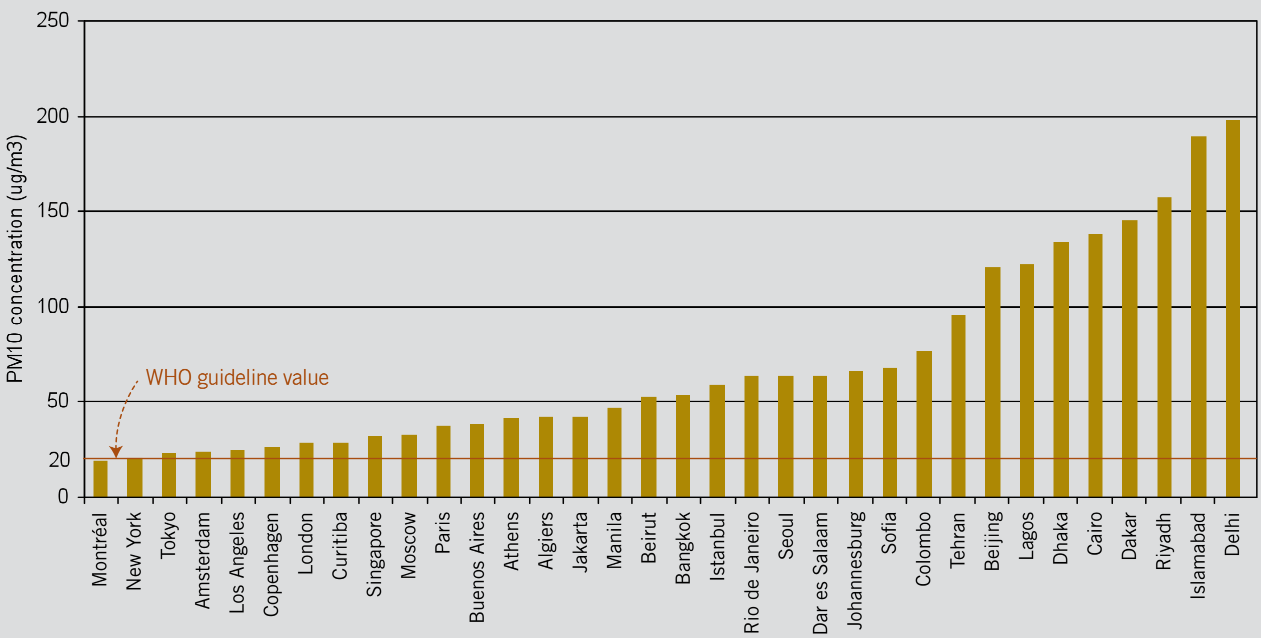
In European cities, road transport is estimated to be responsible for up to 30% of primary $PM_{2.5}$ emissions.[10] Monitoring in major developing cities suggests that anywhere between 12% and 69% of ambient $PM_{2.5}$ concentrations may be attributable to primary vehicle emissions – often this varies seasonally along with rainfall and road conditions.[19] The proportion of emissions attributable to transport in Asian cities has been reported to range from values of 40–98% for CO and 32–85% for NO_x.[20–26]

Along with weak public transport systems and rapid motorization, the high proportion of transport-related pollution in developing cities is often due to factors such as the vehicle fleet age and composition, and a lack of strict maintenance and regulatory regimes.

Motorcycles also account for a substantial proportion of pollutant emissions in many developing cities –because they are both a very large proportion of overall travel and a comparatively polluting mode. Two-stroke engines emit particularly high levels of CO, NO_x and PM_{10}. As noted in Chapter 1, policies to encourage the replacement of two-stroke with four-stroke motorcycles, as well as regulations ensuring regular vehicle maintenance, have significantly reduced pollution from motorcycles in some settings. However, growth in motorcycle traffic is likely to offset such gains. Accordingly, policies to foster lower-emission motorcycles need to be complemented by improved public transport as well as infrastructure for non-motorized modes. With the right package of policies, emerging electric bicycle technologies might combine some of the advantages of motorcycles (e.g. speed) with those of conventional bicycles (no local emissions and moderate physical activity). Policies that encourage shifts to electric bicycles, as compared to motorcycles, might offer a means of facilitating better access while also promoting healthier and lower emission transport modes, although these opportunities have yet to be explored systematically.

In European cities, road transport has been estimated to be responsible for up to 30% of average $PM_{2.5}$ pollution emissions. In developing cities transport's share of particulate emissions varies widely, and often seasonally.

Fig. 5. Average annual PM_{10} concentrations in a sample of large urban areas



Note: Excerpted from WHO's Air Quality Database of over 1000 cities globally. In micrograms/m^3 ($\mu g/m^3$).

Source: World Health Organization 2011.[18]

Heavy air pollution exposures on an Asian street. (Photo: Mark Edwards, Hard Rain)

2.1.3 Reducing disease burden from air pollution

WHO has estimated that reducing average PM_{10} concentrations from 75 µg/m³ (common in many developing cities) to average levels of 20 µg/m³ (the WHO guideline value), would reduce mortality by 15%. Cities with even higher PM_{10} concentrations would experience even greater health benefits from meeting WHO guidelines for PM_{10}.

Thirty years of air pollution mitigation in developed and developing countries have underlined the importance of reducing urban traffic levels, and improving vehicle technologies and fuels, for lower ambient pollution levels and improved health.

In the 32 European Economic Area (EEA) member countries, technical measures led to substantial reductions in pollutant emissions, with PM emissions decreasing by 30% from 1990 to 2007. This is largely attributed to catalytic converters and other technological improvements.[27]

In terms of reduced traffic, one of the most dramatic illustrations of its impacts on air pollution was the recent Beijing Olympics at which stringent restrictions on motor vehicle use were imposed. Compared with the period where there were no measures to improve air quality, asthma outpatient visits were almost halved[28] while $PM_{2.5}$ and PM_{10} concentrations were reduced by 31% and 35% respectively.[29]

Reductions in asthma of a similar magnitude also were observed during the Atlanta Olympics in 1996 when restrictions were placed on motorized travel.[30] Subsequent analysis confirmed that lower rates of respiratory illness during the Olympics were due to reduced pollution, while suggesting that favourable meteorological conditions may have played a larger role than reduced transport.[31]

Modelling studies also have highlighted the co-benefits for air quality, health and climate change that can be derived from transport demand management measures.[32,33] For example, a series published in 2009 in the *Lancet* modelled effects on health from a range of GHG mitigation measures. Within this series, a transport sector study examined scenarios involving shifts to lower-emission vehicles in London and New Delhi, finding substantial health gains from reduced air pollution in both cities, as well as additional gains from physical activity if effective measures to promote more walking and cycling were adopted.[33]

In some countries, tighter motorway speed limits have reduced PM_{10} and NO_x emissions (which are lowest at speeds between 60 km/h and 100 km/h). In the Netherlands, enforcement of speed limit reductions from 100 km/h to 80 km/h reduced PM_{10} emissions by 5–25% and NO_x emissions by 5–30%,[34] as well as reducing ambient PM_{10} and PM_1 concentrations.[35]

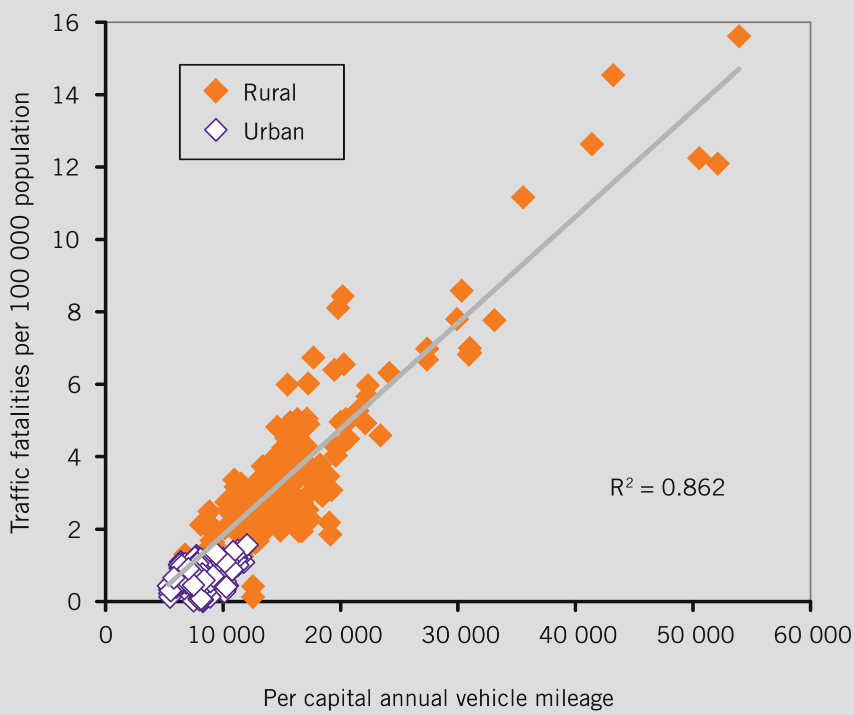
Effective systems for air quality monitoring and enforcement are another critical aspect of air pollution reduction strategies. In developing cities capacity for this often remains limited, and while more monitoring systems have been put into place in recent years they are still noticeably lacking in some regions, particularly Africa.[36] Improving these systems would enable better evaluation of the most critical local pollution sources and their health impacts, as well as monitoring and evaluation of control strategies.

2.2 Road traffic injuries

2.2.1 Health impacts and burden

Road traffic injuries cause 1.3 million deaths[37] and up to 50 million injuries each year.[38] Road traffic injury was the ninth leading cause of death worldwide in 2004 and is projected to rise to the fifth leading cause of death by 2030.[37] Around 90% of road traffic injury occurs in low- and middle-income countries, which often have more hazardous travel environments. Despite the scale of the problem, road traffic injury is considered largely predictable and preventable with the right measures.[38] For instance, vehicle speeds and vehicle kilometres of travel are both important risk factors for road traffic injury. Although per-kilometre traffic death rates have been falling in the United States of America over the last 40 years, due to factors such as safer road infrastructure, per-capita traffic death rates have barely changed because of increases in vehicle kilometres travelled (VKT) per capita.[39] Due to the strong correlation between VKT and road safety (Fig. 6), VKT has been proposed as a proxy indicator for road safety, particularly as traffic injury statistics are often incomplete.[40]

Fig. 6. Vehicle miles travelled and road traffic injury mortality (USA), 1993–2002



Source: Adapted from Litman and Fitzroy, 2010.[41]

Generally, the risk of injury for transit and public transport users is lower. In developed countries, higher transit ridership is associated with fewer road traffic injuries.[39] Cities with strong rail systems have fewer road traffic injuries[42] and, in the United States of America, the injury risk for bus users is much lower than the risk for car users.[43]

Kinetic energy has been described as the key causative agent in road traffic injury[38] and is a function of mass and velocity, both of which are typically higher for motor vehicles than for walkers and cyclists. Thus, if a crash occurs, walkers and cyclists are more likely to be injured than the motor vehicle occupants.[38] The importance of motor vehicle speeds is illustrated by the fact that the risk of death for a pedestrian struck in a 50 km/h collision is about eight times higher than in a 30 km/h collision;[2] interventions to reduce speed (such as 20 mph zones and traffic calming) have significantly reduced injury rates.[44,45]

Motorised two-wheelers are frequently used to transport numerous family members, including children, without proper safety measures such as helmets. (Photo: Satosh Kodukula)

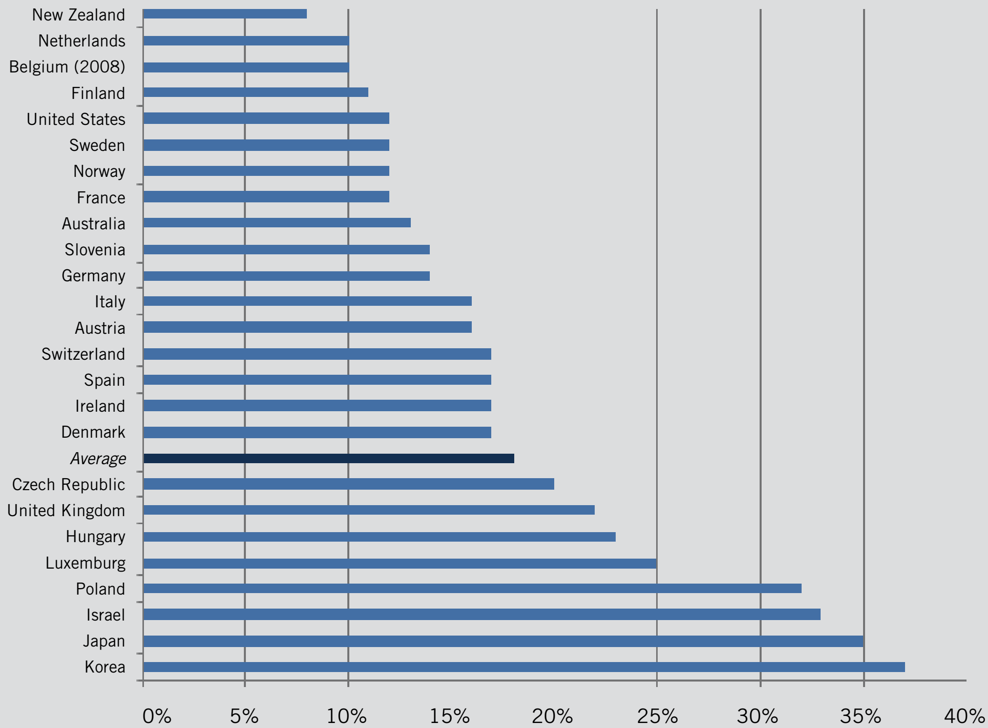
People travelling by foot and bicycle are therefore regarded as "vulnerable road users", as are motorcyclists. Children, elderly and disabled people are at higher risk from transport-related hazards, particularly when forced to travel on faulty sidewalks and in mixed traffic conditions by foot, bicycle, wheelchair, or similar means.[2,46,47] Children also are limited by their own still-developing patterns of spatial judgment, e.g. at street crossings.

Men are often at higher risk of pedestrian traffic injury in comparison to women. In Mexico City, for instance, where some 57% of deaths from traffic crashes in the mid to late 1990s were pedestrians, pedestrian death rates for men were more than twice those for women. A study of over 8000 trauma victims in Tehran hospitals during 1999–2000 also found that more than twice as many men were admitted for pedestrian injuries, and five times as many men died because of their wounds.[47–49] Some of men's increased risk could be related to a tendency to spend comparatively more total time in travel in many societies, commuting to and from work, as well as in the performance of certain jobs e.g. repairs, deliveries, etc. Behavioural studies, however, also have linked men's relatively higher risk to gender-based differences in risk-taking, rule compliance and modes of spatial assessment (e.g. at road crossings).[49]

Globally, a WHO survey found that vulnerable road users account for 46% of road traffic deaths.[50] In Delhi, 75% of road traffic injury deaths occur in pedestrians, cyclists and users of motorized two- and three-wheelers.[19] In many countries, crashes involving pedestrians or cyclists are poorly reported in official road traffic injury statistics, so actual injuries in these groups may be even higher.[51]

The excess injury risk for walkers and cyclists varies widely, however. For instance, cyclist fatality rates per kilometre of bicycle travel in the Netherlands and Germany are only a quarter as high as those in the United States of America, and pedestrian fatality rates are only a tenth as high.[52] This may reflect, among other factors, the more sensitive infrastructure planning for non-motorized travel in European cities. Put another way,

Fig. 7. Pedestrian fatalities as a percentage of all road fatalities in 26 OECD countries (2009)



Source: OECD/ITF (2011), *Pedestrian Safety, Urban Space and Health. Summary Document* (Fig. 2) http://www.internationaltransportforum.org/jtrc/safety/safety.html

pedestrian fatalities form a smaller proportion of road deaths in the Netherlands than in the United States of America – even though the pedestrian share of travel in the Netherlands is many times higher (Fig. 7).

2.2.2 Trends in road traffic injury

Increasing motorization in countries, which occurs with rising per-capita income, has long been known to be associated with rising road fatalities.[38] Higher traffic volumes are a particularly strong risk factor for child pedestrian injury, and decreased traffic volumes are generally accompanied by reduced rates of child pedestrian deaths.[38]

Motorized two- and three-wheeled vehicles, including motorcycles, pose a particularly high injury risk to users. In countries where these vehicles are most common, as many as three quarters of road traffic deaths occur among users of motorized two- and three-wheeled vehicles.[50] In Viet Nam, a 29% increase in the number of motorcycles in 2001 was associated with a 37% increase in the number of road traffic deaths.[38] As motorcycles are a relatively inexpensive means of motorized transport, restraining or reversing increases in motorcycle use in low- and middle- income countries is challenging and likely to require measures that address both demand for motorcycles and supply-side alternatives. Given the rapid expansion of motorcycle use in the last 10–15 years, researchers and policy-makers need to pay increased attention to the issue of escalating motorcycle-related injuries.

2.2.3 Reducing road traffic injury

While user behaviour and vehicle design have traditionally received the most attention from road safety experts and campaigns, the need for safe networks for non-motorized transport, traffic calming, pedestrian crossings and connectivity to key destinations is increasingly recognized. Improved pedestrian road conditions can encourage a "virtuous cycle" that also encourages more walking and cycling.[53] Neglect of pedestrians and cyclists' environmental safety tends to perpetuate a "vicious cycle" of road hazards, making people even less likely to walk or cycle.

In developed countries, higher rates of walking and cycling are associated with lower risks, per kilometre travelled by pedestrians/ cyclists. This may reflect a "safety in numbers" effect, and/or environmental improvements that make people more inclined to walk/cycle.

In developed countries, higher rates of walking and cycling are generally associated with lower injury risks, per kilometre travelled, for pedestrians and cyclists.[54,55] This may reflect a possible "safety in numbers" effect for walking/cycling. However, this association could also plausibly be due to environmental improvements and to the fact that people may be more inclined to walk and cycle in areas that are already safer. Although more walking or cycling may be associated with a comparatively reduced risk per walker or cyclist, in absolute terms total number of injuries may still be higher because walkers and cyclists remain at higher injury risk than car drivers.[56,57] Overall, if a "safety in numbers" effect does exist it can only complement, but not replace, strong environmental measures to prevent injury among vulnerable road users.

Many of the same environmental strategies that have been found to be effective in road traffic injury prevention, such as improved non-motorized transport and public transport networks,[38] also have the potential to reduce GHG emissions. In cities, for instance, lower speed limits can reduce injury risks as well as removing safety barriers to walking and cycling, so that more travel is by non-motorized modes. "Smart growth" land-use policies that reduce the number and distance of people's motorized trips reduce GHG emissions and people's exposure to road traffic injury risk and traffic-related air pollution.[38] Lower speed limits on motorways also can reduce road traffic injury risks, as well as GHG emissions, due to more efficient fuel combustion.[58]

2.3 Physical inactivity, obesity and noncommunicable disease

2.3.1 Health impacts and burden of disease

Lack of physical activity is responsible for over three million deaths per year globally.[59] 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 2 diabetes and some types of cancer. These diseases are no longer just developed country diseases, indeed most noncommunicable diseases (NCDs) now occur in low- and middle-income countries.[60] Rising rates of overweight and obesity are one consequence of inactivity,[60] but physical activity has health benefits regardless of whether or not a person is obese.[61]

Outdoor physical activity may be particularly important, since sunlight exposure can increase people's vitamin D levels. There is increasing evidence that higher vitamin D levels are associated with reduced risks of major diseases such as cardiovascular disease, type 2 diabetes and some cancers.[62] 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 help to maintain both physical activity and vitamin D levels for urban residents.

The effectivness of active travel as a means of integrating more physical activity into lifestyles has been well documented in a body of prior WHO research.[63–65] This is supported by systematic review findings that walking reduces cardiovascular disease[66] and that physical activity also improves many other facets of health (Table 6). 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.[67]

Sunday in La Candelaria, Bogotá, Colombia, when the streets are closed to motor traffic and opened for cyclists until 2 pm. (Photo: Sean Sprague/Still Pictures/specialiststock.com)

Two large epidemiological studies in different world regions (Shanghai and Copenhagen) also showed that cycle commuters have approximately 20–30% lower chance of dying in a year than commuters using other means of transport – even after injury risks and other risk factors were considered.[68,69]

Countries with a higher proportion of trips made by walking, cycling and public transport also have lower obesity rates on average, although such studies do not demonstrate causality.[70] A wide range of confounding variables must also be considered, such as diet and leisure time physical activity.

In polluted urban areas, people who walk and cycle regularly may, however, be exposed to heightened risks of air pollution as compared with car users,[71] due to longer travel times and higher respiratory rates. However, other evidence has found higher exposures for occupants of cars compared with other modes,[72] and overall current evidence is insufficient to conclude whether pollution exposure is generally higher for active

Table 6. Health benefits 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 bone health and for preventing cardiovascular disease and type 2 diabetes**
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**	

Source: US Department of Health and Human Services, 2008.[74]
Key: ** strong evidence; * modest evidence

transport users such as cyclists than for car passengers. In any case, exposure is likely to be dependent on the overall severity of urban air pollution, as well as route (e.g. near traffic or through parks) and relative travel times.

Risk of traffic injury is even more tangible for pedestrians and cyclists as they lack the protective shield of an automobile. Yet even in heavily motorized developed countries like the UK, research has found that health benefits from walking and cycling generally far outweigh its risks. [1, 2,73]

2.3.2 Trends in transport-related physical activity (active travel)

Urbanization and motorization have generally been accompanied by a decline in active travel. For instance, in Beijing, travel by bicycle was reported to have declined from 38% to 23% between 2000 and 2007, while car travel increased from one quarter to nearly one third of the modal split in the same period.[75,76]

Yet, as noted in Chapter 1, wide variations in motorization patterns mean that in some affluent European cities (e.g. Amsterdam and Copenhagen) pedestrian and cycle trips comprise a third of commuting travel.[77] This is in comparison to North American cities, where pedestrian and cycle travel may be 10% or much less.[70]

Compared with motorized transport, walking and cycling both reduce emissions and improve health through physical activity. In car-oriented developed cities and in developing cities with heavy mixed traffic volumes, air pollution and traffic injury mitigation are important to minimize the risks, and maximize the benefits, of active travel.

2.4 Noise

Road traffic is the biggest cause of community noise in most cities. Noise levels increase with higher traffic volumes and higher traffic speeds. Other factors, such as the proximity of the noise source, determine actual human exposure levels.[78]

Community noise exposure has a range of health effects. As well as provoking a more general annoyance response, excessive noise exacerbates stress levels, increases blood pressure, and leads to sleep disturbance.[78] There is increasing evidence that chronic noise-induced stress raises the risk of cardiovascular disease[79,80] and that it negatively affects mental health.[78] Children living in areas with high aircraft noise have been shown to have delayed reading ages, poor attention levels and high stress levels.[81] High levels of road traffic noise have been associated with impaired reading and mathematics performance.[82]

An assessment of the burden of disease from environmental noise concluded that traffic-related noise accounts for over one million healthy years of life lost annually to ill health, disability or early death in western European countries. This burden was due to annoyance and sleep disturbance but also to heart attacks, learning disabilities and tinnitus.[83]

Reducing traffic volumes reduces noise exposures, as well as GHGs, and improves health. Additionally, traffic calming measures, such as lowering speeds and diverting traffic from residential streets, can help support active transport in neighbourhoods, and thus may indirectly reduce noise emissions further by promoting mode shift towards walking and cycling.

2.5 Land-use impacts on health, well-being and social capital

Land-use patterns are key determinants of transport patterns and have both direct and indirect influences on health.[84,85] By determining the proximity of people to their potential destinations, land use influences both distance travelled by motorized transport and the feasibility of non-motorized transport.[86]

Clustered land use, mixing residential and commercial areas facilitates good cycle access, and very high rates of cycle travel, in Amsterdam, The Netherlands. (Photo: Andrea Broaddus)

Patterns of land use also influence the proximity of people to transport hazards such as air pollution, noise and pedestrian injury. Hence, the negative health impacts of transport tend to be concentrated along busy roads and in inner-city areas with high traffic density.[2] 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 GHG emissions per capita.[42]

Systematic reviews have shown that land-use factors are associated with child and youth obesity and, in some studies, with adult obesity,[87] though the variety of measurements used makes direct comparison of studies difficult. As much research on land-use factors and health comes from a limited number of developed countries, more research is needed in other settings.

Cars and roads use up a very large proportion of urban space. Compared with active travel or public transport, this reduces the land available for other uses such as green spaces. Access to green spaces is associated with increased life expectancy[88] and also appears to buffer people's mental health during stressful life events.[89] Green spaces, including woods, parks and lakes provide various forms of air filtering, shade and physiological cooling, and climate control functions that help reduce the "heat island" effect of cities, promoting resilience to climate change.[90] These health implications of land use and urban landscaping are reviewed in more depth in Chapter 4 of this report, as well as in a companion report on housing in this *Health in the Green Economy* series.[i]

There is some research to show that neighbourhoods based around active transport have better social outcomes. Residents on low-traffic streets are more connected to their neighbours,[91] and more "walkable" communities have higher levels of social capital (such as connectedness to neighbours, trust in other people and social engagement).[92] Better social networks and social capital are associated with better health.[93,94]

Active transport can also be discouraged by high rates of street crime.[95] However, certain land-use and built environment features can help deter street crime and promote more positive street traffic. Such features include mixed land use of residential and

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i See "Urban Landscaping." In: Röbbel N et al. (WHO, 2011) *Health in the green economy.* Health co-benefits of climate change mitigation – housing sector. Geneva, World Health Organization, 2011 (http://www.who.int/hia/green_economy/en/index.html).

A pedestrian path in Durban, South Africa draws considerable traffic. (Photo: Luke Reid).

commercial areas, and appropriate street design, e.g. good lighting and other features, such as street windows, that enhance neighbourhood pedestrian appeal.[96–99] Higher residential densities in the United States of America are associated with fewer homicides and lower mortality rates from road traffic injury.[100]

Along with injury exposures, travel can be stressful due to long car trips in traffic[101] or lengthy public transport commutes.[102] Reducing travel times through a combination of improved public transport and better land use can potentially help reduce such stress.[41]

Sustainable land-use planning can be seen as a process to "facilitate allocation of land to the uses that provide the greatest sustainable benefits."[103] Typically, this includes effective use of urban land for more intensive, and less space-consuming, travel modes such as transit/BRT and non-motorized transport.

As well as being important in their own right, there is evidence that cities with more walkable land-use patterns have higher levels of employment productivity. One analysis found that these productivity gains were even larger than the economic savings in terms of health, and reduced health care expenditures, resulting from higher levels of active transport.[104]

These urban characteristics associated with better health and social outcomes, such as higher densities and mixed land use, are often referred to as "smart growth," in contrast to "sprawling" urban characteristics that tend to be associated with worse outcomes. Differences between these two urban forms are described further in Table 7.

In low- and middle-income countries, where most of the world's urban population growth is occurring, cities are mostly growing horizontally, in forms of sprawl. [106,107] Some one third of urban growth is in slums and informal settlements on the urban periphery that lack basic housing, transport and utilities. High-income groups also generate sprawl, however, when they relocate to low-density suburbs on the urban outskirts.[84]

Key distinguishing features of housing in slums and informal settlements are described in more detail in the aforementioned *Health in the Green Economy* report on the housing sector. In terms of infrastructure, slums and informal settlements are likely to be sited in vulnerable locations, e.g. flood plains or mountainsides, and thus highly vulnerable to extreme weather, as well as lacking access to key social and economic opportunities via good public transport networks.[84,85]

Suburbs that are more affluent also often lack strong public transport access – leaving people dependent on motor vehicles. The net results of car-oriented land use over time are more inefficient use of land resources; greater distances between homes, schools and commercial facilities; and still greater vehicle dependency. Sprawl also contributes to other "knock-on" social and equity impacts, such as potentially greater social exclusion and alienation[2] and, in terms of environment, the loss of peri-urban green spaces, agriculture, and potentially greater heat island impacts.

Improved planning of communities on the urban periphery and in metropolitan regions will thus be key to fostering more integrated land-use and transport systems that are socially inclusive, resilient to climate change, less polluting and more energy efficient – and ultimately healthier.

Table 7. Comparing smart growth and sprawl

	Smart growth	**Sprawl**
Density	Compact development	Lower-density, dispersed activities
Growth pattern	Infill (brownfield) development	Urban periphery (greenfield) development
Land-use mix	Mixed land use	Homogeneous (single-use, segregated) land uses
Scale	Human scale; smaller buildings, blocks and roads; more detail, since people experience the landscape up close as pedestrians	Large scale; larger buildings, blocks, wide roads; less detail, since people experience the landscape at a distance as motorists
Public services (shops, schools, parks)	Local, distributed, smaller; accommodates walking access	Regional, consolidated, larger; requires automobile access
Transport	Multi-modal transportation and land-use patterns that support walking, cycling and public transit	Automobile-oriented transportation and land-use patterns that are poorly suited for walking, cycling and transit
Connectivity	Highly connected roads, sidewalks and paths, allowing relatively direct travel by motorized and non-motorized modes	Hierarchical road network with numerous loops, dead-end streets, unconnected sidewalks and paths, with many barriers to non-motorized travel
Street design	Streets designed to accommodate a variety of activities; traffic calming	Streets designed to maximize motor vehicle traffic volume and speed
Parking supply and management	Limited supply and efficient management	Generous supply, minimal management
Planning process	Planned and coordinated between jurisdictions and stakeholders	Unplanned, with little coordination between jurisdictions and stakeholders
Public space	Emphasis on the public realm (streetscapes, pedestrian environment, parks, public facilities)	Emphasis on the private realm (yards, shopping malls, gated communities, private clubs)

Source: Litman 2010.[105]

Healthy land-use and transport systems also are a critical factor in the well-being of people with cognitive, sensory or mobility impairments – who depend heavily on pedestrian and public transport networks to independently access key destinations. Cities and neighbourhoods that are not designed to meet the travel needs of disabled people are, in fact, more likely to exacerbate health inequities for many other population sectors as well – including children, older people, women, and pedestrians.[108] These issues are discussed in the next section.

2.6 Transport impacts on health equity

2.6.1 Gender, age and disability inequities in travel and mobility

Vietnamese teens ride to school in Hanoi. Worldwide, cycling offers many teens an important form of independent mobility. However, cyclists in Asia now have to cope with the risks of increasingly heavy motorcycle and car traffic. (Photo: Thomas Pickard/Aurora/SpecialistStock)

Good access to employment, education, income, health care, community networks, public services, and other social factors are all important influences on health. These are among the "social determinants of health".[109]

A growing body of research focuses on how transport can improve access to many health-enhancing services and networks (particularly for disadvantaged groups) or, conversely, create barriers. Transport thus serves as a critical determinant of "health equity".

Even in affluent and highly motorized societies, many people do not have constant access to a car and others cannot drive. This includes children and most teenagers, many older adults, disabled people and, in varying combinations, students and young adults, many urban dwellers and members of poorer socio-economic groups.[110]

Poor pedestrian environments, including non-existent sidewalks or lack of sidewalk connectivity, obstacles on sidewalks and poor signalling or design of street crossings create severe barriers to walking, and even larger risks for groups such as children and some older people. Children who cannot move about safely and independently on foot and bicycle often become more dependent on their parents for mobility needs, and less physically active themselves. This, in turn, reduces opportunities for children to develop certain cognitive, motor and physical skills – as well as contributing towards childhood obesity risks.[2,111]

The same urban features that impede the independent movement of children also create barriers for older people and people with physical disabilities. Without accessible transportation, people with disabilities are more likely to be excluded from services and social contact, notes the WHO *World Report on Disability*.[108] It refers, for instance, to one survey in the United States of America, where people with disabilities described lack of transportation as a key factor in discouraging them from seeking work. Yet these issues are widely ignored in transport planning. Among 114 countries surveyed in 2005, most did not have accessibility standards for outdoor environments and streets. Even when good public transit does exist, the lack of such "travel chain continuity" for pedestrians generally, and particularly for people with disabilities, severely impedes public transport access.[108] As one practitioner's guide to inclusive BRT systems observes:

> "A major reason why more seniors and persons with disabilities do not use public transit – especially in areas with emerging economies – is simply that they cannot reach transit stops and stations. Roads with no sidewalks at all, broken sidewalks that are not contiguous, sidewalks jammed with vendors, motorcycles operating or parked on sidewalks, and the absence of a culture of safety may come together to sharply limit access to public transit."[112]

Bus transport in Asia. Many women worldwide rely upon public transport for independent access to jobs and services. (Photo: Sinopictures/CNS/Still Pictures)

In many countries, a significantly smaller proportion of women, as compared to men, hold driver's licences. Women who do drive may be less likely than men to have exclusive access to a car and, in some settings, a woman's access to a shared car may also be secondary to that of male household members. In economies where car allowances are a common part of professional remuneration, women wage earners may be less likely to enjoy such benefits if they are clustered in lower-paying jobs. Also, due to their dual role as caregivers, women in many societies travel less than men. When women do travel, they may be more likely to move locally in and around the community and neighbourhood, where good walking and bicycle systems are important.[46] While some societies discourage women from cycling or using public transport, these remain important means of independent mobility for women – insofar as they allow for safe movement to work, shop, and social opportunities.

2.6.2 Socioeconomic equity

Major socially patterned differences in health exist within cities, and many of these are linked to excessive exposure to traffic.[84] In the case of air pollution, for instance, people exposed to higher levels of air pollution tend to be of lower socioeconomic status compared with the urban population as a whole, likely due to the lower value of homes in close proximity to major road traffic.[9] Less affluent urban neighbourhoods also tend to suffer disproportionately from the environmental impacts of urban roads and highways that pass through their communities, carrying commuters from more affluent areas elsewhere.[113] Heavy traffic through urban communities also feeds social isolation and alienation.[91] High-income groups, such as suburban commuters, may be responsible for more of the vehicle-related hazards in the poorer communities that they pass through.

Even though there are significant exceptions (e.g. in many European countries business executives and government ministers are rail and bicycle patrons), public transport passengers in many motorized countries may be disproportionately older or younger, female and/or lower wage earners. Thus, the quality of public transport and non-motorized networks strongly influence the extent to which economic opportunities are available to diverse population sectors. Even in the United States of America, which has the highest rates of car ownership globally, lack of car access has been associated with lack of geographical access to employment, and greater unemployment risk.[114]

Active transport (walking and cycling) is generally free or low-cost, while motorized transport (especially private car use) is typically much more expensive.[19] According to economic theory and the income elasticity of demand, high prices disproportionately reduce consumption for low-income groups. In developed countries, private vehicles often remain out of reach for many low-income households.[46] In the developing world, as IPCC notes, public transport remains inaccessible, or unaffordable, to many people. Commuting by public transport in Manila, for instance, was estimated to use 14% of the income of the poor, and only 7% of non-poor.[58] Low-income workers also often spend disproportionate amounts of time commuting compared to higher-income groups.[115]

Cities that require private motorized transport to access essential goods, services and other health needs, while neglecting development of efficient transit services, indirectly subsidize the travel modes of high-income groups more than the majority of other transport users. Investment in roads can thus disproportionately benefit the well off, particularly in metropolitan areas. Active, non-motorized transport and low-cost public transport are more equally accessible across all social groups.

On a global scale, as well, inequities between countries exist. It is well-recognized that high-income countries have experienced most of the economic development benefits from activities that emit GHGs, including motorized transport, while low- and middle-income countries are likely to bear most of the health burden from climate change.[116]

Many of the newest low-emission vehicle technologies will be more expensive than existing technologies.[58] Thus newer, cleaner vehicles are likely to be adopted first in high-income settings, with poorer communities the last to benefit from pollution reductions. Older, more polluting vehicles that are imported at low prices from developed countries can add to the health risks of developing cities, particularly if there is a lack of infrastructure and capacity for adequate vehicle maintenance as well as control of fuel quality.[117] This, in turn, contributes to higher air pollution exposures and injury risks. A few countries also continue to use leaded gasoline.[19] Thus, without appropriate policies, low- and middle-income countries risk becoming "pollution havens" for older vehicles, even more so than they are, as well as for dirtier, and less safe modes of transport.

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3

Ron Giling/Brazilie Lineair/Still Pictures

Curitiba, Brazil, was one of the cities that pioneered bus rapid transit (BRT). Here a bus shelter protects passengers from weather and improves flow. But steps into the station can create obstacles for people with disabilities, or parents pushing strollers.

Evaluating health benefits of transport-related greenhouse gas reduction strategies

3.1 Introduction

It is well-recognized that policies outside the health sector can have profound implications for health.[1] Thus a policy with a particular primary goal (e.g. reducing greenhouse gas (GHG) emissions from the transport sector) may also have additional co-benefit effects, some of which may be health effects. A recent *Lancet* series reviewed and quantified health co-benefits from mitigation strategies in several sectors including transport in case studies from developed and developing cities.[2]

At global levels, however, health co-benefits have not been systematically studied in the context of mitigation policies. This omission is the most striking aspect of the IPCC assessment, which is expected to synthesize the best available scientific knowledge on mitigation options for the transport sectors. Important health risks and benefits are associated with transport mitigation strategies discussed by IPCC. Without broad analysis of those risks and co-benefits, the full accounting of costs and benefits to society of strategies to be undertaken remains incomplete, and transport mitigation decisions will be ill-informed.

This analysis takes an initial step in the direction of more systematic appraisal. It assesses the health co-benefits of the main mitigation measures considered by the IPCC (Table 8). The health evidence is discussed in terms of the three main categories of transport

Table 8. Selected transport sector policies, measures and instruments shown to be environmentally effective in multiple national cases, as summarized by IPCC

Category title (as used in this report)	Policies, measures and instruments shown to be environmentally effective	Key constraints or opportunities
Modified vehicles & fuels (IPCCa)	Mandatory fuel economy/CO_2 standards for road transport; shifts to lower-carbon fossil fuels, biofuels, CNG & hybrid/electric vehicles; other vehicle design modifications	Partial coverage of vehicle fleet may limit effectiveness
Modified pricing of vehicles, fuels, infrastructure (IPCCb)	Taxes on vehicle purchase, registration, use; taxes on motor fuels; road and parking pricing; congestion/area pricing	Effectiveness may decline with higher incomes
Land-use changes and/or mode shifts from private to public/transit and non-motorized modes (IPCCc)	Influence mobility needs through land-use design/regulations and infrastructure planning; prioritization of, and investment in, public transport and non-motorized transport infrastructure and amenities	Particularly appropriate for countries that are building their transportation systems; or cities undergoing rapid expansion

Source: adapted from IPCC Working Group III *Summary for Policymakers*[6] (Table SPM.7) and *Climate Change 2007: Synthesis Report*[7] (Table 4.2).

mitigation strategies identified by the IPCC: (i) modified vehicles and fuels; (ii) modified pricing of vehicles, fuels and infrastructure; and (iii) land-use changes or mode shifts from private to public transport and/or non-motorized transport.

Based on this broad review, the types of health co-benefits, or risks, arising from each mitigation strategy, as well as the relative expected magnitude of benefit/risks, are presented.

3.1.1 Characterization of the health literature

As noted in the *Introduction* (methods) of this report, literature about health impacts is reviewed primarily in terms of evidence regarding increased/reduced i) environmental health risks and evidence of ii) increased/reduced disease – with targeted references to health equity and summaries of relevant literature – as identified in the broader search. Most of the health-oriented studies identified in the literature search are observational epidemiological studies, especially cross-sectional studies, as well as several cohort studies. The cross-sectional studies use a combination of individual and ecological variables, with some multilevel analyses. There are also some evaluations of interventions, including randomized controlled trials, but these are less common. It should be emphasized that while, in biomedical research, randomized controlled trials are commonly regarded as providing the most robust evidence of causation, there are many practical barriers to using this design in research into the environment health risks of transport and land-use factors.

The review also identifies several mathematical modelling studies, which are used, in particular, to assess future population health outcomes under different transport and land-use scenarios. Limitations in the health analysis are discussed in more detail in Section 3.6.

3.1.2 Characterization of the mitigation literature

In each section, key IPCC findings for each mitigation strategy are summarized and followed by a discussion of the strategy's "mitigation potential."

Mitigation potential refers to the amount of GHG emissions that can be reduced cost effectively, as measured by cost per tonne of CO_2. In the IPCC review, mitigation is considered cost effective if the price of emissions reduction is less than US$ 100 per tonne of CO_2 (US$ 100/tCO_2).[i] Mitigation potential is thus an important measure of what strategies are realistic in terms of implementation and scale-up, as reflected in cost effectiveness.

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i The mitigation potential of a particular strategy is typically influenced by a number of factors beyond the GHGs emitted by the travel technology. These include: current and overall future demand for travel, modal split of travel, and vehicle capacity estimates. GHG emissions are typically assessed in terms of passenger kilometres (passenger-km) of travel to account for variances in vehicle occupancy rates, e.g. in terms of CO_2-eq (carbon dioxide-equivalent) emissions per passenger-km of travel. Average CO_2-eq emissions per passenger-km of travel tend to vary widely between developed and developing countries as a result of variations in vehicle fleets, age of vehicles, typical passenger loads, and urban and rural driving conditions. Demand for travel is also extremely important, as strategies that reduce distances travelled (vehicle kilometres travelled, VKT) can lower emissions at least as much as strategies that reduce emissions per passenger-km.

A key limitation of the IPCC assessment of mitigation potential is that information on the global potential for vehicle fuel and technology change was derived largely from two major studies. These studies were *World Energy Outlook*[3] and *Mobility 2030*,[4] the latter sponsored by the World Business Council for Sustainable Development (WBCSD), a CEO-led global organization of some of the world's major corporations, including the oil and automobile industry.[ii]

In this report, IPCC-identified assessments of mitigation potential for land use and mode shift to public transport, walking and cycling were thus supplemented with other estimates from the peer-reviewed literature, where available. However, this review found no global studies, and only a few regional and local-level studies, that look systematically at climate change mitigation potential either for modal shift towards public transport, walking and cycling, or for land-use changes. The studies that are cited here also have widely varying scopes and assumptions, especially about the feasible scale of mode shift and land-use change.

This limited availability of global, or even regional, analysis of mitigation potential for land-use and mode-shift measures appears to reflect a major gap in mitigation assessment overall. Given the large potential health co-benefits of these measures, they should receive much greater attention in future assessment of transport sector mitigation potential.

Inclusion of life-cycle processes could significantly alter estimates of emissions, and thus mitigation potential, for modified fuels and vehicles. Compared with estimates that focus only on vehicle operation (such as fuel consumption), estimates including non-operational factors (such as vehicle manufacture and infrastructure requirements) can sometimes increase estimated emissions for motor vehicles by over 50%.[5]

The IPCC review of mitigation potential refers to the WBCSD's assessments of "well to wheel" emissions associated with fuel extraction and production/distribution. This type of assessment, as defined,[iii] does not include emissions associated with the production of transport vehicles, the materials used in them, or those associated with building infrastructure such as roads.[4] An incomplete consideration of life-cycle emissions for modified vehicles and fuels also would have important implications for comparisons of the mitigation potential and cost-effectiveness of those strategies with mode shift to non-motorized/public transport and land-use changes.

[ii] WBCSD website: http://www.wbcsd.org/about/members.aspx

[iii] Noted in *Mobility 2030* as follows: "Transport emissions are assumed to include not only direct emissions from the combustion of fuel used by transport vehicles but also emissions associated with the production and distribution of transport fuels – i.e. "well-to-wheel" (WTW) emissions," and "It should be noted that these projections are "well to wheels" (or WTW) projections, in that they include not only the emissions produced by the operation of transport vehicles, but also emissions generated by the extraction, processing, and distribution of the fuels used by these vehicles. However, they do not include emissions involved in the production of transport vehicles and the materials used in them."

3.2 Modified vehicles and fuels (IPCCa)

3.2.1 Summary of IPCC-reviewed mitigation measures (IPCC 5.3.1.1–3, 5.5.1.4)

The IPCC considers that prospects for transport mitigation are "strongly dependent on the advancement of transport technologies", and considers technological improvements to be the most promising mitigation approach in the near term. The chapter identifies several strategies involving modified vehicles and fuels that may reduce GHG emissions. In particular, the IPCC emphasizes improving drive train efficiency (IPCC 5.3.1.2), using diesel and alternative fuels (IPCC 5.3.1.3), while imposing tighter fuel economy standards for road transport (IPCC 5.5.1.4). Reducing vehicle loads (such as by using lightweight materials in vehicle construction, IPCC 5.3.1.1) and more fuel-efficient driving techniques ("eco-driving" including reduced idling, IPCC 5.3.1.6), may also improve fuel efficiency – as may labelling requirements for vehicle fuel efficiency, vehicle maintenance requirements and lower speed limits on motorways (IPCC 5.5.1.3).

Drive train efficiency can be improved by the use of advanced direct injection diesel or gasoline engines, improved transmissions, reducing idling, and hybrid-electric drive trains. Alternative fuels include biofuels such as ethanol and biodiesel, compressed or liquefied natural gas (CNG, LNG), hydrogen fuel cells and electric vehicles. Among these, the IPCC emphasizes the very immediate gains that could be achieved from shifting from gasoline to diesel-powered vehicles in terms of fuel economy and reduced CO_2 emissions. Fuel economy standards (and CO_2 emission standards), which vary widely between countries, also are emphasized as a measure to improve the fuel efficiency of the vehicle fleet. The IPCC notes that CNG engines have been popular in polluted cities because they reduce local pollution emissions. Although the IPCC assessment notes that modern gasoline vehicles can compete with CNG in terms of local emissions reductions, that would likely not be the case for diesel.

CNG fueling station.
(Photo: CNG Holdings)

3.2.1.1 Mitigation potential from modified vehicles and fuels

The IPCC estimates that these strategies could reduce global emissions from light-duty vehicles (LDVs) in 2030 by about 800 $MtCO_2$ (about 21%) compared with business-as-usual scenarios. IPCC estimates that 718–766 $MtCO_2$ could be achieved at a cost less than US\$ 100/tCO_2 and up to 697 $MtCO_2$ at costs less than US\$ 0/tCO_2 (i.e. using cost-saving measures).[8] Even with these reductions, however, there would be a 26% rise in emissions compared with a 2000 baseline due to increased traffic and travel. A persistent issue in the transport sector is that, in the absence of other travel demand management or modal shift measures, fuel efficiency gains are typically overwhelmed by increased emissions due to growth in travel; these scenarios are no exception.

IPCC also cites estimates of the mitigation potential of shifts to biofuels in the transport sector, reflecting a possible mitigation potential of between 600 and 1500 $MtCO_2$ in 2030 at a relatively low cost of less than US$ 25/tCO_2.[8]

Wright and Fulton (2005) estimated mitigation potential for different fuels in a study intended to inform climate change mitigation in developing country settings. By applying International Energy Agency cost estimates for advanced technologies, they found that converting buses from diesel to compressed natural gas (CNG) could reduce CO_2 emissions by 0–10% at costs of US$ 442 or more per tonne of CO_2 (although local pollutant emissions of CNG would be substantially lower than diesel). Converting diesel buses to hybrid-electric vehicles could reduce CO_2 emissions by 5–20% at costs of between US$ 148 and US$ 1912 per tonne of CO_2; conversion to fuel-cell vehicles could reduce CO_2 emissions by 30–75% at costs between US$ 463 and US$ 3570 per tonne of CO_2.[9]

While studies like that of Wright and Fulton, for instance, suggest that CNG is not cost effective as a mitigation strategy, CNG vehicles and fuels are in fact being used very widely in south and south-east Asia, the eastern Mediterranean region (Islamic Republic of Iran, Pakistan and Egypt) and Latin America, presumably due to their greater immediate fuel cost advantages as well as a comparatively lower urban pollution emissions profile.[10,11]

The mitigation potential of different technologies is cited here as a means of framing the review of health impacts from alternative fuels, presented just below. What is very clear, however, is that much more systematic exploration of the most current technologies and their potential for use is vital, not only in terms of better defining GHG mitigation potential but also in terms of better defining how different alternative fuels and modified vehicles may impact serious health risks such as urban air pollution exposures.

3.2.2 Health impacts of mitigation measures

3.2.2.1 Impacts on environmental risks/disease outcomes

Historically, the last two decades of improved vehicles and technologies have helped mitigate some major health impacts of vehicle travel, namely air pollution and injury. The United States of America's Clean Air Act was found to reduce the negative impact of fuel consumption on cancer and cardiovascular disease – this was attributed largely to improvements in vehicles and fuels.[12,13] More recently, one modelling study of cities in the Americas found that implementing a range of readily available technologies to reduce GHG emissions would also lead to substantial reductions in mortality and morbidity, although the scenario covered policies not just for transport but also for housing, industry and the energy sector.[14]

This review identified relatively few studies directly assessing the health impacts of vehicles or fuels modified to reduce GHG emissions. Most of those identified focused on health impacts in terms of air pollution exposures. While a few studies related to injuries were identified, a more focused search using specific keywords related to this topic area would be useful. There is also a large body of work addressing the health impacts of biofuels, which is briefly discussed.

Modified fuels – diesel

A key element of the IPCC assessment is the immediate potential to shift from gasoline to diesel fuels. Such shifts could, however, worsen human exposures to health damaging small particles (PM_{10} and $PM_{2.5}$). Diesel fuels are a primary source of exposures to these small airborne particulates in cities and the primary transport source.[15] As noted in Chapter 2, there is a direct correlation between levels of particulate exposures and premature mortality, and exposure to even "low" particulate levels (below guideline values) is associated with health risks.[16] Diesel particles also contain black carbon, a short-lived climate change pollutant – although biomass combustion is a more important source.[17,18]

An older diesel bus belches heavy exhaust on the road from Addis Ababa to Debre Lebanos, Ethiopia. (Photo: iStockphoto)

Moreover, diesel exhaust has been identified as a probable carcinogen,[19] although the evidence supporting this is still contested by some.[20] There is less evidence to suggest that gasoline exhaust is carcinogenic.[19] Among studies that separately assess the effects on health of diesel and gasoline exhaust, some find no difference[21,22] but at least one study has associated lung cancer with exposure to diesel, but not gasoline, exhaust.[23]

Only a few researchers have attempted to quantify the likely air quality impacts of a major shift to diesel vehicles. Mazzi and Dowlatabadi (2007) modelled the air quality impacts of British consumers switching from gasoline to diesel cars. They estimated that this would increase premature mortality related to particulate matter by up to 570 excess deaths annually per Mt/CO_2 abated (depending on the emissions profile of the vehicles in question).[24]

Jacobson et al. (2004) modelled the effects of converting the United States of America's gasoline-powered fleet to modern diesel vehicles, and concluded that such an approach may increase photochemical smog.[25]

The extent to which shifting from gasoline to diesel will worsen health is likely to be strongly dependent on the strength of the environmental standards applied to diesel vehicles and fuel, especially with respect to PM filtering and sulfur content.[16] However, it is notable that even when tighter particulate emissions standards are applied these can be overwhelmed by increased diesel traffic. This is evident from experience in European cities over the last decade. Despite the introduction of much tighter diesel particulate emissions standards, large vehicle fleet shifts to diesel were associated with stable (instead of lower) PM_{10} levels, and no improvement in air quality-related health impacts.[26]

The IPCC also notes that vehicles powered by CNG can provide relatively low greenhouse gas emissions for fossil-fuel powered vehicles. As already noted, CNG vehicles are already widely used in many low- and middle-income countries due partly to lower fuel costs.[10,11] But CNG for buses or taxis has also been promoted and, in some cases, required explicitly as a means of reducing urban pollution emissions (e.g. all public buses in New Delhi, India; auto rickshaws in Dhaka, Bangladesh).

In comparison with diesel buses, CNG-powered vehicles in service have generally been found to produce significantly less health-damaging particulate pollution. One study estimated that an urban bus powered by CNG emitted 30 times less particulate matter than a diesel-powered bus.[27] The IPCC assessment, on the other hand, notes that the most modern gasoline vehicles can achieve local pollution reductions comparable to CNG – although they do not evaluate this in detail in terms of the pollutant profiles of the different vehicle types. While this is highly technology dependent, nevertheless the available evidence suggests a significant health benefit for CNG vehicles in the public transport and freight domain where diesel is commonly used. This is a finding compatible with the emphasis that many countries have already placed on developing CNG bus and light-duty freight vehicle fleets.

Modified fuels – biofuels

The IPCC also suggests that shifts to biofuels in the transport sector may have significant mitigation potential, particularly in terms of cost effectiveness. Biofuels are already being introduced widely into the transport sectors of many countries, with many governments promoting their production at a national level through mechanisms such as targets, mandates and subsidies.[28] They also receive much IPCC attention as a transport mitigation measure[8] yet their full impacts on GHG emissions are still unclear, as are their impacts on non-climate domains such as health.

In terms of air pollution, this review identified one study suggesting that although introducing biodiesel in Belgium could reduce particulate emissions, it was not a cost-effective strategy for achieving this goal.[29] Another study – a comparison of cellulosic and corn ethanol with gasoline – found that while cellulosic ethanol could potentially reduce $PM_{2.5}$ and GHG emissions, corn ethanol may increase $PM_{2.5}$ emissions without reducing GHG emissions.[30]

However, there are also growing concerns about the health risks associated with the increased use of biofuels in transport, which can occur when food cropland in poor countries shifts from food to fuel production. If such shifts result in a net increase in basic food commodity prices and/or reduced quality, diversity and affordability of local food sources, then food security and nutrition suffer, particularly among the world's poor. A brief summary of this issue, by no means exhaustive, is presented here (Box 2). These issues require special attention among mitigation analysts in both the transport and the agriculture sectors.

Modified vehicles

There is a large body of literature, historical and more current, examining how vehicle improvements such as seat-belts, air bags and certain "passive" body design features have helped reduce injury risks to passengers and pedestrians – although their effectiveness also depends on environmental conditions and user behaviour.[44]

More recently, there has been speculation that lighter, more fuel-efficient modified vehicles, driven at somewhat lower speeds, would have injury reduction co-benefits – but much more so in truly "low carbon" scenarios where less travel was in private vehicles and more by non-motorized modes.[45–47]

In terms of air pollution, bus fleet improvements (including both vehicle and fuel modifications) were found to substantially reduce associated mortality from $PM_{2.5}$ in one study.[48] In another study, bus rapid transit (BRT) systems were predicted to influence passenger exposure to air pollutants by reducing the penetration of emissions from surrounding traffic. Exposure of bus passengers to CO, benzene and $PM_{2.5}$ was reduced after implementation of a new BRT system in Mexico City in which new vehicles replaced older minibuses and buses.[49] Many of these same new vehicles, however, include better particle filters. In a separate study, installation of particle filters on heavy-duty trucks

Box 2. Potential impacts from biofuels

At the global level, biofuel production that displaces food production may reduce global food availability and increase food prices.[31,32] One analysis suggests that actual national plans for biofuel expansion could lead to price increases for food staples of 8–26%, and increase global child malnutrition by 4%.[33]

Biofuel production may carry local risks for those producing fuels. Energy crops require water, which in situations of water scarcity could reduce the availability of water for other important uses including drinking, cooking, sanitation and irrigation of local food crops.[33,34] Poorly managed use of inputs (including fertilizers) could also pollute water supplies.[35–37] If biofuel demand is high, high-value energy crops could replace lower-value food crops, reducing local food security.[33] Cultivation of biofuel crops may carry associated occupational health and safety risks; these are particularly well-described for sugar-cane production.[28,38]

The effectiveness of biofuels in mitigating climate change also influences their long-term health impacts, given the health risks posed by climate change. While estimates vary, biofuel production may only minimally reduce GHG emissions as they may only replace a small share of global energy supplies and offer small energy efficiency gains over gasoline.[28,33,39] Of critical importance, clearing natural vegetation for biofuel production mobilizes its carbon stocks, which are especially large in the case of tropical forests on peatland. The carbon debt incurred by such clearances can render mitigation benefits of biofuels questionable for decades to come.[28]

Some strategies for biofuel development appear more environmentally sound and pro-poor than others. Using crop residues to produce biofuels may help provide farmers with additional income from crops and communities with cheaper energy, while also competing less with food crops, thereby reducing impacts on food availability and prices.[33,40]

Standards and certification methods have been developed to promote sustainable bioenergy production, although greater efforts are needed to ensure these schemes address all relevant life-cycle impacts such as emissions and environmental outcomes.[28] In addition to direct impacts on health, indirect impacts through land-use changes are not sufficiently addressed by these methods. For instance, growing energy crops on marginal land not suitable for food production may be a useful strategy but such crops must not accelerate soil erosion or degrade water quality, which in turn produce health impacts.[33,41] Use of crop residues for biofuels also could divert feed stocks used by the poor in livestock production.

In comparison to large biofuel undertakings (whose products are more likely to be sold on national or international markets), smaller-scale and rural-based production may generate more benefits for the poor, including for their health, as well as posing less of a threat to small-scale farming upon which food security may depend.[28,34,42,43] It is also necessary to establish whether biofuels can be produced without contributing to the further clearance of more natural vegetation elsewhere. If biofuel production results in deforestation, either by directly replacing forest or by increasing the overall level of demand for arable land, the overall climate impacts of increased biofuel production could be negative – forests typically sequester more carbon than agricultural land so the loss of sequestered carbon could be greater than the reductions in transport fuel emissions.

and local buses was, in fact, predicted to worsen fuel efficiency and CO_2 emissions – although it was indeed a cost-effective strategy for particulate reduction.[29]

As per the discussions of fuels above, this vividly illustrates the tradeoffs between health and GHG emissions that can be particularly problematic in scenarios that emphasize greater dependence on present-day diesel technologies.

Shifts to more fuel-efficient and less polluting vehicles in London and New Delhi were, nonetheless, predicted to improve health in a modelling study by Woodcock et al. (2009). The scenarios examined average PM and CO_2 emissions factors for current and theoretical future vehicle fleets, presuming adoption in New Delhi of recent European emissions standards and a shift in London to smaller, lighter vehicles than those in use now. Health benefits for the scenario involving improved vehicles were, however, significantly lower than benefits in a scenario involving greater mode shift from motorized to non-motorized travel (see section 3.4.2.2.).[50]

Electric vehicles also can potentially offer substantial local air pollution reductions and fewer health impacts when compared with conventionally fuelled vehicles, particularly in heavily trafficked urban areas.[8] One modelling study that examined the effect of replacing diesel buses with electric buses estimated that such a shift could avoid 140 deaths annually from PM_{10} pollution in Tel Aviv-Jaffa, which has relatively high rates of PM_{10} pollution in comparison to many other developed cities. The study also found that anticipated health benefits of the electric buses would offset, considerably, the health impacts of pollution from the fossil fuel electricity generation required to power the vehicles. This was due partly to the fact that the power station's own pollution emissions were subject to better technological control as well as being somewhat further removed from a population centre, and also subject to a certain atmospheric drift (e.g. in this case out to sea).[51]

The study illustrates one of the issues to be considered in terms of the total co-benefits of electric vehicles, which are likely to depend on a local source of electricity generation. Therefore, vehicles powered by fossil fuel power plants in closer proximity to population centres might not offer the same pollution emission reductions as those powered by a cleaner alternative fuel, or facilities further away. Moreover, this discussion does not consider electric car manufacture's life-cycle impacts on health or environment. Nevertheless, insofar as separating emission sources from people can improve health then electric vehicles could potentially offer some health co-benefits in terms of air pollution exposures.

Portland, Oregon, USA: An electric vehicle plugged in at a charging station near Portland State University. This is one of seven car chargers that exist on a whole city block, coined "Electric Avenue" in Portland. (Photo: iStockphoto)

Typically much quieter than conventional vehicles, electric vehicles could also potentially reduce community noise levels, although this review identified no studies of this potential effect. However, as pedestrians and cyclists rely on both visual and auditory cues to avoid collisions with motor vehicles, it is possible that very quiet electric vehicles could heighten injury risks for vulnerable road users. People with visual impairments could be particularly at risk.

In summary, the potential of modified, fuel-efficient vehicles to reduce air pollution is relatively apparent, despite the relative lack of studies found by this review. However, there were no studies indicating that low-carbon vehicles (or fuels) would affect health through pathways other than air pollution. It has also been noted that VKT (vehicle kilometres travelled) growth may offset reductions in pollutant and carbon emissions from improved vehicles or fuels.[26,52] In addition, motor vehicles that consume less fuel have lower running costs, which could incentivize motorized travel (a "rebound effect").[53] Increased motorized travel would have negative health impacts, as reviewed in Section 3.3.2.3. Uncertainties remain in some areas – the air quality impacts of biofuels in particular remaining unclear, as well as their immediate and long-term impacts on food security. Some strategies to reduce GHG emissions, particularly switching from gasoline to diesel, may pose health risks. The impacts of quieter electric cars on noise and injury risks require further investigation.

3.2.2.2 Impacts on health equity

This review found no studies directly assessing the impacts of modified vehicles or fuels on health equity. However, insofar as improved vehicles are more expensive, they are less likely to be purchased by low-income populations, and their introduction into rapidly motorizing low-income countries is more likely to lag. As car ownership is higher in high-income populations, reductions in air pollution from more fuel-efficient or electric vehicles are likely to improve air quality more in high-income areas. However, as low-income populations are more likely to live next to roads with high traffic volumes, if improved vehicles penetrate into local traffic then the benefits in terms of air pollution could be comparatively greater for households living adjacent to major roads.

3.3 Modified pricing of vehicles, fuels and infrastructure (IPCCb)

3.3.1 Summary of IPCC-reviewed mitigation measures (IPCC 5.5.1.2)

As described by the IPCC: "transport pricing refers to the collection of measures used to alter market prices by influencing the purchase or use of a vehicle. Typically measures applied to road transport are fuel pricing and taxation, vehicle license/registration fees, annual circulation taxes, tolls and road charges and parking charges."

Pricing measures that affect the price of travel can influence travel demand, and thereby GHG emissions. As the IPCC also notes, "many countries do heavily tax motor fuels and have lower rates of fuel consumption and vehicle use than countries with low fuel taxes." Public transport pricing may also have important effects on its utilization, although the IPCC discussion of transport pricing focuses on private motorized transport and freight, with little attention to transit pricing or the impacts on public transport of pricing strategies that target other travel modes.

Some pricing measures differentially target vehicle or fuel types. For example, vehicle registration/circulation charges may be set at a lower level for fuel-efficient vehicles than for inefficient vehicles. This differential pricing primarily alters the relative use of different vehicle types rather than the overall amount of travel. However, if the net effect is to change the average cost of travel (e.g. subsidizing biofuels, without changing the cost of other fuels) then travel demand may also be affected.

Buying a public transport ticket in the Netherlands. Pricing policies can be used to reduce greenhouse gases and pollution emissions from private vehicles – although public transport needs to be efficient and affordable to avoid health risks and inequities. (Photo: Tom Koene/Still Pictures)

3.3.1.1 Mitigation potential from modified pricing of vehicles, fuels and infrastructure

The IPCC-reviewed literature highlights several approaches that have successfully reduced CO_2 emissions, energy use and vehicle travel. Most of the measures identified involved pricing to achieve mode shift rather than pricing that increases use of improved vehicles and fuels. One of the oldest examples of congestion pricing is the area licensing scheme introduced in Singapore in 1975 involving a fee to enter a restricted zone during the morning commuting period. It reduced car traffic by 75%.[54]

The London congestion tax, which uses cameras to automatically levy a £10 charge on all vehicles entering the restricted zone (except for exempt vehicles such as residents' cars), is another noteworthy example insofar as it was introduced in one of the developed world's most highly motorized economies. First introduced in 2003, the charge was estimated to have reduced CO_2 emissions within the charging zone by 20% in the first years after its introduction; a similar trial in Stockholm led to a 13% reduction.[8] Greene and Schafer (2003) estimated that a subsidy for low-carbon fuel and introduction of carbon pricing could each reduce transport sector emissions in the United States of America by 6% in 2030. Converting insurance costs paid annually to a fuel surcharge included in the price of each refuelling was estimated to potentially reduce transport emissions by a further 9%.[55]

3.3.2 Health impacts of mitigation measures

3.3.2.1 Evidence of direct impacts on disease outcomes

Few studies have discussed the direct health effects of pricing of vehicles, fuels and infrastructure. Taking into account likely relationships between transport pricing, vehicle travel and road traffic injury, it has been estimated that optimum transport pricing could reduce road traffic injury mortality by about half,[56] while a modelling study predicted that a 20% increase in fuel prices would lead to substantial reductions in mortality from road traffic injury and air pollution.[57]

Two studies of fuel prices found that higher fuel prices were associated with more cycling[58] and less obesity.[59] However, another potential effect of rising fuel prices could be increased use of motorcycles, which use less fuel but carry a much higher risk of injury. Increased fuel prices in the United States of America were correlated with more motorcycle fatalities.[60]

As previously noted, the London and Stockholm congestion schemes have yielded 20% and 13% reductions respectively in CO_2 emissions. Annual impact monitoring of the London scheme suggests that total road traffic-related pollution emissions within the charging zone have also been reduced by 13% for NO_x and 16% for PM_{10}.[61] However, modelling of mortality reductions achieved by the congestion charging schemes in both London and Stockholm concluded that these health impacts, while statistically significant, remained comparatively small.[62,63]

In the case of London, it was also difficult to discern an effect on road traffic injuries, as injuries were already decreasing across the city as a whole. However, modelling results suggested that congestion charging had led to 40–70 fewer traffic injuries per year.[61]

In terms of a carbon tax, per se, another modelling study predicted that applying a carbon tax in Thailand would decrease air pollution and that the associated health benefits would have a positive effect on GDP.[64] Another study in Yorkshire, England found that an increase in bus subsidies was associated with more bus use and more road traffic injury among bus users, but no difference in total population road traffic injury.[65]

3.3.2.2 Impacts on travel behaviour and environmental risks

Transport pricing strategies may be categorized according to the target of the pricing measure.[8,53] While relatively few studies have examined direct health impacts of transport pricing, there is a larger body of literature discussing the travel impacts of pricing. It should be emphasized that any pricing policy (existing or proposed) generally involves a mix of measures – and finding the right balance in that mix may be critical in ensuring co-benefits to both health and equity. For instance, a study in the United States of America found that both higher fuel and parking charges were associated with less single-occupant car use and with higher rates of carpooling, transit use, walking and cycling. Conversely, lower transit fares were associated with higher transit use.[66] This report does not pretend to capture all of the available literature in this area but presents some highlights as identified in the literature review, and with reference to key pricing strategies noted by the IPCC.

Fuel pricing and taxation

Fuel pricing measures include fuel taxes and, indirectly, carbon taxes. For some time transport economists assumed that car travel was relatively "inelastic" – that is, it would grow regardless of the price of fuel. That view was challenged, and largely reversed, in a major review conducted by the Royal Commission on Environmental Pollution in the early 1990s. This found that travel was considerably price elastic so that when fuel prices rose, total private VKT dropped considerably.[67]

More recently, a review of developed country literature by Goodwin et al. (2004) suggested that a 10% increase in fuel prices would lead to a 2.5% reduction in fuel consumption in the short run (up to one year). Long-run elasticities were higher, with a 10% increase in fuel prices predicted to lead to a 6% reduction in fuel consumption after five years.[68]

A study of the United States of America estimated that a carbon tax could reduce American transport sector GHG emissions by 6% by 2030 by reducing total private motor vehicle travel. Conversely, introduction of a subsidy for low carbon fuels was projected to have a similar effect on travel. In addition, converting insurance costs paid annually to a fuel surcharge included in the price of each refuelling was estimated to reduce transport GHG emissions by a further 9%, again through overall private vehicle travel reductions.[55] While these studies did not address health directly, the fact that overall motor vehicle travel would be reduced could have health implications such as reducing air pollution from motor vehicles.

A study of the Republic of Korea estimated that a carbon tax of about US$ 50/tonne would reduce gasoline consumption by about 4% nationally, with higher taxes leading to correspondingly larger reductions in fuel consumption.[69] Conversely, another European study concluded that if European countries had applied fuel taxes that were as low as those in the United States of America then European fuel demand would be twice as high.[70]

Charging for street parking.
(Photo: capl@washjeff.edu)

Pricing that discourages travel by private motor vehicle thus appears to have the potential to reduce both health risks and GHG emissions.

Tolls, road charges and parking charges

Road-based pricing includes congestion charging, as in the examples of London and Stockholm discussed in Section 3.3.2.1. Parking for private motor vehicles is another potentially important target for pricing strategies. It has been estimated that parking charges that reflect the full cost of providing parking facilities could reduce travel by 10–30%,[53] although more empirical research is needed.

Vehicle registration fees and annual circulation taxes

Vehicle-based pricing (e.g. taxes on new vehicle purchases or on annual vehicle registration) has been used to moderate the rate of new car purchases, or purchases of certain vehicle types, in some emerging economies. This was due in part to concerns with traffic and pollution. Since the 1990s, due partly to concerns over burgeoning pollution, Israel has maintained higher registration fees for private diesel vehicles than for gasoline models, even while diesel fuel was priced comparatively lower than in Europe (thereby reducing costs for the freight transport industry).[71]

However, policies in this area are likely to extend beyond environmental priorities to reflect other economic priorities, domestic and trade-related. Like fuel taxes, vehicle purchase and registration taxes are also lucrative sources of government revenue so that a range of fiscal and economic considerations may drive policies.[71]

Distance-based (e.g. “pay-as-you-drive”) pricing involves the conversion of vehicle insurance, registration, taxes and lease fees into per-kilometre units, based on annual average vehicle mileage. According to a review that applied theoretical price elasticity values, distance-based pricing could reduce annual mileage by 10–15%.[53] However, more evidence of actual mileage reductions in specific country settings is needed.

A traffic jam in South Africa. It is projected that there will be more vehicles in developing countries than in the developed world by 2030. (Photo: Brent Eloff)

Public transport pricing

Although not a focus of the IPCC review, it is noteworthy that increasing the cost of car use through the measures discussed above provides an incentive to use alternative travel modes such as public transport, walking and cycling. For example, one study in this review found that lower transit fares were associated with higher transit use.[66] However, this review identified no other studies of the impacts of public transport pricing on health.

In summary, the health effects of transport pricing strategies appear likely to depend on the aspect of transport that is targeted. Pricing that incentivizes shifts from private motorized travel to more rapid transit and active transport could have broad health benefits, including reduced risks from physical inactivity and air pollution. In contrast, pricing that encourages the use of improved vehicles and fuels could reduce air pollution, as discussed in Section 3.2.1, but will not influence other transport-related health risks such as physical inactivity and traffic injuries.

In addition, subsidies for improved vehicles and fuels could, in principle, increase motorized travel whereas raising the price of undesirable vehicles or fuels would be likely to decrease overall motorized travel. Finally, while pricing strategies should influence health, and there are some indications of health benefits from fuel price increases, direct empirical evidence is currently limited.

3.3.2.3 Impacts on health equity

Although an exhaustive review of equity-related literature was not performed, several themes emerge from the available literature.

In terms of fuel taxes, it has been suggested that fuel tax increases may be regressive and impose a greater burden on poorer populations. However, this depends on the local context and exactly how the tax is applied. For instance, a study in Costa Rica suggested that gasoline price increases would most affect high-income households but diesel price increases would most affect low- and middle-income households because they were greater users of transit/public transport, commonly diesel-powered.[72] The IPCC assessment also notes that the urban poor already spend a comparatively large proportion of their disposable income on public transport – 14% of income in the case of Manila poor, in comparison to 7% of the non-poor.[8] In this context, increasing the overall cost of transport (e.g. by a flat increase of fuel taxes) can indeed have a larger impact on the disposable income of low-income groups as compared to high-income groups. And given the relationship between income and health, this could have negative effects on health equity.

The use of high vehicle purchase taxes and registration fees as a means of deterring rapid increases in traffic has also been criticized as inequitable when it also makes transport more expensive for middle- or low-income households, as compared to the affluent.

Still, if tax revenues from private vehicle ownership or travel were to be dedicated to significantly improving public transport/rapid transit services then health equity could benefit – firstly by reducing urban pollution and secondly, by reducing the cost of healthier, alternative means of transport for low- and middle-income groups.

It has also been suggested that congestion pricing can, in some settings, have unwanted socioeconomic consequences if it discourages lower-income consumers from entering the city centre, or drives urban businesses and customers from more expensive urban locations to the suburban periphery.[67] In turn, this can also reinforce lower-density patterns of land use and vehicle dependency, similar to the way that free parking at out-of-town shopping centres attracts customers.[71,73] Indirectly, this also spurs air pollution and barriers to access via walking, cycling and public transport. This is perhaps an example of how pricing tools can have unforeseen, cascading impacts.

On the other hand, if parking is used as a pricing tool and applied uniformly throughout suburban shopping areas, where parking is often free, then the net result of the pricing measure might be to encourage more use of public transport/walking and cycling to commerce. This would avoid imposing an added cost on public transport users and would also avoid preferential treatment of one shopping area (with free parking) over another (without).

Women-only rail cars have become popular among Indian women to avoid sexual harassment on crowded public transport routes. But safety and comfort issues still prompt shifts to private vehicles among those who can afford it. (Photo: Joerg Boethling/Still Pictures)

In some cities, drastic non-monetary measures have been taken to constrain soaring traffic, such as restricting car travel by license plate number on alternate days of the week. However, wealthier households with more than one car can often circumvent such measures.[74] Beijing, in the face of severe air pollution challenges, has created a lottery for awarding new registration permits rather than relying solely upon pricing strategies.[75]

In summary, the impact of pricing tools on health equity depends very much on how well public transport and non-motorized transport alternatives are supported by the pricing strategy, as well as the local context. But in general, if the pricing measure makes private vehicle travel more expensive, while making travel by public transport and non-motorized modes more accessible and affordable, then health equity will be improved, as compared to pricing measures that impose a flat across-the-board tax on travel.

3.4 Land-use changes and mode shifts from private to public or non-motorized transport (IPCCc)

3.4.1 Summary of IPCC-reviewed mitigation measures (IPCC 5.3.1.5, 5.5.1.1, 5.5.1.5)

The IPCC's transport chapter prioritizes technology improvements but also acknowledges that, even with new technologies, "transport GHG emissions will continue to increase into the foreseeable future. Only with sharp changes in economic growth, major behavioural shifts, and/or major policy intervention would transport GHG emissions decrease substantially".

Also as noted by the IPCC, "collective modes of transport use less energy and generate less GHGs than private cars. Walking and biking emit even less." Key public transport services include rail and bus. Urban rail can deliver large numbers of passengers more efficiently than traditional bus services by operating at large volumes on dedicated routes. However, BRT is gaining much attention as a lower-cost alternative to rail, delivering similar performance in some settings. Both light rail and BRT are typically much cheaper to build than metro systems, which usually require heavy underground excavations.

Walking and cycling rates have been declining in many countries. However, the potential for active travel is acknowledged by the IPCC, citing the Netherlands where 47% of trips are made by active modes. Aspects of the built environment and the safety of walking and cycling are considered to have important impacts on the use of these modes. The mitigation potential of active transport and public transport is briefly reviewed.

As already noted, while motorization is increasing globally, there is still a broad diversity in the levels of car use – with many advanced industrialized countries maintaining high levels of active transport and public transport. Maintaining high usage of these modes, and slowing motorization, is considered to require the integration of land-use and transport planning. Land-use factors associated with motorized travel include density and mixed-use development of commercial and residential areas. Improving public transport can divert a proportion of people from car to public transport use.

Low floor BRT eases access in Curitiba, Brazil. (Photo: Ron Giling/ Brazilie Lineair/Still Pictures)

Section 5.5.1.5 of the IPCC mitigation review discusses transport demand management (TDM), which is described as: "a formal designation for programmes in many countries that improve performance of roads by reducing traffic volumes". The IPCC considers TDM to be particularly appropriate in developing country cities. The term TDM covers

a range of different strategies – pricing and improved land use can be considered to be TDM strategies. Other strategies reviewed include employer-based travel plans to reduce car commuting, removal of parking subsidies (e.g. free or very low cost parking), and more telecommuting, and computer-based or remote shopping and marketing.

3.4.1.1 Mitigation potential from land-use changes

The IPCC provides little information globally about the mitigation potential and costs per tonne of CO_2 of land-use changes, making this an important area for future investigation. Other studies not included in the IPCC report do exist but vary widely in scope, e.g. urban versus national; developed versus developing regions; time period; and type of land-use change considered. A few indicative examples identified in the literature search are cited here.

Barías et al. (2005) examined the costs required to reduce transport's GHG emissions through changes in the existing urban form of Santiago, Chile (Table 9). He found that a hypothetical "optimal land use" reallocation could achieve a 67% reduction in transport emissions in the city over a 20-year period, although costs were prohibitively high. However, more moderate measures to relocate residential and commercial facilities closer together reduced emissions by 21% and were cost-effective in carbon mitigation terms (US$ 91/tCO_2 reduction over 20 years). Very low-cost measures to relocate schools closer to residences could potentially achieve a 12% reduction in transport emissions in the same period for only US$ 2 per tonne of CO_2 reduction.[76]

While the relative cost of more optimal land-use measures (e.g. compact urban development) is higher in terms of CO_2 reduction, costs may be significantly lower in new urban development compared with reorganizing existing urban areas. Additionally, co-benefits to health and climate change of savings from more energy-efficient housing that can be derived from more compact urban land use could shift the equation further.

This is reflected in assessments conducted in Canada that take an "integrated urban energy use" approach, considering both housing densities and energy efficiencies. Bataille et al.[77] estimate that in the long term approximately 40–50% of Canada's urban

Table 9. Estimated mitigation potential and costs of land-use measures in Santiago, Chile

Land-use strategy	Reduction in transport emissions	Cost (US$/t$CO_2$) over 20 years
Relocating educational facilities in proportion to residential locations	12%	US$ 2
Relocating non-residential land uses in proportion to residential locations	21%	US$ 91
Concentrating a high proportion of residential and non-residential land uses into subcentres on urban edges	40%	US$ 538
Hypothetical optimum land use reallocation	67%	US$ 2014

Source: Barías et al. 2005.[76]

GHG emissions could be avoided for under US$ 200 per tonne of CO_2-eq,[iv] through a package of aggressive land-use policies that reduce travel demand, shift transport modes and emphasize more densely built and energy-efficient housing. This estimate is based on the review of three other Canadian studies estimating the potential community-level GHG reductions from aspects of integrated urban energy systems to be approximately 43% (Jaccard et al., 1997[78]), 47% (CSCD, 2004[79]), and 50% (CUI, 2008[80]). As their name implies, transport mitigation policies are integrated holistically with built space and housing policies so that it becomes difficult to assign savings to one sector or the other.[77]

In the United States of America, a country with very similar patterns of travel and land use, projections of land-use changes' potential to reduce GHG emissions have been far more pessimistic. Greene and Schafer (2003) estimated that only 3–5% of the United States of America's transport sector GHG emissions could be avoided by 2020 and 2030 respectively through changes in urban planning over several decades.[55]

Hankey and Marshall (2010) are somewhat more optimistic about the potential of land use to impact emissions in the United States of America. In an analysis of historical patterns of sprawl and associated increases in passenger vehicle travel, they projected that large savings in GHG emissions could be achieved if existing American urban and suburban areas were "densified" ("complete infill") rather than constantly expanding on the urban periphery as historically ("suburban nation"). In the urban infill scenario, annual passenger vehicle emissions could be reduced by 18–30% by 2020 as compared to the baseline year of 2000. This scenario assumes a national population growth of 18% and annual 14–18% reductions in passenger vehicle emissions as a result of new fuel efficiencies compared with 2000.[81]

Car parking consumes huge swathes of urban space. (Photo: iStockphoto)

Reviewing the urban planning literature, Ewing et al. (2007) estimated that compact development could reduce VKT per capita by 30%. Combining this with what were considered realistic assumptions about the likely market share of compact development, growth rates and the relationship between VKT and CO_2 emissions, smart growth was estimated to potentially reduce transport-related CO_2 emissions by 7–10% by 2050.[82]

3.4.1.2 Mitigation potential from mode shifts from private to public or non-motorized transport

As noted previously, the actual efficiencies of alternative modes of travel are strongly

[iv] *IPCC Summary for Policymakers* notes: "The definition of carbon dioxide equivalent (CO_2-eq) is the amount of CO_2 emission that would cause the same radiative forcing as an emitted amount of a well mixed greenhouse gas or a mixture of well mixed greenhouse gases, all multiplied with their respective GWPs [global warming potentials] to take into account the differing times they remain in the atmosphere [WGI AR4 Glossary]."

influenced by the age and type of vehicle and by urban and rural driving conditions. Table 3 (Section 1.3) notes indicative ranges of travel emissions for various passenger modes, as relevant to developing countries. These calculations are highly dependent on assumptions about occupancy rates and electricity generation methods, so their application to individual countries will depend on local context. This illustrates, however, that when operating at full or near-full capacity, rail and bus modes typically emit fewer GHGs per passenger kilometre of travel than private motorized travel. Travel by walking and cycling emits no GHGs at all. In principle, greater reliance on public transport, walking and cycling can significantly reduce GHG emissions.

For instance, Barías et al. (2005) found that a comprehensive bicycle network in Santiago, Chile could increase bicycle mode share by 3–6% – which would in turn reduce CO_2 emissions by 27 000 to 100 000 tonnes per year at a cost of US$ 30–111 per tonne.[76]

Unlike the case of vehicle technologies, very little macro-level assessment of the mitigation potential of modal shifts has been carried out on a global level. However, a few limited studies are nonetheless cited in the IPCC review. They indicate very high cost effectiveness of modal shifts, particularly in developing countries.

IPCC cites a study by Wright and Fulton (2005) estimating that increases in the mode share of walking in Bogotá, Colombia from 20% to 25% of travel could reduce transport emissions by 6.9% at a cost of US$ 17/tCO_2. Increasing the mode share of cycling from 1% to 10% of all travel could reduce emissions by 8.4% at a cost of US$ 14/tCO_2. Increasing the mode share of BRT from 0% to 10% could reduce emissions by 8.6%, but at a higher cost of US$ 59/tCO_2. Notably, a package combining BRT, walkways and cycleways could reduce emissions by 25.1% at a cost of US$ 30/tCO_2 (Table 10).[9]

3.4.2 Health impacts of mitigation measures

Findings of the literature review on land-use factors and alternatives to private motorized transport are summarized in Table 11 and Table 12.

Table 10. CO_2 reduction potential and cost per tonne CO_2 reduced using public transit policies in Latin American cities

Transport measure	GHG reduction potential (%)	Cost per tCO_2 (US$)
BRT mode share increases from 0% to 5%	3.9	66
BRT mode share increases from 0% to 10%	8.6	59
Walking share increases from 20% to 25%	6.9	17
Bike share increases from 0% to 5%	3.9	15
Bike mode share increases from 1–10%	8.4	14
Package (BRT, pedestrian upgrades, cycleways)	25.1	30

Source: Kahn Ribeiro et al. 2007 (Table 5.6), based on Wright and Fulton 2005.[8,9]

3.4.2.1 More efficient land use: implications for health

The "three Ds of urban design" – greater urban density and less sprawl, more diverse and mixed land use, and better street design and connectivity – were associated with improved health outcomes, with a large number of studies assessing these factors (See Table 11). A small minority of studies found land-use factors to be associated with worse health outcomes.[83–88,126] This is a plausible finding: for example, increasing residential density in areas with heavy traffic could increase population exposure to transport-related hazards. Optimum health outcomes may thus require urban intensification to be accompanied by strong measures to constrain traffic.[89]

Table 11. Health-related outcomes associated with land-use factors

Factor	Studies finding improved outcomes	Studies finding worse outcomes
Higher **density**, less sprawl, high residential density	More walking, cycling or active transport[58,66,94,110–123]	Less active transport[86]
	More physical activity[84,110,116,118,124,125]	Less physical activity[87,126]
	Lower BMI/less obesity[113,116,118,127–135]	Poorer reported health status[85]
	Less road traffic injury[136,137]	
	Lower air pollution exposure/effects[100]	
	Better quality of life or reported health status[138,139]	
	Lower risk of specific health problems[113,118,139]	
	Lower mortality/higher life expectancy[140]	
Land-use **diversity**, mixed land use, greater proximity and density of destinations	More walking, cycling or active transport[66,83,86,94,95,112,119,121–123,141–167]	Less walking, cycling or active transport[88]
	More physical activity[90–92,123,153,158,168–174]	Less physical activity[84]
	Lower BMI/less obesity[131,134,153,158,175–179]	
	Less road traffic injury[137]	
	Better quality of life or reported health status[158,180,181]	
Street **design**, e.g. street connectivity, intersection density	More walking, cycling or active transport[66,94,96,112,119,120,122,144,145,148,154,182–188]	
	More physical activity[84,90,126,187]	
	Lower BMI/less obesity[129,134,189,190]	
	Better reported health status[85,189]	
Green and open spaces, parks and sports grounds	More walking, cycling or active transport[96,117,119,143,148,153,169,178,191,192]	Less active transport[83]
	More physical activity[91,125,153,169,193,194]	
	Lower BMI/less obesity[195]	
	More favourable social factors[196]	
	Higher quality of life or reported health status[181,196]	
	Lower mortality/higher life expectancy[197]	
Aesthetic features	More walking, cycling or active transport[86,95,96,145,148]	Less walking[121]
	More physical activity[90,91,93,172]	Less physical activity[198]

Table 12. Health-related outcomes associated with active transport, public transport and car use, and their infrastructure

Factor	Studies finding improved outcomes	Studies finding worse outcomes
Use of different travel modes		
More active transport (walking, cycling)	More physical activity/fitness[199,205–218]	More road traffic injury[50,200,219]
	Lower BMI/less obesity[177,190,207,218,220–226]	Higher personal exposure to air pollution[205]
	Lower air pollution exposure/effects[50,227]	
	More favourable social factors[228]	
	Higher quality of life or reported health status[181,196,229]	
	Lower risk of specific health problems[207,229]	
	Lower mortality/higher life expectancy[230–233]	
More use of public transport	More walking, cycling or active transport[121,234]	Higher risk of tuberculosis[235]
	More physical activity[205,236–238]	Higher personal exposure to air pollution[205]
	Lower BMI/less obesity[220,223,234,239]	
	Lower air pollution exposure/effects[48]	
	Lower noise levels[240]	
	Higher reported health status[189]	
	Lower road traffic injury risk for public transport users[219,240]	
Lower car use, car ownership and traffic volumes	More walking, cycling or active transport[88,94,142,144,147–149,152,160,162,165,166,186,191,241–243]	Less walking[155,244]
	More physical activity[84,193,211,245]	Fewer social trips[246]
	Lower BMI/less obesity[176,177,189,245,247–250]	Higher BMI/more obesity[59]
	Lower air pollution exposure[251]	
	Less road traffic injury[137]	
	Higher reported health status or functioning[252]	
	Lower risk of specific health problems[253]	
Infrastructure for different travel modes (including presence and proximity of infrastructure)		
More infrastructure facilitating walking (including general assessments of walkability of neighbourhoods as well as presence of specific features, e.g. pavements)	More walking, cycling or active transport[83,88,94–96,123,148,157,160,166,169,182,198,226,254–260]	
	More physical activity[91,93,169,174,198,226,254,256,261–268]	
	Lower BMI/less obesity[126,178,250,257,262,267]	
	Lower air pollution exposure/effects[262,268]	
	Lower risk of specific health problems[126,253]	
	Lower mortality/higher life expectancy[197]	
More infrastructure facilitating cycling	More walking, cycling or active transport[83,95,96,152,154,157,183,186,256,269–271]	
	More physical activity[92,93,123,171,172,256,272]	
	Lower BMI/less obesity[250]	
More infrastructure facilitating public transport use	More walking, cycling or active transport[66,122,148,153]	Less walking, cycling or active transport[88,94,112,243,273]
	More physical activity[84,124,153,171,172,194,256]	Lower reported quality of life[181]
	Lower BMI/less obesity[134,179]	
	Lower air pollution exposure/effects[49,274]	
Less infrastructure facilitating car travel (including parking, motorways)	More walking, cycling or active transport[66,273]	
	Lower BMI/less obesity[59]	

The review identified two other land-use factors consistently associated with health. The presence of more green and open spaces, parks and sports grounds was associated with a range of improved health outcomes in a large number of studies, while aesthetic features of neighbourhoods were associated with more physical activity[90–93] and active travel.[86,94–96] As green spaces and aesthetic features were associated with more active transport, they also have the potential to substitute for motorized transport and reduce emissions.

A large amount of research showed associations between land-use factors and physical activity, active transport, obesity and related outcomes. Evidence of associations between urban form and air pollution and its effects was weaker. Only two studies associated land-use factors with reductions in air pollution and its effects. Increased urban density is associated with less motorized travel,[97] reducing air pollutant emissions. However, increasing urban density may also concentrate both emissions and population within a smaller area, potentially increasing exposure.[98] While some studies have found higher urban density to be associated with reduced pollutant exposure,[99,100] others have found the reverse.[101–103] Given this uncertainty, compact growth may best be accompanied by complementary strategies to reduce population exposure to air pollutants.

Only two studies found land-use factors to have a beneficial effect on road traffic injury. However, other research has shown a strong linear relationship between VKT and road traffic injury rates, as well as an abundance of evidence associating land-use factors with VKT.[97,104]

No studies were identified on land-use factors and noise. One previous study found traditional urban forms reduce traffic and noise pollution.[103] The acknowledged importance of traffic volume in noise emissions[105] and of land-use factors in affecting the amount of motorized travel[97] provide indirect evidence to support an effect of land-use factors on noise, but empirical studies are needed.

Little research has examined land-use factors' effects on social capital or social networks. One study found an association between neighbourhood greenness and social coherence. Another found an association between land-use factors and social capital.[106] Walkability and social capital have been found to be linked,[107,108] but other research has found that compact cities reduce social interaction.[109]

3.4.2.2 Mode shift and travel infrastructure: implications for health

Physical activity and related outcomes

Many studies show associations between use of active or public transport and improved health outcomes. In particular, many studies find associations between active transport and higher physical activity levels and/or lower body mass index (BMI). Even electrically assisted cycling can provide physical activity of moderate intensity.[199] Lower levels of car use are also consistently associated with better health, especially higher levels of physical activity and active transport, and lower BMI. A small minority of studies find worse health outcomes associated with active and/or public transport. For example, some studies found that public transport infrastructure was associated with less active transport use. This may suggest that public transport availability displaces walking and cycling trips. However, the overall balance of evidence strongly favours active and public transport.

Infrastructure for active transport and public transport – including availability and proximity of walking and cycling paths, public transport stations and general neighbourhood walkability scores – is also associated with better health (especially more physical activity and active travel, and lower BMI) in a large number of studies. A small number of studies show that less car infrastructure (including motorways and parking availability) is associated with improved health outcomes.

As previously noted, Woodcock et al.[50] used modelling to show that predicted health benefits from mode shift with less motorized travel and more active travel were much higher than those for improved vehicles. Health benefits of the former were seven times higher for New Delhi, and over forty times as high for London. A combined scenario using both measures gave almost double the emission reduction benefit but only slightly increased health benefits compared with the mode shift scenario alone. This analysis took into account health effects from physical activity, air pollution and road traffic injury.

Road traffic injury

One modelling study of road traffic injury predicted that large increases in active travel would be associated with a decreased risk per pedestrian and cyclist; road traffic injuries across the total population could either increase or decrease depending on the local context.[50] Other modelling suggests that for very large shifts from cars to walking and cycling it would be possible to reduce the total number of injuries, but for smaller shifts, total injuries may increase.[200] This is likely to be due to the greater vulnerability of walkers and cyclists (compared with car users) outweighing the reduced risk per walker and cyclist. However, other research shows that lower levels of VKT are strongly associated with decreased road traffic injury.[97] In addition, per-capita road traffic injury deaths are lower for cities and countries with more active transport and public transport and less car travel, while GHG emissions per capita are also lower.[201,202] Ecological comparisons also suggest that countries and cities with more active transport have consistently lower road traffic injury rates.[203]

Lack of bicycle infrastructure can make cyclists more vulnerable. (Photo: Ashley Cooper/SpecialistStock)

Noise and social capital

Although motorized vehicle traffic is acknowledged to be the most important source of community noise,[105] this review identified no original research examining the effect of different travel modes on health outcomes via noise exposure. However, other research has looked at noise exposures without directly measuring health effects. For example, a study of New York mass transit systems found that noise exposure for all forms of transit were above the threshold for noise-induced hearing loss.[204] There was also little research on social factors, although one study found greater walkability of neighbourhoods to be associated with higher social capital.[108]

In summary, most of this literature focused on physical activity, active transport, BMI and related outcomes, finding consistent associations. In contrast, this review identified only a few studies showing that mode shift improved air quality; one study found that users of active transport and public transport had higher pollutant exposure than car users, if humidity factors were controlled for.[205]

3.4.2.3 Impacts of both land use and infrastructure on health equity

Barriers to access for vulnerable/disadvantaged groups

As already noted in Chapter 2, use of public transport and non-motorized modes is typically more common among lower-income groups in developing countries as well as among certain vulnerable groups throughout the world, particularly children, people with disabilities, and older people. In many motorized countries, women may be more dependent on public transport and non-motorized modes, at least for independent mobility, as they have less access to vehicles. Additionally, as noted in Chapter 2, walking and cycling and use of public transport are the only means of independent travel for children and most teenagers.

Children walk on roadside in rural Tanzania. (Photo: HardRain)

Since compact and mixed land use improve the accessibility of destinations via walking and cycling, vulnerable groups are likely to benefit from such land-use measures. Strategies that improve the safety of active transport also are likely to yield particular benefits for vulnerable groups who are at greater risk of road traffic injuries. For similar reasons, investments and polices that improve public transport systems are likely to benefit vulnerable groups in particular. At the same time, benefits will be widely shared among many groups since, even in highly developed countries, many people do not have constant access to a private vehicle.

In the literature search, some other striking aspects of equity did emerge. For instance, studies in the United States of America, Canada and New Zealand have noted that children from disadvantaged (e.g. low-income or ethnic minority) families are more likely to walk or cycle to school.[86,88,141,162] This may also be the case in some rapidly motorizing developing economies in which driving a child to school may be a matter of economic status, as well as convenience or personal security. Along with facilitating access, walking and cycling improvements may be particularly beneficial to facilitating physical activity among disadvantaged groups who have comparatively less time or money for other recreational forms, and among whom active transport can be a particularly important means of meeting physical activity requirements.[111,208,212]

Certain features of the built environment have been shown to play a "facilitating" role for healthy physical activity opportunities in lower-income neighbourhoods, including street connectivity and access to local cycle trails or other outdoor recreational resources.[157,187,261] In one study, living in an active community environment was found to have a particularly strong association with higher levels of transport-related physical activity for low-income individuals, compared with high-income individuals.[254]

A mother crosses in traffic with her pram. (Photo: iStockphoto)

Other studies, however, have found that the relationship between built environment variables and BMI was in fact stronger for high socioeconomic status neighbourhoods.[179] In one such study, higher neighbourhood walkability was also more closely associated with more walking to school in high-income neighbourhoods than in low-income neighbourhoods.[95] But these findings may be very contextual. For instance, unlike many parts of the world, low-income wage earners in North America may commute by private car, and urban walking levels may be lower overall.

Altogether, much more needs to be done to explore the impacts of built environment characteristics on neighbourhood travel in different settings and cultures, and with regard to other mitigating factors.

Impacts of local neighbourhood quality on disadvantaged populations

Some developed country studies have noted a connection between a lower-quality built environment in disadvantaged neighbourhoods and less physical activity. In one study in the United States of America, counties with lower incomes and more ethnically diverse populations were less likely to have land-use plans that supported physical activity – including transport-related physical activity.[256] In another, walkability levels were lower in low-income neighbourhoods than in high-income neighbourhoods.[275]

Other research found that differences in women's walking levels by educational status were largely a function of what could be described as "environmental inequalities" in neighbourhood street connectivity, and the coastal proximity of neighbourhoods.[182] Another study found that heavy traffic and lack of greenery and aesthetic features were important contributors to socioeconomic differences in transport-related walking.[276] However, other research suggests that neighbourhood characteristics may not fully explain the tendency for disadvantaged groups in some developed cities to walk less than their more affluent counterparts.[192]

Clearly, ensuring that disadvantaged neighbourhoods do not suffer from degraded physical environments appears to be an increasingly important feature supporting more active travel in developed countries. This finding may also apply to large cities of emerging economies where people have other motorized means of travel.

In conclusion, land-use and transport-mode policies that favour active and public transport have obvious and direct equity applications in promoting access to employment and services essential to health for many diverse groups, including women, children, older people, and those without cars – indeed most of the world's population.

Improved infrastructure and environments supporting active travel also can generate particular physical activity benefits for more disadvantaged groups for whom many lifestyle choices are largely a function of their environments – and not a matter of "choice".

At the same time, physical activity benefits from infrastructure improvements also may be reaped by more affluent groups in developed as well as developing societies, particularly in cities. For instance, time-constrained people of certain top socioeconomic levels also have little time for daily exercise – hence the increased popularity of walking and cycling to work in affluent countries.

Moreover, just as good-quality built environments may be an important motivating factor in active travel among different socioeconomic groups in developed countries so they are likely to be more important in the large cities of emerging economies, as motorized alternatives become more widely available.

Caution should be applied in the way in which the findings on active travel presented here are interpreted in developing countries. Clearly, both health and equity requirements mean that there needs to be a balance of motorized and non-motorized travel options available for poorer socioeconomic groups, as for those who are better off. In particular, health and equity are seriously undermined by exposure to a range of other transport-related risks when those (particularly children, elderly people and other vulnerable groups) seeking to access schools, employment and services are obliged to walk or cycle very long distances with exposures to extreme heat or cold, inadequate food or water, and risky and dangerous road conditions.

The availability of healthy transport options – including motorized transport for longer distances – is thus essential for well-being, yet is something that many people in the world still lack. Rural transport was not a focus of this study, however, it can be noted that the needs of isolated and rural communities can also be met more equitably by increasing the local availability of employment, education and basic services. Much larger, more strategic investments in public transport to nearby cities, as well as interurban rail, for both passengers and freight are also required. Emphasizing such approaches serves everyone in a community, not just those with vehicles, and can help avoid sprawl and loss of valuable open spaces while also preserving rural communities. Together, such approaches can help to avoid the need for extreme journeys under extreme conditions.

3.5 Limitations and research gaps

Limitations of the health and mitigation analysis in terms of the types of studies identified, and their design, were discussed briefly in the introduction of this chapter. It was not possible in this review to quantify the health impacts of IPCC-recommended mitigation strategies numerically, though differences were identified in the magnitude of likely health impacts between some strategies. As this topic was too broad to undertake a systematic review, it is likely that not every relevant study was detected. However, sufficient studies were identified to indicate the strength of the available evidence in key areas. There is also considerable overlap between some of the topics that were searched for. For example, "walkability" could be treated as infrastructure for walking as a travel mode or as an aspect of urban form. However, this overlap is unlikely to have influenced the conclusions of the analyses in this report.

Along with the limitations of the search regarding transport and health equity, this review identified very few studies examining road traffic injury outcomes. While there is an extensive body of literature on factors associated with road traffic injuries, this review focused on factors that would affect not only road traffic injuries but also GHG emissions. This excluded studies of factors such as seat-belt use and alcohol intake as well as those that examined the injury risk of a single mode (e.g. cycling) without comparing injury risks between modes.

Bike parking lot in Chengdu, Sichuan, China. (Photo: K. Wothe/Blockwinkel/Still Pictures)

Although differences in road traffic injury risk for users of different travel modes are well-described,[44] there appear to be fewer studies assessing the impacts of population-level shifts in travel mode on population rates of road traffic injury. A previous WHO review acknowledged the probable link between land-use planning and road traffic injury rates, but identified few primary studies on this subject.[44] This review identified some additional primary studies relating to land-use aspects including density, mixed land use and street connectivity.[97] Given the important effects of land use and mode shift on GHG emissions, and on other aspects of health such as physical activity, further research on these factors' effect on injury outcomes would be valuable.

Despite the limitations of this review, its findings are consistent with previous reviews of transport, the built environment and health. For example, Heath et al. (2006) found sufficient evidence to conclude that community- and street-scale urban design and land-use policies and practices were effective in promoting physical activity.[277] Gebel et al. (2005) focused on nutrition as well as physical activity as contributors to obesity.[278] They found four urban form characteristics associated with physical activity:

(i) mixed land use and density
(ii) footpaths, cycleways and facilities for physical activity
(iii) street connectivity and design
(iv) transport infrastructure that links residential, commercial and business areas.

Bauman and Bull (2007) found a wider range of factors associated with physical activity and/or walking outcomes, including physical activity facilities, access to destinations, high residential density, land use and urban walkability scores.[279] A WHO review concluded that interventions targeting the built environment were an effective approach for improving physical activity.[280] A review of policies to promote active travel suggested that they were likely to lead to large individual health benefits from physical activity and to smaller population-level benefits from air pollution and noise reduction.[281]

3.6 Conclusions

While all three IPCC transport mitigation categories have some potential to improve health, the strategies of improving land use, increasing non-motorized transport, and shifts from private motorized travel to public transport appear to have the greatest potential. A combination of measures, with emphasis on land use and alternatives to motorized transport, seems likely to have the greatest effects. Pricing measures would be needed to support such modal shifts, although key pricing measures required to support more public transport were not fully evaluated by the IPCC. The predicted effects of the three IPCC transport mitigation categories are summarized in Table 13.

Table 13: Appraisal of health implications of IPCC-assessed mitigation strategies

Mitigation strategy	Potential to reduce emissions (illustrative example)	Likely reduction of health risk factors			Additional effects, limitations and comments
		Size and direction of effect		Strength of evidence	
IPCCa Modified vehicles and fuels	21% reduction in CO_2 emissions of light-duty vehicles by 2030 under a high-efficiency vehicle scenario, almost all at costs less than US$ 100/tonCO_2.	Air pollution	- to ++	Moderate	Increasing fuel efficiency could lower travel costs and thus promote more motorized transport. Alternatively, improved vehicles may be more expensive, reducing their use in low-income settings. Particulate emissions may be higher from diesel engines than from equivalent gasoline engines per unit of travel, which could worsen health. Air quality impacts of biofuels remain unclear. Significant concern exists regarding biofuels' production impacts on food security and nutrition for the poor.
		Physical activity	0	Weak	
		Road traffic injury	0	Weak	
		Noise	0	Weak	
		Social effects	0	Weak	
		Land use	0	Weak	
IPCCb Pricing policies regarding vehicle and fuel use, and pricing of travel to urban centers or by different modes (e.g. congestion pricing)	Depends on whether target is pricing of modified vehicles and fuels (IPCCa) or land-use changes and alternatives to private motorized transport (IPCCc). Congestion charges have reduced emissions by 13–30%, while a subsidy for low-carbon fuel has been estimated to reduce emissions by 6%.	Air pollution	- to ++	Weak	Pricing policies to encourage vehicle/fuel improvements are likely to lead to health benefits similar to IPCCa, but not to reduce travel. Pricing to encourage use of non-motorized transport and public transport is likely to lead to health benefits similar to IPCCc. Policies would have different effects on health equity depending on mode targeted, e.g. public transport or private, and type of pricing tool, e.g. taxes or subsidies.
		Physical activity	0 to ++	Weak	
		Road traffic injury	0 to ++	Weak	
		Noise	0 to ++	Weak	
		Social effects	0 to ++	Weak	
		Land use	0 to ++	Weak	
IPCCc Land use changes and alternatives to private motorized transport	Package of walkways, cycleways and bus rapid transit could reduce emissions by 25% at a cost of US$ 30/tonCO_2.[i] Improved land use could reduce emissions by 21% over a 20-year period at a cost of US$ 91/tonCO_2.[ii]	Air pollution	++	Moderate	Can help ensure equity of access for people without cars. Can make walking and cycling safer for vulnerable groups, e.g. children, older adults and people without cars. Increases in walking and cycling need to be accompanied by improvements in the safety of the walking and cycling environment.
		Physical activity	++	Moderate	
		Road traffic injury	++	Moderate	
		Noise	++	Weak	
		Social effects	++	Weak	
		Land use	Not applicable		

Note: Size and direction of likely health effects were rated from "--" (strongly negative effects) to "++" (strongly positive effects), with the midpoint "0" representing no significant effects.

Strength of evidence was rated from 0 (no evidence) through weak (small number of observational studies only, or good (theoretical or indirect rationale for an effect) to moderate (large number of observational studies, or observational studies plus clear theoretical rationale).

[i] Wright L, Fulton L. Climate change mitigation and transport in developing nations. *Transport Reviews*, 2005, 25(6):691-717.

[ii] Barias JL et al. *Getting on track: finding a path for transportation in the CDM.* Winnipeg, International Institute for Sustainable Development, 2005.

Physical activity and related health outcomes were the topics with the most evidence identified by this review. This evidence suggests that different travel modes have markedly different effects, notably the following.

- Active travel was associated with increased physical activity and reduced obesity and BMI in many studies.
- Public transport was also associated with more physical activity, less obesity and a much lower risk of road traffic injury compared with other modes, though fewer studies showed these effects.
- Increased car use had negative health effects and was associated with less physical activity and more obesity.

The available evidence suggests a hierarchy of travel modes with respect to their health impacts, with active transport the most beneficial, public transport intermediate and private motorized transport the most harmful. The same ordering applies to GHG emissions, with private motorized transport having the highest emissions and non-motorized transport having essentially zero emissions. This relative desirability of different travel modes should thus be a cornerstone of transport policy for reasons of both health and emissions, 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 in York, England.[282]

While this review found many studies suggesting that higher urban density was associated with outcomes such as more walking, more physical activity and less obesity, densification may also carry risks. Some authors have suggested that increasing urban density could increase exposure to hazards such as air pollution, noise and road traffic injury risk due to greater concentrations of traffic. This has been dubbed the "paradox of intensification" and suggests that residential intensification needs to be accompanied by effective measures to restrain car use in intensifying areas in order to prevent a high concentration of motor vehicle-related hazards.[89] While highly culture and setting dependent, clearly there will also be upper limits to the health and social benefits of intensification. For instance, very dense housing occupancy is also unhealthy. High rise land-use development can also limit the independent mobility of children and have other unintended impacts on the urban environment, socioeconomic integration (enclaves either of affluent or disadvantaged households) and social cohesion. While not the focus here, these all need to be explored more systematically to arrive at a more holistic vision of truly healthy, low-carbon cities.

Rio de Janeiro, Brazil: infrastructure for cyclists and pedestrians enhances a vibrant street life of leisure physical activity as well as active travel. (Photo: Carlos F. Pardo)

There are no global studies, and few regional and local-level studies, that look at mitigation potential either for modal shift towards public transport, walking and cycling, or for land-use changes. Given the large potential health co-benefits of these measures, they should receive much greater attention in an overall assessment of transport sector mitigation strategies.

Care is needed when applying these conclusions to the poorest settings within developing countries. People from communities that have no access to public or private motorized transportation, and who are forced to travel long distances on foot, in unpleasant and unsafe conditions in order to access employment, education or other services, are unlikely to benefit from additional physical activity. However, providing local services to these communities would be a land-use intervention with great benefits; the provision of safe public transport services would also greatly improve the lives of people in these communities.

In summary, by combining transport mitigation measures with the strongest health co-benefits (land-use changes and alternatives to private motorized vehicles) into a single third category, the IPCC review underemphasizes the measures that are most promising from a health perspective. Instead, it gives much greater prominence to the mitigation potential of improved vehicle and fuel technologies which offer relatively few health co-benefits. All of these measures are needed but available health evidence suggests that optimizing gains for both climate and health requires a much greater emphasis on land use, active transport and public transport.

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4

"I just ride around here and to the shops, I don't cycle to school because it is too dangerous for me. I always cycle with my brother, so I don't cycle alone. I like it because It gives me energy." Britney Koopman (right) with brother Alamandro in Homestead, Kimberley, Northern Cape, South Africa.

Achieving win-win health and transport mitigation strategies

This chapter delves more deeply into how transport policies with the greatest health co-benefits can be optimized, based on the strategies appraised in Chapter 3, and into barriers to the implementation of these policies. If carefully implemented, these same strategies may have additional co-benefits for other transport sector priorities, such as congestion reduction, cost containment, energy security and job creation.

Overall, globally, there is a huge range of mobility patterns and needs. In rural areas of developing countries, greater access to motorized transport could assist many people to reach more distant destinations, although good public transport is vital to making rural mobility accessible to all. In many urban and developed country settings, car-oriented transport systems can create significant health impacts, pose barriers to independent mobility and access, as well as contributing to climate change.

Despite this diversity, the key goal of travel in both developing and developed countries is *access*. Strategies to improve access, while at the same time limiting climate impacts, are thus important in both settings. These strategies should also aim to manage the health impacts of transport. Some universal goals for "healthy transport" can usefully be identified, based on the definition of health outlined in WHO's 1948 constitution and noted in the preface to this document.[i]

4.1 Principles of healthy transport strategies – universal enabling factors

Tentatively, one overarching goal for transport could be defined as:

> Achieving the highest possible level of access, regardless of age, economic status, gender, and disability, to economic and social opportunities that support health, livelihoods and well-being, via modes of travel that enhance the health benefits of mobility, e.g. via physical activity, and reduce the health risks of transport-generated air pollution, noise and injury.

Regardless of a country's development status, this requires a careful balance between public and private transport modes, as well as between motorized and non-motorized modes – in order to support equitable access and mobility among many groups, as well as health and a low-carbon future.

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i "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity." WHO Constitution, 1948.

Based on the above goal, the findings in Chapters 2 and 3 and previously published strategies for healthy and sustainable transport (Section 4.4.1, Box 3), this report identifies four strategies that offer win-win results for climate and health (Table 14). Several of these strategies reduce vehicle kilometres travelled (VKT), thus reducing greenhouse gas (GHG) emissions. Reducing VKT can also lower emissions of other air pollutants and of noise. Lower VKT is also associated with less road traffic injury, 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.

Table 14. Win-win transport strategies to maximize health and climate gains

Strategy	Key pathways
1. Develop compact land use that reduces the need for travel, particularly by clustered and mixed-use commercial and residential development built around transit and active transport networks	Increases proximity of destinations, reducing need for car travel and VKT Improves access by walking, cycling and rapid transit/ public transport
2. Invest in and provide transport network space for pedestrian and bicycle infrastructure	Improves access by walking and cycling Encourages shift from car use to walking and cycling, reducing VKT
3. Invest in and provide transport network space for rapid transit/ public transport infrastructure	Improves access by rapid transit/public transport Encourages shift from car use to rapid transit/public transport, reducing VKT
4. Undertake engineering and speed reduction measures to moderate leading hazards of motorized transport	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 increasing safety Technological improvements reduce production of hazards per vehicle (GHGs, pollutants, noise)

4.2 Optimizing mode-shifts to active transport and public transport

The literature reviewed in Chapter 3 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 reductions in body mass index (BMI) and obesity. Providing infrastructure for walking, cycling and public transport is also associated with more active transport and physical activity. Travel by these modes is also more physically active, and provides more opportunities for social interaction than car use. Enabling access by these modes improves health broadly, and health equity for low-income groups, vulnerable groups and others lacking access to private vehicles.

Improving access by walking, cycling and public transport can also reduce emissions associated with people accessing essential goods, services and other requirements for health and well-being.

Conversely, car use is not only less active but also poses hazards to other travellers. Moderating these hazards is especially important in cities with high population densities and more vulnerable road users such as walkers and cyclists.

While improvements to vehicles and fuels are limited by technology, the enormous variation in travel modes globally reflects large opportunities as well as the challenges of supporting travel that is healthier, low-carbon and physically active. For example, one review reported that active travel makes up 18% of travel in selected European cities, 19% in Asian cities (a combination of developed and developing cities), but only 5% in cities in the United States of America. Similarly, public transport makes up 48% of passenger kilometres in the same Asian cities and 23% in European cities, but only 3% in cities in the United States of America.[1]

To attract customers that have other choices, public transport needs to offer a "micro-environment" that is thermally comfortable, safe, clean and pollution-free. South Africa's new Gautrain is one effort to provide high quality transit service in a country built around the automobile. (Photo: Susan Wilburn)

A very high proportion of motorized trips in Europe and in the United States of America cover short distances.[2,3] Recent research has highlighted the potential for replacing more of those short car trips with cycling or walking. This substantial potential for further shifts to active modes is likely to offer substantial health gains from physical activity and air pollution improvements,[3,4] and warrants much more investigation.

The limited mitigation studies of modal shifts and land-use changes that have been undertaken (e.g. in Latin America, Canada) also reflect a very large, but still untapped, mitigation potential of walking, cycling and public transport measures with large health potential and very high cost effectiveness. Similarly, fostering mixed land use, such as locating commercial areas closer to residences, also has significant cost-effective mitigation potential. In some cases, cost effectiveness is higher than for some vehicle and fuel technology measures. Cited in Chapter 3, the study of relocation of schools closer to homes in Santiago, Chile reflects the very high potential cost effectiveness of such measures in the medium term (US$ 2 per tonne CO_2 over 20 years).[5]

Needless to say, these kinds of measures can have a potentially large impact on health-related factors such as childhood physical activity and obesity, though only limited evidence of such an effect is currently available.[6] Similarly, siting homes in greater proximity to shops and services could have a significant impact on patterns of adult physical activity, sedentary behaviour and ultimately diseases such as cardiovascular disease, stroke and type 2 diabetes, as noted in Chapter 3.

While there is increasing evidence that better land-use planning, more walking and cycling, and mode shift from cars to public transportation are all associated with improvements in some domains of health, robust evidence of the most effective policies and interventions for achieving these goals is only slowly emerging. For instance, a systematic review of travel behaviour change programmes for promoting active travel to work and school found very limited evidence that these targeted strategies were effective at achieving mode shift.[7] This lack of apparent effectiveness may have been exacerbated by implementing these interventions in isolation, without complementary policies that improved infrastructure for public transport or active transport, or policies that supported healthy land-use patterns.

The impact of good urban design in supporting mode shifts is much more clear, as reviewed in Chapter 3 of this report. Systematic reviews have also identified specific infrastructure design measures that can promote active travel, such as separated cycle paths, access to green spaces and increasing urban density (Table 15).[8] However, many research gaps remain. Other research has demonstrated the effectiveness of traffic calming measures and slower speed zones, for reducing road traffic injuries – which may help remove safety barriers to walking and cycling.[9,10] While not systematically reviewed as yet, economic measures such as fuel pricing, parking charges and pay-as-you-drive pricing are likely to be another important way to encourage shifts from car use to public transport and to walking and cycling, thus reducing VKT.[11]

Identifying effective interventions for improving land use may be even more challenging. As identified in Chapter 3, several land-use patterns are consistently associated with better health but more work is needed to describe strategies that can best achieve these land-use patterns. Clearly, governance and planning measures are one important pathway for improving urban land use (see Section 4.4). Table 15 summarizes recent systematic review evidence relevant to land use, mode shift and health.

Table 15. Systematic review evidence relating to land use, mode shift and health

Citation	Policy/intervention area and outcomes/effects	Key findings/conclusions
Ogilvie et al., 2004[12]	Interventions to promote walking and cycling	Targeted behaviour-change programmes may lead to mode shift away from cars of 5% in motivated individuals; some evidence that commuter subsidies and new railway stations change behaviour, but lack of evidence at population level
Heath et al., 2006[13]	Land-use and transport policies for increasing physical activity	Community- and street-scale urban design and land-use policies and practices effective in promoting physical activity
Ogilvie et al., 2007[14]	Interventions to promote walking	Some interventions targeting individuals or groups can be effective, but evidence for targeting workplaces, schools or geographical areas is weaker
WHO, 2009[15]	Interventions to promote physical activity	Environmental interventions targeting the built environment, policies that reduce barriers to physical activity, transport policies and policies to increase space for recreational activity were among the most effective interventions identified for increasing physical activity. Multifaceted approaches promoting active commuting were moderately effective
Hosking et al., 2010[7]	Effect of workplace and school travel behaviour-change programmes	Insufficient evidence to determine effectiveness at achieving mode shift or improving health
Fraser and Lock, 2010[16]	Effect of environment on cycling	More cycling associated with cycle routes/paths, separation from traffic, high population density, short trip distance, proximity of green space, safe routes to school, less traffic danger and absence of steep inclines
Yang et al., 2010[8]	Interventions to promote cycling	Community-wide promotional activities and improving cycling infrastructure modestly increased cycling
Wong et al., 2011[17]	Environmental correlates of active school transport	Shorter distance associated with active school transport, but no consistent association for density, land-use mix or intersection density
Chillón et al., 2011[18]	Interventions to promote active transport to school	Most interventions showed some increase in active transport, but the effect size varied greatly

Thus, although the theoretical potential for win-win strategies for health and mitigation involving land use and mode shift is very high, more experience is needed in what are the most effective strategies to achieve this. However, it is becoming increasingly clear that packages of strategies are often needed – involving a combination of infrastructure, regulatory, planning and pricing policies. Barriers to change can occur in any one of these areas, as explored further below.

4.3 Overcoming structural barriers to healthy and low-carbon modes

Factors that can limit mode shift in practice include existing land-use patterns; public and policy-maker awareness and attitudes; and the extent to which existing governance, investments and pricing policies favour private over public or non-motorized modes.

4.3.1 Urban spatial growth trends – the role of governance and planning

Cities and metropolitan regions (particularly in the fastest-growing developing cities) are developing in new shapes and directions that could make healthy, sustainable transport choices challenging to implement in the future.[19]

These include the development of extensive metropolitan regions, urban corridors, and mega-urban regions with tens of millions of inhabitants. These developing conglomerations can be major centres of economic activity, but they also can create unprecedented demands on traditional land-use planning mechanisms.[19] As noted in Chapter 2, contrasting trends are driving this process. In some cases, informal settlements on the periphery are more affordable for lower-income groups than most city-centre locations. In other cases, more affluent groups relocate on the periphery to flee the environmental hazards of urban centres. Both of these processes can entrench an "urban divide" in which richer and poorer communities become increasingly segregated and alienated, geographically as well as socially.

Stronger urban governance and planning policies are needed to provide a more adequate mix of housing opportunities for different groups of people in more compact sustainable cities that also facilitate efficient transport to education, employment, recreation and social services. Good planning and governance mechanisms are needed to ensure investment in urban or communal green spaces, locally-provided health and social services, and other collective amenities that make urban living appealing.[19,20] And at the same time, siting of homes and neighbourhoods in close proximity to urban health hazards, such as industrial areas or major roads, needs to be avoided. (Other things being equal, neighbourhoods along heavily polluted and trafficked corridors will also have lower property values reflecting a lower 'locational' value).[21]

When a city's physical and social hazards outweigh its benefits, affluent populations with access to cars will often relocate to satellite or dormitory cities or suburbs that are greener, less dense and correspondingly more car dependent. Some employment opportunities and services will follow, although they, too, will primarily be accessible by car. Meanwhile, lower income groups may be left behind in city centre or peripheral neighbourhoods with high concentrations of traffic and arterial routes bringing commuters into the city, or urban parking spaces, and less available space for neighbourhood walking, cycling and recreational activity.

In other cases, urban trends have seen lower wage earners locating in less expensive neighbourhoods on the periphery because center city housing is unaffordable. Here, too, the provision of adequate transport to jobs and employment plays a key role in urban equity; good public transport can ease the burden of accessing employment and services, while prolonged journeys on dangerous roads or on cramped public transport compounds it.

Transport can thus be seen as a city's 'skeleton' – defining how its form takes shape and also playing a key role in urbanization patterns, and patterns of economic opportunity and social organization.[19,22]

4.3.2 Using transport as a driver for more successful and healthier urbanization

Successful densification needs to achieve a balance between compact built spaces and ample green/open spaces, while also managing factors such as community noise levels and personal security. The complexities are often challenging.[19,23] Still, cities such as Curitiba (Brazil)[24], Bogotá (Colombia)[25] and Portland (United States of America)[26] have provided examples of strategies that used transport to make an important turnaround in the overall urban fabric of life.

Urban green space in Belfast, Ireland. (Photo: Dominik Schmid)

In transport terms, key measures that have been shown to make a difference include investing in and prioritizing low-pollution public transport systems; traffic calming measures to reduce speeds; expanding networks for walkers and cyclists; and prioritizing public parks over parking lots, thereby preserving or restoring the quality of urban residential life. In turn, these measures must be accompanied by parallel efforts in urban and region-wide planning, housing, employment, and social/cultural services. Overall, reducing the transport hazards of urban life can help stimulate urban revitalization and make cities more attractive "magnets" – counterbalancing the outward pull of automobile-oriented growth.

Although challenging, increasing residential density in areas initially characterized by low spatial densities has the potential to increase the proximity of residents to potential destinations, thus improving access while reducing the need for private motorized transport. To ensure health, social and equity benefits, however, higher concentrations of amenities such as health and social services, education and employment opportunities, transit nodes and green spaces need to be located in close proximity.

Improving quality of life for the urban poor, in particular, means addressing social and environmental determinants of health in an integrated manner, including safe and healthy shelter with secure tenure as well as local availability of basic needs such as education and health services.[19,21]

4.3.3 Addressing entrenched travel and mode choices in developed countries

While this report suggests that land-use changes and mode shift are the most promising strategies for health and climate, entrenched travel behaviours create large barriers to change. This is particularly true in developed countries but also in developing cities where the growth in private vehicles has already outpaced other modes.

With its relatively greater emphasis on the mitigation potential of lower-emissions vehicles and fuels, the IPCC assessment reflects the perspective that mitigating GHG emissions while preserving current travel behaviours is the most realistic option – and the more desirable in light of the tremendous global interest in more flexible and personalized forms of individual mobility.[27] However, it is these high levels of personal mobility that incentivize sprawling cities and lead to heavily trafficked roads with attendant dangers of injury and pollution. In other words, there is a mismatch between the benefits of mobility for drivers, and the major negative impacts for populations. Addressing those aspects of entrenched personal travel behaviours that increase health risks for society as a whole is thus an important challenge to be met if greater health co-benefits, particularly in terms of physical activity and health equity, are to be derived from mitigation policies. As will be noted in Section 4.3.4, an integrated approach to pricing, infrastructure and planning policies is needed.

4.3.4 Creating healthier 'micro-environments' in transport

Vehicles have become powerful symbols of status, freedom, individuality and power in contemporary society. However, some researchers have observed that part of this allure, beyond the symbolic element, is the fact that cars and motorcycles are able to create a powerful microenvironment, which is more likely to be under an individual's control. In contemporary urban societies where freedom and individual expression are increasingly perceived as universal values, increasing one's personal mobility can have a powerful attraction.

Research has shown that people do not make decisions based solely on health criteria, but on a mix of health and non-health features – transport is evidence of this.[28] Yet at the same time, many of the features that attract some people and repel others are, in fact, rooted in health-conscious choices. The quality of travel by different modes can thus have important effects on mode choice and can also influence the health impacts experienced by travellers.

For instance, in cities where being stuck in a traffic jam is perceived as inevitable due to the lack of dedicated transit corridors, then the 'micro-environment' of a private car with air conditioning is almost sure to be more attractive, for those who can afford it, than a crowded bus with windows open to outdoor exhaust fumes.[29] Even in more more affluent, developed cities, noise exposures on mass transit systems can be above the threshold for noise-induced hearing loss.[30] At the same time, if transit services feature cars or cabins with a healthy micro-environment including good air quality, noise control, cleanliness and thermal comfort, and move on dedicated routes that enhance their efficiency, then they will be more competitive with private travel modes.

Similarly, a separated cycle path, or a walking path along a green space or "linear park" that avoids the traffic of a busy urban area, can also offer the user a high-quality micro-environment. Where such routes are available, research has shown that people will engage in more active transport – enhancing health. In contrast, travelling by foot or bicycle along the side of a traffic-clogged road in the heat and sun, without a road shoulder to provide safety, will exacerbate multiple health risks and hazards, and deter people from using that mode of travel.

If transit and NMT modes are to attract users who have other options, they need to offer healthy micro-environments that are safe, clean, thermally comfortable, and pollution-free as well as efficient. In other words, the combined efficiencies and quality of travel by transit, walking and cycling needs to match or exceed the quality of private motorized travel. This is consistent with findings that aesthetic features and the attractiveness of the built environment are associated with more active travel, as summarized in Chapter 3.

Affordability is essential but good public transport also needs to be of high enough quality to attract all population sectors, including the affluent, and not be regarded as transport "for the poor". Indeed, the affluent groups in emerging economies are in particular need of the physical activity that active transport provides. Middle-class households that do own a car may be extremely pleased to consign its use more to pleasure trips rather than daily driving, and to have safe active transport and public transport networks for themselves and their families that can supplant the need for a "second car".

4.3.5 Improving two-wheelers: from combustion to electric engines

Two-wheel modes of travel are clearly powerfully attractive, as evidenced by the huge global increase in both motorcycle and bicycle sales and interest. They offer improved individual flexibility and autonomy and low costs in travel – valued transport commodities in contemporary society. In many emerging economies, two- and three-wheelers are important generators of income, serving as delivery vehicles and taxis as well as passenger travel for work and pleasure. Unfortunately, as noted in Chapter 2, there is a considerable downside in terms of injury risks and pollutant emissions from motorcycles.

Shifting from gasoline-powered to electric two-wheelers is a potential strategy for reducing GHG emissions. The International Energy Agency (IEA) estimates that 50–75% of powered two-wheelers could be electric by 2050 if encouraged by favourable policy settings, compared with a baseline of 9% share in 2005.[31] Electric two-wheelers are the lowest-cost form of motorized transport in China, due to low maintenance costs and affordable electricity.[31] Mode shift from gasoline-powered to electric two-wheelers could lead to health co-benefits by reducing urban air pollutant emissions. In addition, in comparison to motorcycles, electrically-assisted bicycles can provide physical activity of moderate intensity.[32]

Paris, France: low-priced bicycle rentals. (Photo: Carolyn Sparling, flickr.com/photos/clinc)

It should be noted that increases in the prevalence of electric bicycles in China have been associated with increased injuries among users of this mode, suggesting that stronger measures to control injury risk are needed.[33] In addition, care is needed to ensure that the promotion of electric two-wheelers does not diminish networks and access for non-motorized active transport, which still have comparatively greater benefits for physical activity and emissions. Strengthening urban transit systems as the 'backbone' of a multi-modal urban transport environment also can help enhance the options of two-wheeler motorists, who may then be able to park at transit stations, and continue longer journeys aboard BRT or rail. Stronger traffic regulation and calming measures, as applied to motorcycles, also may help constrain injury risks from two-wheeler traffic by limiting incursions into networks dedicated to pedestrians and bicycles.

4.4 Identifying governance drivers of healthy transport

4.4.1 National and regional governance as drivers

Globally, alternatives to private motorized travel remain low on the list of countries' policy priorities. A WHO survey found that fewer than one third of countries had national or local policies that promoted walking and cycling as alternatives to motorized transport; many also lacked policies to encourage public transport.[34] 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.[35] Improvements in these areas are likely to be an important part of global efforts to shift travel behaviours.

Governance at both national and regional levels can help support health co-benefits in transport policies. The experience of Europe, which has a long record of policy action on healthy and sustainable transport, is used here as a positive example.

Beginning in the mid-1980s, growing awareness about health and environment throughout Europe led to the convening of the First Ministerial Conference on Environment and Health (in 1989). Out of this conference, the European Environment and Health Committee (EEHC) was created to support and facilitate an ongoing European environment and health process, that includes regular ministerial meetings every five years. The EEHC is a multi-stakeholder committee that includes health and environment ministries, WHO, European Commission, United Nations Environment Programme (UNEP), Organisation for Economic Co-operation and Development (OECD) and United Nations Economic Commission for Europe (UNECE).

The EEHC's first activity was a state-of-the-art review of environment, development and health issues in Europe. *Concern for Europe's Tomorrow*[36] clarified how different sectors of the economy (including transport) were affecting health and environment, and identified effective interventions.

This review led to a series of regional meetings and discussions that culminated in a *European Charter on Transport, Environment and Health*, adopted at the Third Ministerial Conference on Environment and Health held in London in 1999.[37] The Charter described the health and environment costs of unsustainable transport, reviewed actions so far and proposed a way forward for more integrated policies that included:

- a framework of principles and approaches for transport that is sustainable for both health and environment, including the "polluter pays" principle, "integrated decision making across the sectors", "public participation"; "access to information" and "precaution and prevention";

- policies that would be pursued, including a reduction of the need for motorized transport, and a shift towards healthy and clean modes of transport (see Box 3);
- tools for selecting transport policies with best results, including the use of health and environment impact assessments, of indicators and monitoring;
- 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, nongovernmental organizations (NGOs) and international organizations. It was agreed to implement a programme of joint action. This joint programme became known as the Transport Health and Environment Pan-European Programme (THE PEP).

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

Established in 2002 at the Second High-Level Meeting on Transport, Health and Environment, the initiative, known as THE PEP, pools capacities and skills from Europe, the Caucasus, central Asia and North America, translating national policy into local action. It offers a unique tripartite platform for countries to share information and know-how and benefit from experience. It has support from the WHO Regional Office for Europe and UNECE which facilitate effective use of resources and coordination at the national and international levels. THE PEP provides a policy framework around four priorities:

1. investment in environment- and health-friendly transport;
2. sustainable mobility and more efficient transport systems;
3. reduction of emissions of transport-related GHGs, air pollutants and noise; and
4. 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 provided to regions, countries and cities through THE PEP Partnership, which conducts joint projects, as well as national and local workshops, on themes such as healthy and safe urban walking and cycling. Experiences and good practices are exchanged on THE PEP clearinghouse (www.thepep.org), as well as the THE PEP toolbox's *Healthy Transport* web site (Box 4). Special attention is given to the needs of the eastern, south-eastern European and central Asian countries and to particularly environmentally sensitive areas. Although THE PEP is a voluntary initiative, it has been successful in bringing together transport, health and environment sectors at regional, national and local levels. It has led the development of tools such as 'HEAT' for estimating the health benefits of investments in walking and cycling (See Chapter 5), and supported implementation of international and regional policies at national and local levels.

4.4.2 Governance at urban and national level: emphasizing integrated approaches to pricing, policies and infrastructure measures

Policies directed at mode shift and improving land use (for example) can not only improve health and reduce GHG emissions but also may help improve energy security, thus meeting both city- and national-level objectives. Globally, policy development

Box 3. Strategies for healthy and sustainable transport from the European Charter on Transport, Environment and Health

The *European Charter on Transport, Environment and Health* was adopted in 1999 at the Third Ministerial Conference on Environment and Health in London, UK. It identifies ten key strategies that can synergistically promote healthy and sustainable transport:

1. reducing the need for motorized transport by adaptation of land-use policies and of urban and regional planning;
2. shifting transport to environmentally sound and health-promoting modes;
3. implementing best available technologies and best environmental and health standards;
4. applying strategic health and environmental indicators and impact assessments, with the involvement of environmental and health authorities;
5. relating the costs of transport more closely to mileage travelled and internalizing transport-related environmental and health costs and benefits;
6. raising awareness of transport and mobility sustainable for health and the environment, including efficient driving behaviour;
7. applying innovative methodologies and monitoring tools;
8. establishing partnerships at international, national, subnational and local levels;
9. promoting pilot projects and research programmes on transport sustainable for health and the environment;
10. providing information to the public and involving them in relevant decision-making processes.

Source: WHO Regional Office for Europe, 1999.[37]

Box 4. THE PEP tools and activities

THE PEP-toolbox

The *Healthy Transport* web site (THE PEP-toolbox) is designed to help policy-makers and local professionals solve transport problems that affect health and the environment. In addition to tools and good practices, the site offers 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 is available on the web site (www.healthytransport.com).

that integrates these three disparate outcomes is likely to be much more cost effective than addressing each of these issues in isolation.[38] Good urban governance thus has an important role to play in aligning disparate policy outcomes – a challenging task, but one that can achieve desired outcomes at lower costs. Failure to pay attention to alignment of policy areas may lead to one area being sacrificed in order to achieve gains in another: for example, diesel subsidies in India may reduce GHG emissions per vehicle kilometre, but may also lead to worsening air quality and health costs.[39]

Informing communities and residents about healthy urban development, as has been done using the Healthy Location Index,[40] may be one way to provide added impetus and demand for good land-use planning. Similarly, identifying principles of good community design and monitoring progress towards better community design (as in the example of Transport and Land Use Health Indicators[40]) can help develop momentum for ongoing urban land-use improvement. Tools for healthy transport design, assessment and monitoring are discussed at more length in Chapter 5.

Box 5. The Sustainable Urban Transport Project (SUTP)

The SUTP (www.sutp.org) aims to help developing cities worldwide achieve sustainable transport goals. The project has three branches in Asia and Latin America, and some activities in Africa. SUTP's series *Sustainable Transport: A Sourcebook for Policy-makers in Developing Countries,* addresses key areas of urban transportation. The more than 30 modules include a recent report on *Urban Transport and Health*.[41] Among the other themes are land-use planning, demand management and climate change. SUTP also conducts training courses for technicians and decision-makers in key developing cities, and provides technical advice on urban transport policies and projects. SUTP is a partnership between Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and a range of international, regional and municipal partners, including: UN Habitat, the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), and Bogotá, Colombia's TransMilenio BRT system.

4.4.3 The neighbourhood microenvironment: building leadership capacity

Just as people respond to the transport microenvironment, so they respond to their environment at a neighbourhood level. Polluted areas are not only potentially hazardous but also have low amenity values so that people tend to avoid those parts of town and property prices tend to be lower.[20] In many societies, the feeling that public spaces cannot be controlled (unlike the interior home environment – or car) can lead to those spaces being abandoned and politically neglected. Building leadership and capacity to promote healthy communal spaces is another critical element that needs to be explored further in the context of low-carbon planning.

An important feature of land-use and transport planning is that decisions relating to these areas are often made at the local, rather than the national level. This enables local voices to be heard more easily. In contrast, improved vehicle and fuel technologies are influenced more strongly 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 implemented consistently across different cities. Given this, local decision-makers are likely to require strong guidance and support from national and global levels to ensure that appropriate urban planning and transport strategies are put in place. Stronger information systems also can help inform policy-makers about the progress of initiatives, and help make the link between healthier transport policies and actual health outcomes in terms of increased physical activity and reduced levels of air pollution and injuries.

4.4.4 Empowering vulnerable groups

Many measures that improve the accessibility of transport systems for people with disabilities also have other benefits,[42,43] some of which can improve other health and climate outcomes. For example, provision of safe, direct and accessible road crossings can facilitate access to transit stations and other destinations for both disabled and non-disabled people. Similarly, improving pedestrian infrastructure (such as footpath quality) can facilitate active travel for the whole population, but is particularly important for people with mobility impairments. Improving lighting in pedestrian areas and at transit stations can both facilitate use by people with impaired vision and also reduce the risk of crime – a significant barrier to the use of active and public transport in many contexts.[44]

Periera, Brazil: elderly people are among the most vulnerable pedestrians. (Photo: Carlos F. Pardo)

Stated another way, certain universal design principles that offer benefits to the whole population often offer even greater benefit to vulnerable groups (such as children) as these groups are often at greater risk from transport hazards. Strategies to improve conditions for children (such as the creation of safer urban spaces that facilitate children's independent activity) may help promote urban development that benefits other vulnerable groups too.[45,46] This suggests that there is an important role for civil society, health and government groups that advocate for equitable outcomes for children, women, older people and people with disabilities. Empowering these groups with more knowledge about how the built environment can be either a mobility barrier or an enabler can help build support for public spaces and transport systems that are accessible for people with and without disabilities.Collaborative approaches with communities, involving different tiers of government and civil society organizations, also can help empower vulnerable groups as well as avoiding a process being dominated by any particular interest group.[19]

4.5 Linking traffic injury reduction to environmental management of transport

Traffic injury reduction is a longstanding area of transport and health inquiry. Nonetheless, this review (Chapter 3) found relatively few studies of associations between land use or mode shift, and road traffic injury. Those identified showed mixed results. Although this may be due to a weakness in the search strategies used, it suggests a lack of inquiry into an important aspect of injury, which is also key to identifying how investments to reduce GHG emissions may support efforts to reduce reduce road traffic injury.

Rio de Janeiro, Brazil: speed limits and dedicated infrastructure for non-motorized transport helps to reduce risks for pedestrians and cyclists. (Photo: Jeroen Buis)

4.5.1 Safer walking and cycling environments

Substantial reductions in injuries can be obtained by improving the safety of the walking and cycling environment, for example by using traffic calming and reduced speed zones (e.g. 20 mph zones).[9,10] Although these strategies do not directly reduce GHG emissions, injury risk is a major barrier to active transport. Thus, creating safer environments for walking and cycling is likely to encourage active transport. Indeed, unless safety barriers to walking and cycling are removed, attempts to encourage these modes are likely to have only a limited effect on mode shift or emissions.

Improving the safety of the walking and cycling environment is thus a necessary component of strategies to achieve mode shift from car use to active transport, and is likely to be fundamental both to reducing road traffic injuries and to reducing transport-related GHG emissions.

4.5.2 Safety potential of public transport

Although car use may carry a lower risk of injury per kilometre travelled than active modes such as cycling, public transport is typically far safer even than car use, at least in developed countries. Given this, along with strategies to ensure the quality and safety of public transport, the promotion of public transport use deserves more emphasis as a low-carbon injury prevention measure.

Particular challenges are posed by the huge role of the informal transport sector in developing countries. Although a form of "public transport", often this runs chaotically under many private operators, may have a poor safety record and limited safety maintenance.[47,48] Regulating the safety of informal transport remains a real challenge but the development of a safe and attractive publicly run transport system may be a useful way to help channel customers away from informal transport.

4.5.3 Shifting from car use to active transport: balancing benefits and risks

Mode shift from car use to active transport can reduce GHG emissions but its effects on injury are complex. All else being equal, reducing car travel reduces injuries to walkers and cyclists. However, increasing walking and cycling can also increase the total number of injuries to walkers and cyclists.[49] What remains important is the overall net effect of mode-shift on injury reduction, which is also context-dependent.

Although mode shift from car use to active transport may not necessarily reduce injuries, it is likely to improve overall health, even when injuries are taken into account. Studies from Copenhagen[50] and Shanghai[51] have shown that cyclists have substantially lower all-cause mortality, showing that the benefits of cycling greatly outweigh the risks. Modelling studies in the Netherlands and Spain have also found that the benefits to cyclists from physical activity are much greater than the risks from injury.[52,53] Another modelling study found that the physical activity benefits of mode shift from car use to active transport would greatly outweigh injury risks in London; in Delhi the same mode shift would actually reduce injuries.[54] More applied research is needed to identify the local circumstances that reduce injury or increase it, and how children and other vulnerable groups can best be protected.

In summary, there is evidence from a wide range of settings showing that, when injuries are considered together with other health outcomes, active transport has a positive overall effect on health. To lead to the best possible injury outcomes – and to remove barriers to mode shift – strategies promoting active modes need to be accompanied by improvements to the safety of the walking and cycling environment. This is especially important for those roads that are most dangerous, and for roads with large numbers of vulnerable road users such as children. As reflected in Table 14, reducing the hazards posed by motorized transport, especially the risks to walkers and cyclists, needs to be a cornerstone of win-win transport mitigation strategies.

4.6 Healthy mitigation: additional co-benefits for urban social and economic vitality

While the primary focus of this report is the health co-benefits of reducing GHG emissions, climate mitigation strategies can also provide non-health co-benefits. For example, 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 for costly road infrastructure.[55] Motorized transport has been estimated to lead to social costs in Beijing of 7.5–15% of the city's GDP – congestion, along with health and climate costs, is a major component of this. Internalizing these external costs of motorized transport could thus lead to congestion, climate and health benefits.[56] Other economic benefits of reducing motor vehicle use include reduced parking costs and costs to consumers.[11] Transport systems with strong walking, cycling and public transport provision are also less vulnerable to future interruptions in the supply of oil.

Cities with good urban planning, strong public transport and active transport infrastructure are often more liveable for their citizens. For example, Portland in the United States of America is well known for its strong planning efforts which have led to achievements such as a multimodal transportation system, a strong green-space network and pedestrian-oriented design. It was also ranked number one among large cities in meeting the country's *Healthy People 2000* goals.[26] Similarly, Vancouver is a leading example of high-density, mixed-use development and has, for most of the last decade, been ranked first in the Economist Intelligence Unit's liveability rankings of world cities.[57,58] Curitiba too has pursued aspects of sustainable urban planning since the 1960s and now has much lower fuel usage and congestion-related delays than other Brazilian cities.[24]

Investments in rapid transit/public transport may also stimulate transit-oriented development. This occurs when urban densification occurs adjacent to transit nodes or hubs, thus increasing the extent to which potential destinations are accessible without private motorized vehicles. Public transport may not only transfer current trips from car to public transport but also may have additional land-use effects that further reduce car use, an effect sometimes known as transit leverage. While it is challenging to design robust studies to accurately measure the magnitude of transit leverage, 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.[59,60]

Improved land use and public transport systems also have the potential to deliver economic benefits. Densely populated cities tend to have lower GHG emissions and provide better opportunities for active transport. They are also associated with higher economic productivity, with one review suggesting that a doubling of density would be associated with a 6% productivity rise.[61] These productivity gains are considered to be due to a range of factors, such as better access to specialized services and to public infrastructure.

Investment in public transport and rapid transit may be an effective means of generating stable local jobs, due to a greater share of investment being allocated to ongoing system operations, as compared, say, to fuel consumption, land acquisition, or road construction projects of short duration.[62,63] Further research is needed to better describe the relationship between public transport spending and employment but public infrastructure projects such as these may particularly benefit the urban poor. Public works projects are labour intensive, and when initiated in disadvantaged neighbourhoods, can have the potential to simultaneously improve local access to public transport and stimulate the creation of long-term jobs, thereby improving economic opportunities within these communities.[19]

Vancouver, British Columbia, Canada. (Photo: Duncan Rawlinson, Fotopedia.com)

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Notes

5

Mike Kolloffel/Still Pictures

Santiago, Chile. One of a number of Latin American cities that are expanding bus rapid transit.

Tools for assessing, planning and financing healthy transport interventions

5.1 Introduction

This chapter identifies tools that can help to ensure that the strategies that optimize both health and climate gains are implemented, and to monitor progress towards identified transport goals. This includes consideration of how transport modelling can incorporate health issues alongside environment and climate change effects. Due to limitations of scope, the main focus here is examples of validated tools that can be used to prospectively quantify the projected health effects of different policy options. The chapter emphasizes noncommercial tools. Although this is not an exhaustive review, it provides information on a wide range of tools that can be used to incorporate health into the assessment process for transport projects. References are provided for readers who require more detailed information.

5.2 Types of tools

Tools to assess the health effects of transport policy options can be classified in three broad categories (Fig. 8).

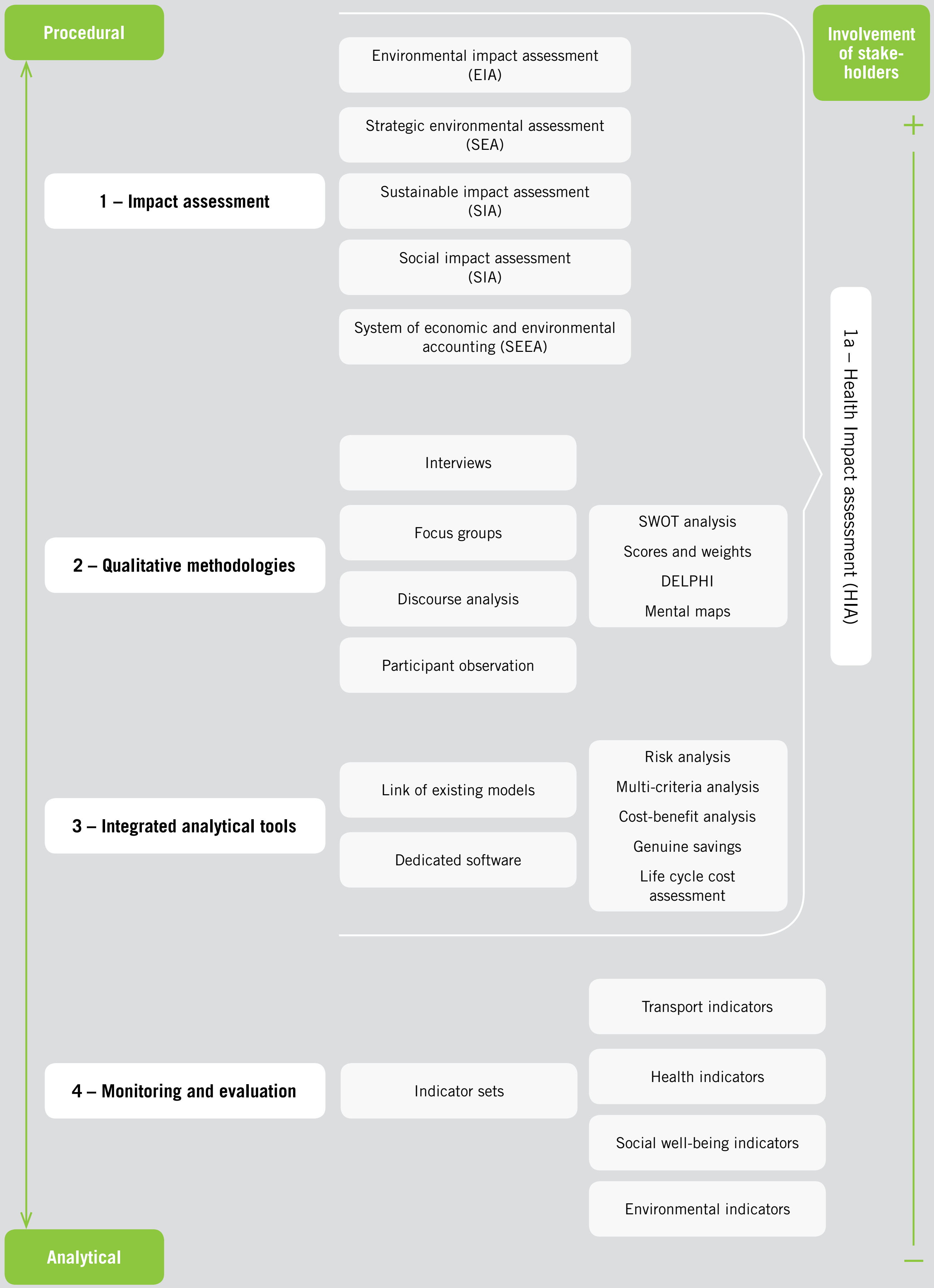
1. Procedural tools such as health impact assessment (HIA), environmental impact assessment (EIA), and strategic environmental assessment (SEA).
2. Qualitative tools (e.g. interviews, focus groups).
3. Integrated analytical tools (e.g. modelling approaches and economic appraisal tools).

5.2.1 Prospective tools

Impact assessment

Impact assessment may be described as a small group of forecasting tools used to improve the basis for policy-making and project approval processes. These are based on methodologies that attempt to incorporate concerns from diverse stakeholder groups into the assessment process.[1] Some of these tools, such as EIA (Fig. 8), are supported by legally binding frameworks. While HIA is generally not legally mandated, it can be integrated with other impact assessments to explicitly predict the health impacts of different policy scenarios or projects (Fig. 9). Often it is used to consider health equity effects. HIA can use a range of different types of qualitative and quantitative approaches, some of which are mentioned later in this chapter. The underlying principles of HIA include

Fig. 8. Tools for assessing potential health impacts of transport policies



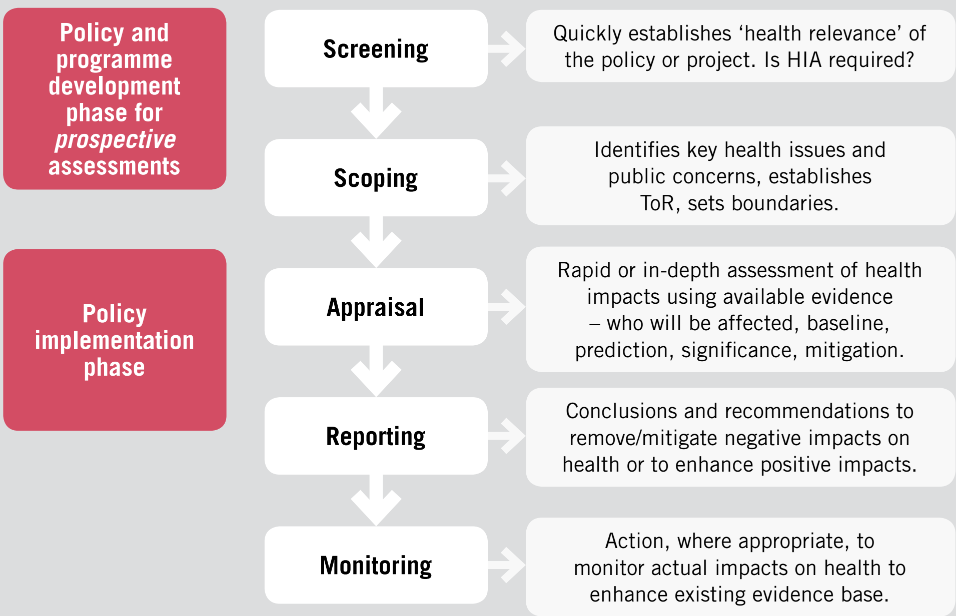
sustainable development, equity (i.e. the distribution of health effects), democracy and ethical use of evidence.[2,3]

Qualitative tools

This group includes a set of very different methodologies that usually do not use mathematical techniques: interviews, focus groups, field notes, videos and audio recordings, pictures and analysis of documents. In practice, qualitative research is used where it is important to convey to policy-makers the perceptions, expectations and experiences of individuals, groups and organizations that may be affected by policies.[4]

Qualitative research can investigate the question of how evidence is turned into practice, and can systematically pursue research questions that cannot be answered easily by experimental methods.[5] For example, as well as asking: "what are the potential impacts?" HIA may ask "by what pathways might the impacts arise?" and "how are actions likely to be implemented in this context?" A simplistic application of quantitative methodologies' estimates can produce an inadequate HIA, "as it 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."[6] In recent years, qualitative assessment techniques have been promoted and have challenged the dominance of quantitative methods.[7]

Fig. 9. The health impact assessment (HIA) process



Source: WHO (www.who.int/hia/tools/en/).

Integrated analytical tools

Tools that belong to this third category represent a further refinement of quantitative tools discussed at length 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. Integrated tools connect different quantitative assessment methods (e.g. dispersion of pollutants or estimation of health impacts) within a modelling framework that produces a measure of impacts. In an integrated assessment, models often comprise many sub-models adopted from a wide range of disciplines.[8] These tools may require the collection of more extensive and diverse data, construction of databases and alignment of different modelling approaches. Examples of such tools are provided in Section 5.4. For example, an air pollution model might apply traffic modelling for different policy scenarios, with results passed through pollutant emission and dispersion models, ultimately leading to estimates of population exposure and health impacts using an epidemiological model.

Economic evaluations also often use integrated approaches to inform decision-making. Examples of such tools include cost-benefit analysis, "genuine savings" and life-cycle cost assessment. A specific example is *TREMOVE: an EU wide transport model*, a tool for the analysis of the economic and environmental impacts of transport and environment policies.[9] This can be used to assess both technical and non-technical measures and policies such as road pricing, public transport pricing and emission standards. Internalization of the external costs of transport has long been an important issue for transport research and policy development in Europe and worldwide.[10] The monetary valuation of negative externalities such as air pollution is not straightforward since, although many of these effects carry a health cost, they have no direct market value.[11] A range of different techniques may be used in assigning monetary values to health costs, including: contingent valuation (using surveys to estimate people's willingness to pay for certain environmental goods and services); travel cost (using prices paid for travelling as a basis of travel's monetary value); and hedonic pricing (focuses mainly on property markets by analysing prices influenced by surroundings). Additional techniques for monetary valuation include factor income, avoided cost and replacement cost.[1]

Geographical information systems

A geographical information system (GIS) is a procedure for linking 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 hospitalized for respiratory outcomes in that area in a given period). GIS is highly useful as a tool for assessing the impacts of both transport and climate change, and is often a component of models for assessing health impacts. Requirements for GIS are similar for both topics. According to Campbell-Lendrum et al. (2003) these are:

- geographical information defining the study points or areas, such as the latitude and longitude of the study points or digitized georeferenced outlines of administrative regions;
- information about the distribution of the exposure (air pollution, climate) in space and time;

- information about the health effects of this exposure, such as the incidence or prevalence of air pollution and climate-sensitive outcomes in the corresponding time and place; and
- information about possible determinants of vulnerability (to air pollution and/or climate change), such as average income, age or housing quality.[12]

The use of GIS enables the different kinds of information for each time and place to be linked. Trends in exposure, modifying factors and 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 places and times.[12]

Linking models

Linking changes in transport factors to changes in health outcomes often requires several models, with outputs from one model forming the inputs for the next. These different models can be integrated either by using a framework to link existing models or by constructing integrated software tailored to the scenario in question. When using a framework to link existing models, models are drawn and developed from existing methods and then linked to create an integrated and coherent loose-coupled modelling system within a GIS. This approach has the advantages of economy of programming and greater flexibility since it allows other models to be incorporated easily and enables modular upgrading and improvements according to need. It also avoids the need for access to the source code of proprietary models, and enables full functionality of existing programmes to be maintained. Thus, researchers can largely continue to work with existing familiar models, thereby avoiding the need for training and recalibration.

Transport infrastructure occupies an increasing share of urban space, while recreational facilities are hard to find in many developing cities. (Photo: Dominik Schmid)

Integrated software can be used in two ways. First, an integrated modelling environment can be implemented on top of an existing GIS framework (or another software platform for complex systems) using a file exchange mechanism or a common data set. The second approach develops new software from scratch. This involves the adoption of a common modelling language, allowing closer model linkage (tight coupling) and the development of a specific user interface that can allow users to enter their own data and apply the software to a specific area or region at a specific space-time scale. Alternatively, different software packages can be "loose coupled" – linked by developing external interfaces and data exchange protocols rather than by adapting the core programmes.[13]

Several challenges must be met when integrating models. One is ensuring that transport models provide sufficient input data for linked models, which can require improvements in transport modelling practice. Origin-destination (O-D) matrices and the network graph of a city are usually fundamental inputs for traffic models. O-D matrices are generated from traffic counts or mobility surveys of city residents that provide questionnaire-based data on recent trips. O-D matrices of private trips by purpose (work, leisure, etc.), complemented by O-D matrices of heavy load vehicles and transit traffic, are used to assign traffic movements between city districts through the network. This provides more precise transport-activity patterns than classical time-activity surveys. The network used in traffic simulation is a simplified network that generally represents only part of a city's street geography. Integrating the network for private motor vehicles with other networks (such as bus, tramway, metro and train networks, but also pedestrian and bicyclist networks) is less common but also necessary for comprehensive exposure assessment.

Another challenge is providing data on exposures in different micro-environments. While the risk of crashes occurs only outdoors on a network, air pollution and noise exposures are a combination of indoor- and outdoor-generated emissions. Existing dispersion models provide a means of predicting outdoor pollutant concentrations but to best assess exposure it is necessary to have estimates of pollutant concentrations for the whole range of different micro-environments in which people spend their time, not just the outdoor environment.

Other challenges include ensuring compatibility of the outputs of one model with inputs for the next. This includes use of compatible spatial scales and the need to integrate hazard maps produced by models with space-time activity data for populations, as well as the need to incorporate important factors such as congestion on road networks. Models primarily used for air pollution and noise must be adapted for road accidents and physical activity.

5.2.2 Retrospective tools

Retrospective assessment often utilizes indicators and indices.[1] Hence, progress towards transport goals can be assessed by collecting data on key transport indicators. As well as environmental and economic outcomes, a number of health and social factors should be monitored in a balanced transport indicator set.[14] Collecting and reporting indicator data allows public assessment of whether transport systems are improving their health performance, and at what pace.

One example of a transport indicator set is the transport and environment reporting mechanism (TERM) that enables monitoring of transport trends in Europe.[15] The most recent TERM report assesses progress towards reducing GHG emissions. It finds that, although vehicle efficiency is improving, growth in travel means that total transport-related GHG emissions continue to rise. However, while TERM assesses progress on environmental outcomes (including GHG emissions, air quality and noise), other important health outcomes such as road traffic injury and physical activity are not included.

In order to lead to improved transport systems, transport indicator sets must adopt a more holistic approach to ensure that human health and well-being outcomes are incorporated.[16] Transport indicator sets are usually large, often including more than 30 indicators, and so identification of briefer, more manageable sets of core indicators is needed.[17] Given the evidence that socioeconomically disadvantaged groups typically bear more of the burden of transport hazards and have poorer access to current transport systems, the social distribution of transport effects should be monitored.

While TERM provides a promising example of transport-system monitoring in Europe, resource and data limitations may mean that low- and middle-income countries require different monitoring approaches. Nevertheless, progress towards healthy, low-emission transport systems is just as important in these countries. The process of developing a sustainable transport indicator set for local government in South Africa illustrated several of the potential challenges. A lack of resources for data collection was compounded by ongoing changes in staff. Despite much work to engage relevant stakeholders there were divergent stakeholder views about the importance of sustainability, and about which indicators best represented sustainability concepts. Furthermore, policy priorities were continually open to change. However, ongoing negotiations led to the adoption of an indicator set that represented many important aspects of sustainability.[18]

5.3 Application of tools

5.3.1 Developing transport and health scenarios

In this context, a scenario means the imagined transformation of a place with respect to its transport and land-use characteristics. In order to build a transport and health scenario, it is necessary to quantify a range of key factors. These include land-use change, vehicle fleet composition, road network configuration and population space-time mobility patterns (Table 16). This provides a snapshot of the current situation, as well as alternative situations with different transport characteristics. Scenarios may range from the baseline case (e.g. current legislation) up to the maximum that can be achieved through full application of all presently available technical emission control measures – the "maximum technically feasible reduction" (MTFR) case.[19] These different scenarios are associated with different levels of exposure of the population to factors such as air pollution, and consequent differences in health outcomes.

Table 16. Examples of scenario components in transport planning

Category	Data items in scenario
Land use	Land-use map Network map Configuration of the street system
Traffic	Fleet composition of vehicles
Population	Population space-time mobility patterns Resident population (for base year and projection year) Epidemiological statistics Physical activity data
Air pollutants	Concentrations of established pollutants (e.g. $PM_{2.5}$, PM_{10}, O_3, NO_x, NO_2, CO, EC, VOCs, PAHs, benzene) Indoor/outdoor ratio
Accidents	Speed on the network
Noise	Noise dispersion map Noise at night

Calculations of associated health outcomes typically rely on epidemiological research that has identified and quantified relationships between exposures (such as air pollution) and health response in a population. This research has been conducted for various air pollutants and for noise for large populations in North America, Europe and Asia. An exhaustive scenario requires an organized and validated system of data collection, although this ideal situation is seldom achieved.

Scenario modelling has some obvious advantages, in terms of facilitating large-scale quantitative assessments of possible future health impacts, as well as disadvantages, in terms of determining plausible scenarios and assessing the levels of uncertainty of key variables which, in turn, affect quantitative outcomes.[20] Approaches may vary in the extent to which health is included in the impact assessment or modelling process, and the extent to which the approach provides robust estimates of health outcomes.

5.3.2 Model outputs

Models can include multiple outputs covering both health and non-health outcomes. In the Clean Air for Europe (CAFE) programme, a set of scenarios was developed that individually or jointly addressed four environmental endpoints: (i) health impacts from $PM_{2.5}$; (ii) ozone; (iii) acidification; and (iv) eutrophication.[19] Common health outputs of health and transport models are described in Table 17.

A number of models have been developed to predict injury outcomes. For example, there are several methods to predict pedestrian injuries, frequently based on numbers of pedestrians and vehicles, but in some cases taking into account other factors such as road width and pedestrian crossings.[21]

For air pollution and noise, the usual metric for measuring health impact is the amount of the observed occurrence of an outcome attributable to the selected pollutant. This can be expressed in terms of proportions, percentages or absolute numbers of cases.

A traffic jam around the commercial centre of Kampala, Uganda's capital city. Chaotic road traffic is commonplace. (Photo: SpecialistStock/Matthew Frost)

Table 17. Commonly used health outputs from transport models

Data	Attributes	Unit
Average population exposed to air pollution (all pollutants monitored)	Population exposed (home, work) per subgroup to pollutant concentrations exceeding limit values	Number of persons exposed per space unit (most detailed scale)
Average exposure to air pollution during travel (all pollutants monitored)	Travel-time exposure per subgroup to pollutant concentrations exceeding limit values	Number of persons exposed while travelling
Yearly air pollution-attributable deaths	Total mortality (all causes without accidents), cardiovascular mortality, respiratory mortality, lung cancer	Number of deaths per year and years of life lost (YLL)
Yearly air pollution-attributable morbidity	Hospital admissions for cardiovascular disease Hospital admissions for respiratory disease Acute bronchitis (aged <15) Chronic bronchitis (adults) Asthma exacerbation (aged <15) Asthma exacerbation (aged 15+) Restricted activity days (aged 20+) Occurrence of respiratory symptoms	Number of persons hospitalized and years lived with disability (YLD)
Exposed to noise	Population exposed per subgroup to noise exceeding limit values	Number of adults exposed
Annoyed by noise	Annoyed and highly annoyed, indoors, in one year	Number of adults annoyed
Sleep disturbed by noise	Highly sleep disturbed (HSD) and sleep disturbed (SD), indoors, in one year	Number of adults sleep disturbed
Severity of accidents	Fatal, severe and minor accidents	Number of accidents by severity
DALYs	Disability-adjusted life-years = YLL + YLD	DALY

Attributable risks are estimated by applying known concentration-response coefficients to the distribution of exposure in the population. This distribution usually consists of the average concentration measured in the area where the population live (can be as large as an entire city) over a given period of time, assuming that everybody in the area is exposed to the same pollutant concentration.

While this approach has been useful in first-generation impact studies, it has several limitations. For example, a constant average concentration over a large population may result from different exposure distributions, and therefore different health impacts in more heavily exposed subgroups. Consideration of population subgroups is important but is often difficult due to limitations in data and methodology. In the case of air pollution, some age subgroups are specifically considered (such as children under 15 years) for some health endpoints (such as asthma). However, in the case of noise, dose/response curves for annoyance are based on surveys of adults at home, and their application to children or outdoor situations is more difficult.

Population subgroups may also differ in sensitivity (exposure–response relationships). For example, mortality among elderly people is much more sensitive to high temperatures than is mortality in younger adults. The temporal scale of health effects, (that is, the latency times from exposure to adverse event) must be taken into consideration. For accidents and acute effects this is not too problematic – they are instantaneous or follow exposure by a few days at most. In the case of long-term mortality due to air pollution, however, this is uncertain.

Migration can affect estimates of population exposure, especially in cities with large immigrant and transient populations.[22] Despite this, most studies do not account for the effects of migration. Finally, double-counting problems arise for some health effects (such as cardiovascular disease) due to air pollution and noise. In any case, health impact methods usually underestimate impacts and are conservative.

Given the inherent limitations of these models, any calculation of attributable fractions or absolute number of attributable cases should state the underlying assumptions. In particular, the following should be addressed:[20]

- justification for applying the exposure–response relationship beyond the bounds of the observed range;
- justification for applying the exposure–response relationship derived from a different population;
- the baseline disease incidence used to estimate attributable cases; and
- explanation regarding the selection of the exposed population.

5.4 Examples of tool applications

This section provides examples of the application of a wide range of tools. Many applications are possible, ranging from simple to very complex exercises, and from urban to international levels. Particular emphasis is given to case studies of integrative analytical tools, which are summarized in Table 18. Examples of the application of other tools such as HIA are also available in other reports.[23]

5.4.1 Health impact assessment

In recent years, the integration of HIA into transport assessment has advanced, particularly in Europe and the United States of America.[27] Examples are provided in many publications (such as the 27 American (USA) case studies noted by Dannenberg et al.[28]) and websites (such as http://www.who.int/hia/examples/en/, http://www.apho.org.uk and http://www.thepep.org).

HIA has been applied in a range of transport planning situations. For example, large infrastructure changes and highways were assessed by means of HIA in different contexts (e.g. Greig et al. 2001[29], Kjellstrom & Hill 2002[30]). In the Netherlands, two simulations were conducted to consider the impacts of (i) reduced speed limits; and (ii) a traffic diversion project to move traffic away from a very dense area to one of lower density by building a new highway.[30]

5.4.2 Qualitative tools

Examples of the use of qualitative tools in the appraisal of transport projects are summarized in Table 19. These do not attempt to quantify the health impacts of these projects. They include SWOT (strengths, weaknesses, opportunities and threats) analysis, scores and weights, and use of key informant interviews, DELPHI interviews and/or focus groups involving experts or transport users and other stakeholders.[31]

Table 18. Summary of case studies applying integrative analytical tools[24]

Area (study)	Description of case study	Scale and/or parameters	Population	Policy and scenarios modelled	Tool	Outcomes
Florence urban planning impacts (HEARTS)[32]	Integrated modelling within a 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	• Mortality (aged ≥30 years, excluding accidental causes) long-term • Acute bronchitis (aged <15 years) • Restricted-activity days (aged 15–64 years) • YLL
Netherlands modal shift [25]	Study of health effects of modal shift from car to bicycle in terms of decreased air pollution emissions, GHG 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	• 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)[26]	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 happens if 1000 additional adults (ages 20–64) become regular urban commuter cyclists?	HEAT	• Estimated 17.5% mortality reduction • Estimated annual savings of NZ$ 765 000
Europe emissions impacts (CAFE)[35]		Continental (EU25) and national	Whole population, approx. 450 million	Starting point of analysis is baseline model(s) of pollution data Uses CAFE CBA methods to assess state of the environment in 2000 and 2020, looking 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) CAFE CBA methodology is applicable only for assessing changes between scenarios, i.e. marginal policy changes	• Chronic mortality from particulate matter (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

Table 19. 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 2015 in medium-size European cities)	DELPHI
Appraisal of central-Asian transport projects	Small sample surveys of road users
Assessment of Merseytram scheme	Interviews and focus groups

Source: European Commission 2009,[31] Health Scotland 2007.[23]

5.4.3 Integrative analytical tools – examples at urban level

HEARTS

The WHO Health Effects and Risks of Transport Systems (HEARTS) project[32] is not a tool but rather a project that includes three case studies to test models for quantitatively assessing the 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 transport plan that included new tramlines, parking facilities at the terminus of tramlines, 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 of the city and increased highway traffic capacity. In addition, the consequences of changing the fleet composition (i.e. improved vehicle technology) were considered.

Traffic scenarios were constructed for 2010 as compared to 2003 (Table 20). The traffic scenarios considered: (1) a baseline; (2) improved vehicle fleet composition; (3) transport network investments and improved vehicle fleet composition; (4) transport network investments but no improvement in vehicle fleet composition.

Based on geocoded traffic modelling results, a chain of different models was implemented. These included 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. The Fast Environmental Regulatory Evaluation Tool (FERET) is a similar tool, developed by Carnegie Mellon University and the University of Washington, which includes a CBA component.[33]

Results of the emissions modelling of the Florence case study scenarios are shown in Table 21. Combined improvements in the transport network and the vehicle fleet, compared with the 2003 reference scenario (Case C) was projected to lead to estimated reductions of 129 deaths, 596 acute bronchitis cases (aged <15 years), 5869 restricted-activity days (aged 15–64 years) and 1400 years of life lost per year.

Table 20. HEARTS scenarios

Emission scenario	Traffic scenario	Vehicle fleet scenario
1	2003	2003
2	2003	2010
3	2010	2010
4	2010	2003

Table 21. Pollutant variations between HEARTS emission scenarios

Variation between scenarios: daily total emissions (%)	CO	NO_x	PM_{10}
Case A (Scenario 1 – Scenario 2)/Scenario 1	43%	37%	21%
Case B (Scenario 1 – Scenario 4)/Scenario 1	29%	16%	21%
Case C (Scenario 1 – Scenario 3)/Scenario 1	59%	48%	38%
Case D (Scenario 4 – Scenario 3)/Scenario 4	42%	38%	21%

5.4.4 Integrative analytical tools – examples at national level

Netherlands: modal shift from car to bicycle

Hypothetical scenarios based on national statistics can offer interesting insights into the health impacts of modal shift to active travel.[25] For individuals shifting from car to bicycle, it was estimated that the beneficial effects of increased physical activity are substantially larger (estimates of 3–14 months gained) than the potential mortality effect of increased inhaled air pollution doses (0.8–40 days lost) and the increase in traffic crashes (5–9 days lost). Societal benefits were even larger due to modest reductions in air pollution, GHG emissions and traffic crashes.

Health Economic Assessment Tool

Developed by WHO, the Health Economic Assessment Tool (HEAT) for cycling consists of a user-friendly spreadsheet that estimates the economic value of reduced mortality from cycling (Fig. 10). Further details are available on the HEAT website (www.euro.who.int/HEAT).[34]

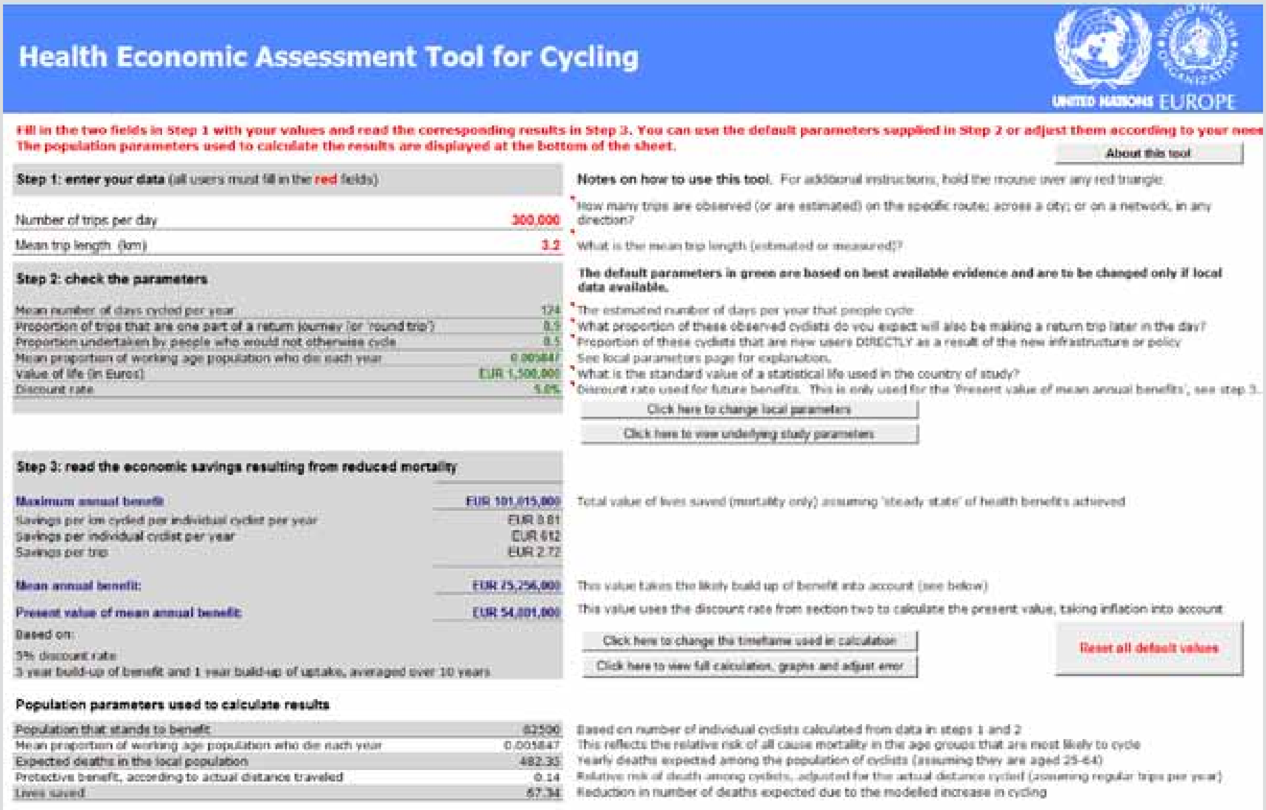
HEAT can be applied in a number of different situations. For example, it allows those planning a new piece of cycle infrastructure to model the impact of different levels of cycling, and to attach a monetary value to the health benefit resulting from increases in cycling when this new infrastructure is in place. This can be compared to the costs of the infrastructure to produce a benefit–cost ratio to inform investment decisions or for use as an input into a more comprehensive economic appraisal. Alternatively, it can be used to value the mortality benefits from existing cycling levels, such as cycling to a specific workplace, or levels of cycling at a national or urban-area level. HEAT can also be used as an input into HIAs. Table 18 provides an example of the application of HEAT in New Zealand. A further example estimated that the current modal share of cycling in Austria (5%) saved 412 lives annually due to mortality reductions associated with physical activity, equivalent to €405 million in monetary terms. Achieving the national goal of 10% cycling share would lead to 824 lives saved – an annual benefit of €812 million in monetary terms.[24]

5.4.5 Integrative analytical tools – examples at international level

CAFE

The CAFE programme includes assessments of the costs and benefits, including health benefits, of potential measures for improving air quality in Europe (for EU-25 countries). In 2000, CAFE estimates found that the annual impacts of air pollution amounted to 3.7 million YLL each year, equivalent to 348 000 premature deaths. PM exposure was also responsible for 700 infant deaths per year. These estimated health damages for 2000 corresponded to 3% to 10% of the EU-25 gross domestic product (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 €87 billion and €181 billion per year, translating into an average benefit of between €191 and €397 per person per year.[35]

Fig. 10. Health Economic Assessment Tool (HEAT) for cycling



Source: WHO (www.euro.who.int/HEAT).[34]

Outdoor air pollution in cities database

Developed by WHO, the outdoor air pollution in cities database is the most comprehensive compilation of air pollution levels measured in particulate matter (PM_{10} and $PM_{2.5}$). The database contains measured data for more than 1000 cities representing more than one third of the world's urban population. It 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.[36] This database also comprises the underlying foundation for the latest WHO estimates of disease burden caused by urban outdoor air pollution.

5.5 Application to climate change

Emissions modelling tools have been developed to assist transport decision-makers. For example, models that employ backcasting 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 to indicate clearly whether or not targets will be met, based on existing policy settings.

One such model, *Visioning and Backcasting for UK Transport Policy* (VIBAT), has incorporated health-related outcomes as part of a multicriteria assessment tool. Some versions of VIBAT can be used to predict not only emission reductions but also air pollution and road traffic injury outcomes for different packages of mitigation measures, helping to demonstrate which approaches carry the greatest co-benefits.[37]

The *Lancet* study (Woodcock et al. 2009) on health outcomes in London and New Delhi from different transport scenarios used outputs from VIBAT models to estimate in more detail the likely physical activity, air pollution and road traffic injury impacts from different mitigation policies for the transport sector.[38] This allowed emissions and health impacts to be estimated concurrently. Results, as noted in Chapter 3, indicated that in both cities, immediate health gains increased active travel and less use of motor vehicles would likely be greater than health gains from increased use of lower-emissions vehicles, although a combination of measures would yield the largest benefits. Health and emissions outcomes were examined concurrently in a study that examined a scenario of British consumers switching from petrol to diesel cars. Although this switch was estimated to reduce CO_2 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).[39]

Monks cycle in South-East Asia.
(Photo: Suriya Donavanik, Fotopedia)

To date, researchers have gained more experience modelling the health impacts of transport in European and North American settings, yet these models can also be adapted for developing countries, again as illustrated by the study of New Delhi in Woodcock et al. (2009).[38] While lack of data may be a 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 available data. 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 of established modelling expertise.

Increasing the extent to which health outcomes are robustly incorporated alongside emissions in the outputs of transport models such as VIBAT 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.

5.6 Health in the cost-benefit assessment of transport systems

The economic savings in terms of health that can be obtained from healthy transport interventions have been modelled and documented by health economic assessment. For instance, one systematic review of over a dozen studies on the economic benefits of cycling networks found a median benefit to cost ratio of 5:1 from infrastructure investments, when the added health benefits of improved physical activity and reduced injury are considered.[40]

CBA is a critical tool in transport decision-making. However, mainstream transport CBAs typically fail to quantify the full range of health benefits (or risks) of projects, particularly for alternative modes of transport development. Mainstream CBAs for transport typically analyse factors such as savings in vehicle operating costs 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 emphasize more investment in mixed modes and modal shift to rail/bus modes, cycling and walking.

A number of standardized CBA tools are used by a wide range of international development agencies to guide international transport investment decisions. One example is Highway Development and Management-4 (HDM-4), sponsored by the World Bank; Overseas Development Institute/Department for International Development (ODI/DFID) in the United Kingdom of Great Britain and Northern Ireland; Asian Development Bank; Swedish National Road Administration; World Road Association; and Inter-American Federation of Cement Manufacturers.[41]

Recent versions of the HDM-4 have been adapted to consider limited environmental and health (for example, road traffic crash) impacts. However, the full spectrum of changes in land use and transport mode choices are yet to be fully considered by any

New road construction in developing countries often fails to include space for pedestrians or cyclists – even though walking and cycling are omnipresent travel modes in rural as well as urban areas. (Photo: BigStock)

single standardized transport modelling tool, particularly with respect to health costs/benefits in terms of injuries, air pollution, access, physical activity, non-motorized travel, etc. For instance, expanding road capacity may reduce traffic congestion in the first years of a road's operation – saving time and vehicle operating costs. However, in doing so, it also stimulates additional vehicle travel.[42] Known as induced travel, this can lead to future indirect health impacts that are not fully measured, such as increased pollution over time, increased reliance on 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-kilometre 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.[43]

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.[43] 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-motorized 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 multilateral development banks.

Recognizing these challenges, the World Bank recently developed initial guidance for more inclusive, multimodal assessment of urban transport investments.[44] However, such guidance recognizes 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".[44] Multimodal CBA may be an important step towards better accounting for the benefits of lower-carbon transport projects.[45]

The report also notes that public transport infrastructure, particularly rail, is typically a much more complex and costly public sector undertaking than roads. Rail and transit systems require greater ongoing public sector involvement in their operation, as well as public subsidy of capital and operating costs not covered by ticket fares. Public transit operation can be financed through a virtuous tax cycle of dedicated vehicle fuel and parking taxes, but this requires policy-maker recognition of the full range of benefits from transit investments.

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, multimodal 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 development and health, sprawl, equity, pollution and GHG emissions. Hence, it is critical that conventional economic assessment of road development generally be integrated with the best available models for health assessment of transport in order 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.[42]

Feeder bus takes passengers to South Africa's new Gautrain, which travels between Pretoria, the international airport and Johannesburg. (Photo: Susan Wilburn)

There exist several examples of integrated assessments of policies to shift travel from car use to more active transport. For example, a study of the upper midwestern United States of America estimated changes in health outcomes and monetary costs arising from changes in air quality and physical activity from replacing 50% of short car trips with bicycle travel. In a population of around 30 million, mortality was projected to decline by approximately 1100 deaths per year, with monetary benefits of over US$ 7 billion per year.[46] This illustrates both the feasibility and the importance of using integrated assessments that account for the health impacts of transport policies and projects.

5.7 Financial tools

A wide range of financial mechanisms exist for transport at urban, national and regional levels – none should be underestimated. Yet international funding for different types of transport projects influences trends in infrastructure development globally, especially in developing countries. While such funding may be supplementary or packaged with private and national financial backing, it can make the difference between a feasible or unfeasible project. It also sends an important market signal in terms of lending trends for new infrastructure development.

The primary focus of this report is health co-benefits and so this review of financing is limited in scope. It examines just two financing mechanisms to examine the extent to which health co-benefits are considered in the financing of transport projects, and the methods by which these co-benefits are accounted for. The mechanisms considered are financing via (i) the United Nations Framework Convention on Climate Change (UNFCCC) Clean Development Mechanism (CDM); and (ii) international development institutions (in this case, the World Bank). Further in-depth consideration of financing mechanisms is considered by the United Nations Environment Programme Green Economy Report.[47]

5.7.1 Clean Development Mechanism

The CDM is a financial mechanism by which high-income countries committed to reduce GHG emissions under the Kyoto Protocol are allowed to invest 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 is the TransMilenio system in Bogotá. Having been registered as a UNFCCC CDM project, this is expected to receive as much as US$ 350 million from the sale of emission credits by 2026.[48] This example demonstrates how CDM can facilitate 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.

One of the first transport projects to be registered under the CDM mechanism is the TransMilenio BRT system in Bogotá. (Photo: GIZ)

All CDM projects use a carbon-calculation methodology approved by the UNFCCC to document emissions saved. Projects that do not fit existing methodologies can propose new methodologies, but this process is time-consuming and there is a substantial risk of rejection. Other steps in the CDM process prior to the issuing of emissions credits include project design, registration, monitoring and certification, with costs at each step. Despite the large emissions reduction potential of transport and their apparent potential to be implemented as CDM projects, transport has been very marginal, so far, in CDM finance. As of November 2011, only 10 of the more than 3500 registered CDM projects worldwide were transport projects (among those Bogotá's TransMilenio BRT system).[48]

Smaller transport initiatives may face higher barriers to CDM use. Some steps of the process are simplified and carry lower fees, and many small-scale CDM projects have been registered,[48] but the transaction costs associated with CDM may still pose a significant obstacle. There has also been limited awareness among potential host countries, particularly among developing countries, of opportunities to apply CDM.[49] Reducing these barriers might enable greater CDM uptake. In particular, more streamlined CDM application processes could help smaller urban-transport projects to enter the funding stream.

The CDM has seen substantial revenue flows into developing countries but most have gone to projects in a small group of countries and many of the poorest countries have not accessed CDM funds. The latter may lack the resources to engage in the CDM process but could benefit from clean development projects. Ensuring that poorer countries are able to access CDM funds (such as by building their capacity to engage with the CDM process) could increase uptake in countries most in need of improved health and clean development.[50]

While many CDM projects may improve health, the presence or absence of health benefits does not currently affect CDM qualification criteria or subsequent revenues as these are calculated solely on GHG emissions. In the case of transport this is a particular gap in the CDM process, given that methods are available for quantifying the health co-benefits of transportation projects via changes in air pollution, traffic injury and physical activity.

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, yet may be less attractive as CDM projects since "compliance" and "outputs" may be difficult to measure in accepted frameworks.

Revision of CDM protocols to estimate such health co-benefits from transport mitigation, and to consider them in project qualification and financing, could increase incentives for healthy transport initiatives. Existing examples of robust modelling of health impacts of transport changes[38] may provide a useful template for consideration of health co-benefits alongside CDM.

Land use is an important determinant of both transport emissions and health but it is particularly difficult to address effectively using current CDM mechanisms. Demonstrating that emission reductions are attributable to land-use changes is a complex process.[49] Better methods and validated indicators are needed to estimate the emissions impact of land-use changes and planning policies in order to integrate this critical area into CDM.

Other climate instruments are also being developed; these could further support policies to reduce travel demand and shift travel mode away from motorized transport. These instruments' effectiveness is likely to depend on a number of factors, including the scale of associated funding and the extent to which transaction costs can be minimized.[51]

5.7.2 International development financing

While many international development financial mechanisms are available for transport infrastructure lending, one of the best-known and most influential institutions is the World Bank. This analysis focuses very briefly on trends in World Bank lending for transport as a reflection on the broader opportunities for, and barriers to, low-carbon transport financing that yields health co-benefits.

Historically, lending from the World Bank has focused on road infrastructure that served transport primarily by truck freight and private motorized vehicles (Fig. 11). Low-carbon transport modes, in particular rail and urban transport schemes featuring mixed bus rapid transit (BRT)/rail/bus and walking/cycling systems, have received far less emphasis. Transport lending therefore has not supported goals potentially compatible with climate change mitigation and health co-benefits as identified here.

The World Bank increasingly considers climate change mitigation, as well as environmental sustainability more generally, within its infrastructure projects and lending policies. Financing of renewable energy and energy efficiency projects has increased markedly – although so has financing for fossil-fuel energy projects.[53] From 2005 to 2010, inter-urban roads and highways continued to be, by far, the leading area for transport lending in absolute terms. However, the proportion of overall lending for inter-urban roads and highways has decreased somewhat over time; lending has increased for "general transport," which typically includes urban transport projects such as BRT and light rail (Fig. 11, Fig. 12).

Fig. 11. World Bank average annual transport lending by mode for 1997 and 2007

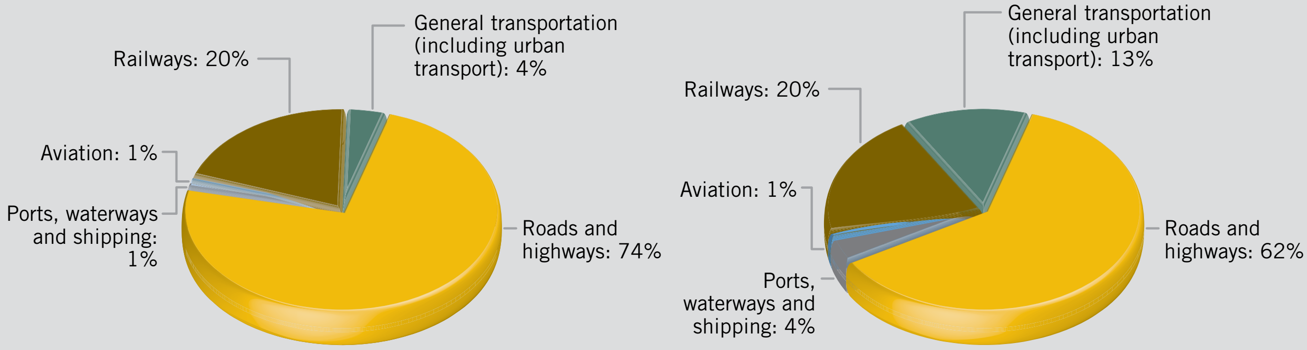
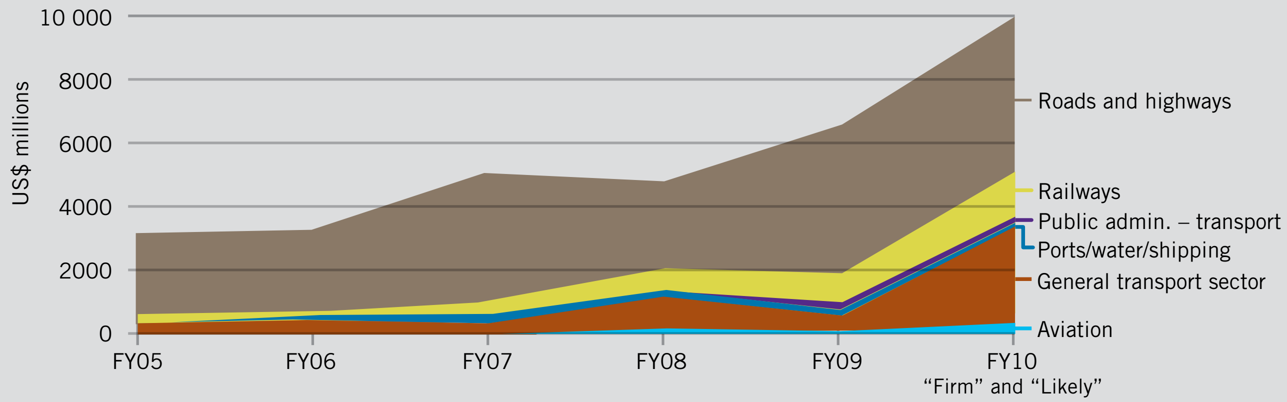


Fig. 12. World Bank transport lending trends, 2005–2010



Source: World Bank, 2011.[54] *Note*: FY – fiscal year

These initial data suggest that stronger direction is needed to ensure that World Bank financing better supports climate and health goals. At the most basic level, reporting on transport lending is not stratified in terms of the renewability or the mitigation potential of the projects in question. Nor is it stratified in terms of projects that foster modal shifts to less-polluting alternatives more generally, such as rail, BRT and walking/cycling networks. Reporting on transport lending in terms and categories relevant to mitigation, sustainability and health could help increase transparency and foster awareness of the transport lending portfolio's overall health, sustainability and carbon footprints. Incorporating environment and health CBA into analysis of transport models is another means to inform financing decisions.

While this review has been brief, it is apparent that both international lending policies and CDM lending protocols require modification and that other financing mechanisms should be considered in order to promote healthier low-carbon urban transport and urban land-use patterns.

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6

Susan Wilburn

Rail is one of the safest and lowest-emission modes of travel. Gautrain, South Africa's new rapid rail from Pretoria to Johannesburg and the international airport.

Case studies

6.1 Measuring public health for a sustainable transport project in Arequipa, Peru

The city of Arequipa, Peru has been reorganizing its transport system to include a new 23 km bus rapid transit (BRT) corridor running through the city centre. This includes modernized fleet and feeder lines and bicycle and walking infrastructure. The project's goals include reducing greenhouse gas (GHG) 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 the WRI Center for Sustainable Transport (EMBARQ), helped to 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 cycling and walking activity among city residents, among other factors. Lastly, for two weeks, measurements of ambient air concentrations of $PM_{2.5}$ were taken along the future BRT corridor. $PM_{2.5}$ is 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 effects reported below.[1]

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 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 to 2009. Pedestrians were involved in 26% of all crashes, nearly double the rate found in north-western 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 walk regularly as a means of transport for at least 150 minutes per week. Only 3% walked

Arequipa, Peru. (Photo: Leo Prieto, Flickr – http://www.flickr.com/photos/leoprieto/)

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 PM2.5. Average outdoor $PM_{2.5}$ concentrations of 164 μg/m^3 (24 hour mean) were found at bus stops along the future BRT corridor, well above the WHO guideline value of 25 μg/m^3.[2] At 222 μg/m^3, $PM_{2.5}$ concentrations were even higher inside the buses where passengers were exposed to trapped bus fumes. The very high concentrations found in the buses and their immediate vicinity suggested that the introduction of low-emission buses as part of the BRT implementation could potentially lead to direct and immediate reductions in $PM_{2.5}$ exposures for those using the buses. This would also benefit people driving and walking along the corridor and contribute to air pollution mitigation in the city as a whole.

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

As of Spring 2011, the Provincial Municipality of Arequipa had built 1.6 km of the trunk corridor infrastructure (Bolivar–Sucre). Road safety audit recommendations are being incorporated into the BRT infrastructure designs and the integrated transport system is due to be completed in early 2013.

A follow-up evaluation will be conducted in 2015, measuring public health indicators including air pollution exposure, road safety and physical activity in order to enable comparison with the baseline study in 2010. The follow-up evaluation will allow policy-makers to assess and improve upon decisions and will 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.

6.2 Aguascalientes: a new urban paradigm

In Mexico, traffic accidents are the leading cause of death between the ages of 5 and 29, claiming 24 000 deaths and causing 700 000 injuries a year. About 50% of these

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[i] Euro 3 standards refers to European Union standards for pollutant emissions in vehicles. In buses, limits on particulate emissions have been progressively tightened over the past 2 decades, beginning with Euro 1 to more recently, Euro 5.

are pedestrians and cyclists. The country's overweight/obese population is one of the highest in the world (68–70%), leading to fatal noncommunicable diseases, some of which can be traced to a lack of physical activity from transportation related to land use. Finally, transportation is responsible for 27% of all CO_2 emissions.

Mexico City. (Photo: Mark Edwards, Hard Rain)

The current pattern of urban expansion in Mexico exacerbates these environment and health trends by promoting low-density residential development accessible primarily by roads and private vehicles, rather than walking, cycling or public transport. The health equity impacts on low-income groups are especially severe. Residents of lower-income neighbourhoods on the urban periphery, far from employment centres and services, spend an estimated 30% of their wages on transportation.

A new approach aims to make new urban developments more livable, safer and healthier. Mexico's biggest mortgage lender, the National Workers Housing Fund Institute (INFONAVIT), finances about 500 000 new homes in Mexico each year. For the first time, INFONAVIT is applying sustainable transport principles in land development and has formed a partnership with EMBARQ/CTS México.

With nearly 700 000 residents, the city of Aguascalientes in central Mexico (like other Mexican cities) is confronting 21st century challenges such as sprawl, inefficient transportation systems, high motorization rates, high traffic fatality and injury rates and an overall abandonment of public spaces. To confront these problems, the city's mayor engaged EMBARQ/Center for Sustainable Transport Mexico (CTS México) in an environmental and health impact assessment examining how a planned new low-income housing development could be designed in a healthier and more sustainable manner. The new development, *Centenario de la Revolución,* is planned for 40 000 residents and is aimed at families earning US$ 200–400 per month.

As a result of the assessment, the design of the first 10 000-unit phase of the development was successfully modified to include transit-oriented development criteria.[3,4] In September 2010, the municipal government changed the development's master plan to accommodate around 70% of the project's recommendations. The new plan incorporates a traffic safety audit, provides four times more commercial lots, higher density, wider sidewalks, 9 km of bike lanes and better parking distribution. Redesigned intersections and traffic calming on main streets as well as improved infrastructure for active modes, including a 1.5 km pedestrian and cyclist corridor, means that traffic speeds are predicted to reduce by 34%.

Planners predict that the proportion of trips to destinations outside the community that are made by public transport (currently 30%) will increase to 60% due to features such as increased transit accessibility and designated spaces for bus stops. Within the community, the combined measures are predicted to increase the proportion of local trips made on foot from 24% to 40%. The proportion of trips made by bicycle is predicted to rise from the current 4% to as high as 50%. Should these projections be realized, in turn they will have impacts on key health outcomes such as physical activity, traffic injury and air-pollution related disease.

Public space is also set to grow by 5–30% and social interaction is expected to quadruple through the addition of four community centres and a 1.5 km pedestrian-cyclist road. Proximity to services will create economic opportunities and reduce car dependency or isolation for residents, most of whom are unlikely to own cars.

The redesign also brings environmental benefits, including less energy consumption and reduced pollution. The construction of the project will require fewer carbon emissions than traditional development in Aguascalientes.

By applying transit-oriented development concepts to the *Centenario de la Revolucion* development, this project promotes development that offers their residents not only a home, but also a community. The project also provides a step towards changing the urban development paradigm in Mexico. A thorough, systematic revision of new urban developments can help foster more transit-oriented development, thereby creating more livable, safer and healthier cities.

6.3 Sustainable mobility in the South African context: opportunities and barriers

Throughout most of the last century, South Africa followed a typical North American trajectory, emphasizing development of fast and efficient freeways facilitating the efficient movement of private vehicles while the needs of public transport and pedestrians, including most of the poor, were neglected.[5] Following South Africa's first democratic elections in April 1994, the needs of the poor and middle classes rose higher on the political agenda and a new national transport policy was articulated in 1999 – Moving South Africa. This new policy emphasized a shift to demand management and from private car to public transport; regulation to ensure more rational route coverage; integrated land-use planning; and greater emphasis on the transport consumer as "customer".

In 2006, the South African National Department of Transport (NDoT) launched a new programme to overhaul public transport systems, aiming to transition the often chaotic services of paratransit (minibuses and taxis) providers into a more organized and regulated BRT system in 12 South African cities and metropolitan regions.[6]

In parallel, following the 2002 World Summit on Sustainable Development in Johannesburg, intersecting concerns with climate change, urban sustainability and equity (as well as economic development interests) have helped forge informal and formal alliances between civil society, technical and government policy-makers to advance a more sustainable transport agenda.

Civil society and research actors, supported by bilateral and United Nations development agencies, have worked as agents of change alongside diverse government agencies, and provincial and city governments, supporting significant new BRT, rail and pedestrian/cycle projects. Some of those advances are outlined below.

- Major new BRT initiatives in three major cities (Johannesburg, Cape Town and Nelson Mandela Metropole). These include the Rea Vaya Bus Rapid Transit System, which has considerably shortened commuting time between poor, primarily black areas such as Soweto and central Johannesburg.[7]
- New initiatives for high occupancy vehicle lanes and non-motorized transport in other large and mid-sized South African cities.
- Gauteng Provincial Government's development of the ultra-modern commuter Gautrain running on South Africa's most heavily trafficked corridor between Pretoria, the international airport and Johannesburg. This has been described as one of the biggest public-private partnerships in Africa.[8]
- Greater urban emphasis on non-motorized transport (NMT) facilities, including facilities for safe walking and cycling; free bicycle stations; and access around the COP-17 convention centre in Durban. Also Global Environment Facility (GEF)-supported projects to develop NMT infrastructure in three small- to medium-sized cities – Mangaung, Polokwane and Rustenburg.
- Heightened enforcement of safety regulations governing private and shared taxis which are responsible for a disproportionate amount of vehicle injuries in South Africa and elsewhere in Africa.[9,10]
- In the city of Cape Town, collaborations between transport researchers at the University of Cape Town, municipal government and bilateral aid agencies have helped support more integrated transport planning at the urban, city level. Under the auspices of a civil society alliance – Transformation towards Integrated and Sustainable Transport (Tran:SIT) – and supported by Danish and other bilateral agencies, the Cape Town researchers helped to develop a system of sustainable transport indicators. These include measures such as percentage of trips by NMT, which was rarely measured before, as part of the modal split.[5]
- Alliances between civil society, government, international and bilateral donors, and United Nations agencies are also a key feature of the Sustainable Transport Project which has implemented the low-carbon BRT and NMT projects in various South African cities, together with a skills and capacity development programme. An initiative of the South African Department of Transport, the project is supported by grant funding from the GEF and implementation assistance from the United Nations Development Programme (UNDP).

BRT in Cape Town, South Africa. (Photo: Bruce Sutherland, *Mobility Magazine*)

In theory, the shift in emphasis to rapid transit should have complemented very well the social goals of the newly democratic South Africa. As observed by Kane (2010)[5]:

> "Transport planning in South Africa has traditionally allocated money on high quality roads and public transport for formally employed commuters. The unemployed, the poor and the informal were traditionally marginalized, either in the informal taxi sector or in the unmaintained pedestrian spaces on the edge of roads or in poorly maintained, sometimes non-existent roads in townships and informal settlements.

> "There are, therefore, two pressing arguments for redressing traditional transport patterns: the equity and social justice argument in the light of a democratic, post-apartheid South Africa, and the energy and climate argument. Presently, neither is high on the local political agenda, which is dominated by a discourse of basic service delivery and economic growth."[5]

Limited surveys of user satisfaction (e.g. in Cape Town) have also highlighted strong dissatisfaction with many aspects of paratransit including comfort, costs, safety and reliability.[11]

Nonetheless, debate and controversy have also accompanied the shifts in emphasis. There has been resistance in certain communities through which some new BRT/rapid transit routes would travel.

Paratransit operators, accustomed to operating in an unregulated and cash-based environment have at times vehemently opposed more formalized systems. In turn, this has slowed the pace of institutional change and development of BRT infrastructure (as of early 2010, only 3 out of 12 planned urban systems were significantly advanced or operational, including Cape Town, Johannesburg and Nelson Mandela Metropole). There has also been debate over the best regulatory approach and institutional arrangement, as well as the optimal public-private mix of roles and responsibilities, for transit in South Africa.[6]

The Gautrain was heavily criticized as an overly expensive infrastructure investment that would consume considerably too much capital and serve the more affluent sectors of the population. Also, the train's competitive edge was temporarily undermined somewhat by improvements to the Gauteng Freeway along roughly the same route – in fact, these eroded the time savings afforded by public transport. Nonetheless, the train is being used by broad swathes of the population and, by most recent indications, is set to meet its ridership targets while serving as a symbol of a new approach to transport.[8]

The design of efficient public transport is also confounded by some objective factors. Unlike developing Asia, South Africa has widely dispersed urban and rural population centres. A *Low Carbon Transport* report (2011) prepared in advance of the 2011 United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP-17) in Durban describes the country as "spatially challenged" noting:[7]

> "South Africa requires more transport relative to its GDP size than any other economy…unlike most countries with a coastline, South Africa's industrial centre is far inland. In addition, the distances between cities are vast. South Africa accounts for 0.4% of the world's total GDP, but 0.7% of the world's transport costs and 2.2% of the world's surface freight tonne kilometres (road and rail combined). In South Africa, 2008 data suggest that the energy used in transportation contributes about 46.3 MtCo2e, or 13% of total local GHG emissions. (This figure does not include emissions from electricity generated to run electric trains or bunker fuels.) "[7]

In health terms, the country's road injury fatalities are among the highest in the world, with pedestrians accounting for as much as 60% of the total.[12] Pedestrians crossing without crossing facilities are one of the greatest causes of fatality. Behrens (2010) points out that this is often linked to faulty pedestrian environmental design due to a failure to measure, analyse and predict pedestrian behaviour in travel surveys:[13]

> "Understanding pedestrian desire lines and walking trip assignment… necessitates that walking be routinely included in travel behaviour analysis, when in the past it has been omitted… methods for analysing and predicting walking trip generation, distribution and route choice need to be developed." [13]

Another key barrier to change is development finance – as also noted in Chapter 5 of this report. Existing UNFCCC Clean Development Mechanisms have not been well-designed for transport projects, notes the South African *Low Carbon* report:

> "The transport sector has not benefited significantly from the existing financial mechanisms under the UNFCCC process and its Kyoto Protocol. For example, only 36 of the 3 329 projects within the Clean Development Mechanism pipeline and six of the 3 395 projects that had been registered by September 2011 are transport sector projects. This calls for a much larger role of the transport sector in any possible future agreement that may come after the first commitment period of the Kyoto Protocol in 2012 or any bilateral and regional initiatives to combat climate change."[7]

On the other hand, the same report observes that National Appropriate Mitigation Actions (NAMAs) are a new global mitigation tool that might serve the transport sector's mitigation needs. Precise criteria for NAMA's frameworks and funding qualifications have yet to be defined by the UNFCCC. However, a mechanism that could reward low-carbon policies that apply to a sector, rather than to an individual project level, might help stimulate the kinds of integrated transport sector initiatives that are often needed to promote sustainability. The *Low Carbon Transport* report notes:[7]

> "The Rea Vaya Bus Rapid Transit System, the first full-BRT system in the African continent, with its dedicated lanes and modern stations, has changed the landscape of the City of Johannesburg. This new transport system not only provides better public transport, but also reduces traffic congestion, improves the environment, creates jobs, and reduces GHG emissions. Projects like Rea Vaya, originated by city

Rea Vaya, Johannesburg's new Bus rapid transit system. (Photo: Brett Eloff)

> government, are ideal candidates for NAMAs. This system is already serving as a model for other cities within South Africa and the rest of the continent. Similar BRT projects in Latin America and Asia are popping up, and two have even received modest CDM funding. There is no reason why governments should not include such systems as part of every NAMA, especially since well designed BRT systems can deliver mobility benefits equal to rail systems in a fraction of the time and cost."[7]

However, some analysts argue that if the concepts of "sustainability" and "social equity" are to succeed as transport goals, they need better integration into the traditional transport models that often have tended to respect "efficiency" and "safety" in transport above anything else. In her retrospective on the experience of developing sustainability indicators for Cape Town transport, Kane notes:[5]

> "….I would argue that there will be not be significant shifts towards sustainable transport in Cape Town, in South Africa and most likely in Africa more generally, unless strategies can be found that both acknowledge the efficiency-safety paradigm within which transport planners and engineers operate and work within the existing political context of pro-poor job creation and basic service delivery. The challenge for practitioners is to find such win-win strategies, knowing that new foci towards walking, cycling, and public investment for the poor are counter to mainstream planning thinking, tools, and data collection."[5]

The *Low Carbon* transport report notes that lower-carbon transport alternatives could support climate change mitigation, time savings, and jobs creation – all clearly elements of sustainable economic growth.[7]

Other analysts also point to the South African economy's unhealthy dependence on imported oil, where unexpected price hikes pose a particular threat.[14] Along with fuel and vehicle efficiency measures, mode shifts to greater reliance upon lower-carbon BRT systems and non-motorized transport alternatives (while difficult to implement) can help to significantly lower South Africa's exposure to oil price shocks and scarcity in the future.[15]

One element of economic analysis, not yet well-developed in the South African transport dialogue, regards the health impacts of overdependence on private travel modes, in terms of obesity, air pollution and traffic injury. Additionally, how much more economic benefit would be achieved if, in addition to commuter time savings and job creation, there was parallel calculation of reduced illnesses from air pollution, traffic injury and reduced increased physical activity among more affluent, or more sedentary, populations?

These issues, perhaps, are yet to be explored by transport analysts in the Southern African context.

6.4 Environmentally sustainable and healthy urban transport (ESHUT) in Asia and the Western Pacific

Asia includes some of the world's largest cities overall, as well as cities in emerging economies with some of the highest rates of traffic growth and air pollution. Over time, health policy-makers have become increasingly aware that uncontrolled motorization is neither environmentally sustainable nor conducive to health.

Since 2000, the WHO has addressed the health effects of urban transport through associated risk factors such as air pollution, traffic accidents, noise and physical activity (or inactivity), through regional activities in Europe, the Americas and Asia.

Now, a new WHO co-sponsored initiative for *Environmentally sustainable and healthy urban transport* (ESHUT) in Asia and the Western Pacific promotes a win-win strategy to achieve co-benefits in reducing GHG emissions, air and noise pollution, road traffic injuries and second-hand smoke; increasing opportunities for physical activity as well as health and social equity by ensuring safe and equal access to urban public transport. The initiative aims to advance implementation of the *Bangkok Declaration for 2020 – Sustainable Transport Goals for 2010–2020* (see Box 6).[16]

Box 6. Bangkok Declaration for 2020: Goals[17]

Goal 1: Formally integrate land-use and transport planning processes and related institutional arrangements at the local, regional, and national levels.

Goal 2: Achieve mixed-use development and medium-to-high densities along key corridors within cities through appropriate land-use policies and provide people-oriented local access, and actively promote transit-oriented development (TOD) when introducing new public transport infrastructure.

Goal 3: Institute policies, programmes, and projects supporting Information and Communications Technologies (ICT), such as internet access, teleconferencing, and telecommuting, as a means to reduce unneeded travel.

Goal 4: Require Non-Motorized Transport (NMT) components in transport master plans in all major cities and prioritize transport infrastructure investments to NMT, including wide-scale improvements to pedestrian and bicycle facilities, development of facilities for intermodal connectivity, and adoption of complete street design standards, wherever feasible.

Goal 5: Improve public transport services including high quality and affordable services on dedicated infrastructure along major arterial corridors in the city and connect with feeder services into residential communities.

Goal 6: Reduce the urban transport mode share of private motorized vehicles through Transportation Demand Management (TDM) measures, including pricing measures that integrate congestion, safety, and pollution costs, aimed at gradually reducing price distortions that directly or indirectly encourage driving, motorization, and sprawl.

Goal 7: Achieve significant shifts to more sustainable modes of inter-city passenger and goods transport, including priority for high-quality long distance bus, inland water transport, high-speed rail over car and air passenger travel, and priority for train and barge freight over truck and air freight by building supporting infrastructure such as dry inland ports.

Goal 8: Diversify towards more sustainable transport fuels and technologies, including greater market penetration of options such as vehicles operating on electricity generated from renewable sources, hybrid technology, and natural gas.

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Goal 9: Set progressive, appropriate, and affordable standards for fuel quality, fuel efficiency, and tailpipe emissions for all vehicle types, including new and in-use vehicles.

Goal 10: Establish effective vehicle testing and compliance regimes, including formal vehicle registration systems and appropriate periodic vehicle inspection and maintenance (I/M) requirements, with particular emphasis on commercial vehicles, to enforce progressive emission and safety standards, resulting in older polluting commercial vehicles being gradually phased-out from the vehicle fleet, as well as testing and compliance regimes for vessels.

Goal 11: Adopt Intelligent Transportation Systems (ITS), such as electronic fare and road user charging systems, transport control centres, and real-time user information, when applicable.

Goal 12: Achieve improved freight transport efficiency, including road, rail, air, and water, through policies, programmes, and projects that modernize the freight vehicle technology, implement fleet control and management systems, and support better logistics and supply chain management.

IV. CROSS-CUTTING STRATEGIES

Goal 13: Adopt a zero-fatality policy with respect to road, rail, and waterway safety and implement appropriate speed control, traffic calming strategies, strict driver licensing, motor vehicle registration, insurance requirements, and better post-accident care oriented to significant reductions in accidents and injuries.

Goal 14: Promote monitoring of the health impacts from transport emissions and noise, especially with regard to incidences of asthma, other pulmonary diseases, and heart disease in major cities, assess the economic impacts of air pollution and noise, and devise mitigation strategies, especially aiding sensitive populations near high traffic concentrations.

Goal 15: Establish country-specific, progressive, health-based, cost-effective, and enforceable air quality and noise standards, also taking into account the WHO guidelines, and mandate monitoring and reporting in order to reduce the occurrence of days in which pollutant levels of particulate matter, nitrogen oxides, sulphur oxides, carbon monoxide, and ground-level ozone exceed the national standards or zones where noise levels exceed the national standards, especially with regard to environments near high traffic concentrations.

Goal 16: Implement sustainable low-carbon transport initiatives to mitigate the causes of global climate change and to fortify national energy security, and to report the inventory of all greenhouse gases emitted from the transport sector in the National Communication to the UNFCCC.

Goal 17: Adopt social equity as a planning and design criteria in the development and implementation of transport initiatives, leading to improved quality, safety and security for all and especially for women, universal accessibility of streets and public transport systems for persons with disabilities and elderly, affordability of transport systems for low-income groups, and up-gradation, modernization and integration of intermediate public transport.

Goal 18: Encourage innovative financing mechanisms for sustainable transport infrastructure and operations through measures, such as parking levies, fuel pricing, time-of-day automated road user charging, and public-private partnerships such as land value capture, including consideration of carbon markets, wherever feasible.

Goal 19: Encourage widespread distribution of information and awareness on sustainable transport to all levels of government and to the public through outreach, promotional campaigns, timely reporting of monitored indicators, and participatory processes.

Goal 20: Develop dedicated and funded institutions that address sustainable transport-land use policies and implementation, including research and development on environmentally sustainable transport, and promote good governance through implementation of environmental impact assessments for major transport projects.

The Declaration was agreed upon by representatives from 22 countries in August 2010, in a meeting involving Asian and Western Pacific countries of all sizes and development stages – from Japan, the Republic of Korea and Thailand; to India and The People's Republic of China; and Lao People's Democratic Republic, Nepal, Bangladesh and Mongolia.

The specific concerns addressed include: air and noise pollution and GHG (CO_2) emissions generated by motor vehicles, road traffic crashes, physical activity or inactivity, exposure to second-hand smoke in confined public transport systems; and lack of accessible or barrier-free transport systems for persons with disabilities and older persons.

The WHO Regional Office for the Western Pacific, United Nations Centre for Regional Development (UNCRD) and the Alliance for Healthy Cities (http://alliance-healthy-cities.com/) are partners in the ESHUT initiative which promotes non-motorized transport (e.g. walking and bicycling) and efficient public transport, thereby reducing the use of private motor vehicles. ESHUT also holds that public transport systems should be fully non-smoking and accessible for the elderly and people with disabilities.[18]

World Health Day in April 2010 took the theme of urbanization and health. WHO Regional Office for the Western Pacific used this occasion to organize a Cities Forum in Manila at which ESHUT activities in several cities in the region were presented. WHO provides further support for the sharing of good practices in ESHUT and the ESHUT initiative synergizes with the WHO global initiative assessing the health effects or benefits of the green economy, including the transport sector.[19]

ESHUT offers a new paradigm for urban mobility and access, based on an environmentally sustainable and healthy alternative, including non-motorized transport (e.g. bicycling and walking) and efficient public transport systems to reduce use of private motor vehicles, easy access to barrier- and smoke-free public transport, and road safety.

Examples of ESHUT activities are:

- bicycle friendly city (provision of cycle lanes, bicycle parking facilities and rental services);
- pedestrianization (safe and accessible pedestrian footpaths/walkways, crossings and overhead bridges, benches, kiosks, public sanitary conveniences, car-free streets and days);
- BRT and mass rapid transit (priority bus lanes, hybrid or electric buses, light rail transport or subways, fare free or reduced fare services);
- increased connectivity at stations/stops (park and ride, bicycle parking, pedestrian access ways, metered taxi stands);
- transport demand management (special toll for private vehicles, fuel tax, parking levies);
- barrier-free and safe roads, walkways and public transport (easy access and use by persons with disabilities, older people, children and pregnant women; lighting at night, road safety measures);
- health-promoting and hygienic public transport (tobacco-, alcohol- and drug-free buses and trains, stations and stops; hygienic and clean public sanitary conveniences).

The WHO Western Pacific Regional Office has worked with a number of cities to document their good practices, including Changwon City (see photo) in the Republic of Korea. This has launched a drive to become known as a "Bike City" by developing well-connected cycle lanes and parking facilities. The city also organizes a cycle rental system and has positioned bicycle stations/centres all over the city for the use of citizens as and when they need them. In addition to the infrastructure support, the city provides a cyclist training programme and cycling campaigns and events. As a result, the citizen's participation in the promotion of bicycle use is very high.

Bicycle race in Changwon City, Republic of Korea, which aims to become known as a "bike city". (Photo: Western Pacific Regional Office/WHO)

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7

Design Pics/Still Pictures

More active transport can help combat increased rates of childhood physical inactivity and obesity, as well as teaching children essential motor and cognitive skills.

Conclusions and recommendations

7.1 Policies with the greatest health benefits

Mitigation policies in transport have missed the vast array of benefits in health that can be obtained. These benefits are immediate, local and important to equity and poverty reduction. Harnessing synergies could help stimulate mitigation efforts in the transport realm where it is urgently needed to achieve global goals.[1]

Mitigation strategies that significantly increase the accessibility, affordability and quality of rapid/public transport and non-motorized transport (NMT), alongside land-use measures supporting access by such modes, will generate much greater health co-benefits than policies that focus only on modifying vehicles and fuel technologies to reduce greenhouse gas (GHG) emissions. The potential of land-use and mode-shift strategies requires much more systematic review in mitigation and health analysis.

7.2 Opportunities to improve health through healthy transport systems

Transport-related health risks are large, including 3.2 million deaths globally per year from physical inactivity, 1.3 million deaths per year from road traffic injuries and 1.3 million deaths per year from urban outdoor air pollution (mostly PM_{10} and $PM_{2.5}$). Win-win transport strategies can address these risks on multiple fronts.

Land-use patterns are linked inextricably with transport. The proximity of people's destinations determines both the distance they need to travel and their preferred mode of travel. Transport systems also shape urban development. Private car travel and extensive motorway networks foster sprawling, low-density cities; "smart growth" and transit-oriented development leads to more compact cities with potential destinations in greater proximity to one another.

From both a health and a climate perspective, transport mitigation needs to rely more upon better land-use planning, along with increasing access to active transport and public transport/rapid transit modes.

This report identifies four key strategies for maximizing the co-benefits of transport while minimizing the risks to health and climate, as described in Chapter 4 (Table 14).

1. Develop compact land use that reduces the need for travel, particularly by clustered and mixed-use commercial and residential development built around transit and active transport networks.
2. Invest in and provide transport network space for pedestrian and bicycle infrastructure
3. Invest in and provide transport network space for rapid transit/public transport infrastructure
4. Undertake engineering and speed reduction measures to moderate the leading hazards of motorized transport.

A win–win strategy from the perspective of climate, health and social well-being involves shifting the focus of transport from mobility provision, as a goal in and of itself, to guaranteeing access.[2]

7.2.1 Reducing noncommunicable diseases and other leading health problems

Integration of healthier transport and land-use strategies into mitigation policies could play an important part in reducing some of the key noncommunicable diseases (NCDs) that now pose a major global burden and are a growing problem in low- and middle-income cities. Leading NCDs and other transport-related health risks include:

- heart disease, stroke, type 2 diabetes and some cancers, which could be reduced through more physical activity;
- cardiovascular and respiratory diseases, some of which could be reduced through lower air pollution exposures;
- injury risks, which affect pedestrians and cyclists in particular.

7.2.2 Improving health equity and social welfare

Health equity can be improved by mitigation strategies that remove current environmental barriers to walking and cycling, as well as access to transit/public transport. These barriers particularly impact the independent mobility of children, older people, people with physical disabilities, and also women, who in many settings tend to move more locally, in and around their own neighbourhood and community.

In cities, socially disadvantaged groups are typically exposed to more transport-related health risks such as air pollution, injury risk and noise as poorer residential areas often are located closer to busy roads and lack adequate transport infrastructure. Low-income groups worldwide also tend to use more of their disposable income for travel, and face higher barriers to accessing vital economic and social opportunities and services when public transport and active transport routes are slow, inefficient or unsafe.

Land-use patterns and transport systems that enable access by active transport and public transport may have other cascading benefits for social welfare, including greater urban vitality and economic productivity. In the case of public transport/rapid transit system investments, the benefits reaped in terms of job creation deserve further exploration. And, the same investments may yield benefits for other transport-sector priorities, such as congestion reduction, energy security and cost containment.

Travel to work. Comfort, sanitation, safety and convenience all are important to making rapid transit more attractive for those with other choices. (Photo: Bigstock)

7.2.3 Avoiding health risks from transport mitigation strategies

Risks to health from prioritizing fuel and vehicle improvements over mode shifts

Clearly, improving vehicles and fuels could reduce some impacts on health, particularly those due to air pollution emissions. But there are also risks associated with the heavy emphasis that the IPCC assessment places on this approach. In particular, this strategy does not address some of the key environmental factors driving physical inactivity and the large and growing human toll of road traffic injuries.

In addition, if total growth in vehicle kilometres travelled (VKT) outpaces improvements in vehicles and fuels as projected then total GHG emissions from transport will continue to rise, and total air pollution emissions will likely rise as well, in the absence of other measures. So if health and mitigation are both to benefit, improvements in fuel efficiency and vehicle technology must complement, rather than replace, policies that emphasize a more balanced modal split, including better quality public transport/rapid transit and active NMT.

Health risks in terms of air pollution exposures from low-emission fuels

- **Diesel:** Exposure to diesel particulates (PM_{10}, $PM_{2.5}$.) is a leading traffic-related urban air pollution risk. It is a particular problem in developing cities where older, and highly polluting, diesel buses, trucks and three-wheelers predominate, and the quality of diesel fuel may also be less assured. Newer diesel vehicles emit lower concentrations of particulate matter (PM) but these efficiencies can be overwhelmed by policies that support even larger shifts to diesel vehicles, as illustrated by the European urban experience over the last decade. As noted in Chapter 1, diesel vehicles are also an important source of black carbon particles which have substantial climate impacts.
- **Biofuels:** These have received much attention as a transport mitigation option, but their impacts on air quality remain unclear, and they may pose risks of food insecurity and malnutrition for the poor if land availability for food production is affected.
- **Compressed natural gas (CNG):** Evidence presented here is initial but it shows that CNG fuel can achieve GHG emissions savings comparable to diesel, with far lower PM emissions. The potential of CNG as a win-win for health and mitigation should be examined much more systematically by the IPCC, particularly for heavy-duty urban buses and trucks.[3,4] At the same time, the comparative health savings (in terms of reduced air pollution) of shifting diesel buses and trucks to CNG will be offset, if the private diesel vehicle fleet continues to grow.

Risks in terms of active transport and road traffic injury

The physical activity benefits of active transport are very large and generally have been observed to outweigh those of road traffic injuries in countries with developed infrastructures. However, active transport must be accompanied by environmental measures to protect cyclists and pedestrians from injury. Improving the safety of the walking and cycling environment, especially through slowing motorized traffic and separating motorized traffic from walkers and cyclists, can be particularly helpful in reducing injuries and also facilitate even greater shifts to walking and cycling, by removing safety barriers to these modes.

Risks in terms of health equity

The emphasis of mitigation policies on vehicle and fuel efficiencies, as compared to mode shift, can reinforce the already heavy and growing worldwide reliance on private motorized modes, as compared to a balance of transport choices. In turn, this would lead to further negative health equity impacts on the very large proportion of people globally who, in any scenario, will continue to lack ready access to private vehicles, especially lower-income groups, women, children, older people and people with disabilities.

Increasing the price of motorized transport (e.g. through fuel taxes) could impose disproportionate barriers on low-income groups. These barriers can be overcome by concurrently improving land-use planning and facilitating access by public transport/ rapid transit and complementary active transport. Health equity issues also arise when developing countries import older, more polluting and less safe used vehicles from affluent countries, particularly in the absence of adequate regulatory, maintenance and fuel quality safeguards.

7.3 Gaps in IPCC analysis

Active transport and public transport

The IPCC assessment may have underestimated the mitigation potential for shifts to public transport, NMT and more compact land use. These are precisely the strategies that have the greatest health co-benefits and potentially greater mitigation benefits if they can be implemented at scale.

This review has identified some supplementary studies on mitigation estimates of public transport, active transport and land-use changes. But more review and quantification is still needed. Certain transport and land-use measures, however, appear highly cost effective. For instance, relocating schools to increase proximity to homes, as noted in the Santiago study in Chapter 3, yielded a cost of just US$ 2 per tonne of CO_2 reduced. This also promotes active travel among children, thus helping to reduce childhood obesity.

Additionally, estimates of the GHG savings from fuel and vehicle modifications, as compared to alternatives, may be overestimated by the IPCC. This is because estimates of mitigation potential are largely derived from estimates of GHG emissions for fuel extraction, refinement and consumption ("well to wheel"), but not including emissions from vehicle manufacture, sale, distribution and disposal, nor from the road infrastructure itself.

Insofar as the total carbon "intensity" of non-motorized modes, for instance, would be much less than for private vehicles (a bicycle manufacture as compared to a vehicle; a cycle lane as compared to a road), then the comparative cost effectiveness of active travel mitigation measures could feasibly be much greater than what is presented. This, again, has profound implications for win-wins in terms of health and climate.

Fuels and modified vehicles

The potential climate and health co-benefits of shifting trucks and buses to CNG fuels appears not to have been fully explored. This is in light of evidence that CNG-powered vehicles appear to achieve GHG reductions comparable to those of diesel – cost effectively too. CNG also appears to significantly reduce health-harmful particulate emissions, per passenger kilometre of travel. Shifts to alternative fuels, in general, do not improve outcomes for injuries, noise or physical activity, and pollution emissions savings can be overwhelmed by increases in the overall vehicle fleet.

Public transit and non-motorized transport have multiple health co-benefits. (Photo: Carlos F. Pardo)

Pricing strategies

IPCC assessment needs to explore more fully pricing strategies for public transport/rapid transit. This issue is critical to developing those systems and has been a subject of considerable study among transport economists. The way in which pricing strategies (e.g. for parking) can be used to promote mode shifts and liberate urban space for active travel and other uses, also needs further development and would provide a basis for better analysis of the associated impacts. Finally, there are notable case study examples of cities (e.g. Bogotá and Curitiba) that have brought about major changes in their vehicle fleets, emissions and modal split. In the case of Bogotá, pricing is a key element of intrastructure funding. Although the TransMilenio system in Bogotá is designed to recover 100% of its operational costs through passenger fares, half of the 25% fuel tax in Bogotá is earmarked to fund the continuing expansion of the TransMilenio system.[3] Pricing strategies such as this deserve further assessment of their potential to provide disincentives for car use while at the same time funding lower-carbon transport alternatives.

7.4 Tools and strategies for healthy transport

Transport policies that reduce GHG emissions and improve health show great potential. Fully accounting for both emissions and health effects can bolster the case for the right transport strategies, and may improve their cost effectiveness. This can also lead to shifts in funding priorities.

- **Health assessment tools:** Well-tested tools exist for considering health in transport and land-use policies, including health impact assessment (HIA, www.who.int/hia). HIA can be used to identify and address health co-benefits and risks at the planning stage, but does not appear to have been mainstreamed by transport ministries or development agencies. It can also take into account specific effects on groups most vulnerable to transport-related risks, including children, women and lower wage earners.

- **International transport finance:** Historically, transport funding, including through international development mechanisms, has emphasized road infrastructure over public and active transport. While some shifts appear to be occurring, the total pattern of investments as reflected in funding portfolios of some major development agencies, still appears to be mostly in roads.
- **Clean Development Mechanisms (CDMs):** CDMs fail to include a significant public transport/NMT component (only 10 transport projects approved out of over 3500). This is problematic and perplexing in light of transport's very large contribution to GHGs. A likely problem is the expense and complexity of meeting CDM requirements and protocols that also do not easily relate to broader "systems approaches" to transport management. CDM protocols for transport need to be examined more closely in order to see how they may be better harnessed in the development of low-carbon transport systems.
- **CBA:** Existing CBA methods often ignore critical indirect effects of transport projects to health, in terms of barriers to walking and cycling, and mode shifts brought about by land-use changes from new highways. A more complete and accurate accounting for the health costs of transport projects requires more comparative analysis of health impacts from alternative modes of transport development scenarios, including emphasis on BRT/transit and NMT networks. This also can help ensure that development financing promotes climate, as well as health objectives, as these are low-carbon modes.
- **Reporting mechanisms:** The health performance of transport systems and policies can and should be monitored to assess progress in reducing health risks. This enhances transparency and accountability, particularly with regards to public funds that are invested in transport projects.
- **Health relevant data and indicators:** Transport indicators have often given more attention to car-focused measures such as vehicle flow, traffic volumes and kilometres of road space, as compared to service and access levels by public and active transport modes. 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 climate and health goals are to be fully realized.
- **Land-use planning:** Strengthening land-use codes can help ensure that cities are healthy places, and that urban form provides equitable access to destinations for all, while minimizing the need for motorized transport. Requirements for provision of infrastructure for walkers, cyclists and public transport, as well as measures that restrain urban motorway development, can help shape urban form in more compact, healthy directions.

7.5 Future work needed

Overall, while much evidence about healthy transport already exists, it is not well-linked to actual policy decisions. Health-oriented operational and intervention research is needed to help build skills, commitment and capacity for practical implementation in cities and in ministries of health and transport.

In view of the great potential for health, and enormous gains for climate, offered by active transport, rapid transit/public transport and land-use mitigation strategies, there would be great value in further comparisons of the health performance of transport interventions that promote these strategies, especially in urban areas. Further quantification will enhance the evidence for the relative costs and benefits of land-use and mode shifts, and contribute to better transport policy-making.

There is also a major need for more accurate and transparent monitoring and reporting on the performance of transport systems, using health-relevant indicators. Examples of such indicators could include air quality measures; use of active transport and public transport modes; urban and neighbourhood walkability indices; and changes in VKT.

More work is also needed to investigate how "health-enhancing" transport modes also generate other social benefits, including job creation, poverty reduction, urban vitality and social equity.

Studies are needed that concurrently model the health and climate implications of different policy options. There is little work addressing the likely equity impacts of different strategies, and more effort needs to be invested in quantification of land-use changes' impacts on emissions and health. Such methods could also inform the further development of financial mechanisms, such as CDM, that incentivize emission reductions through land-use changes.

Cycleway in Amsterdam. Bicycling comprises a large proportion of total travel in this Dutch city. (Photo: Andrea Broaddus)

While it is clear that access by active transport offers much greater benefits than car dependency, some aspects of transport and health are not yet well-understood. For example, it is not always clear where, and in what kinds of settings bus rapid transit, light rail or metro offer the greatest overall benefits for population health. Also, better estimates of the transport-related health burden, including the proportion of air pollutant emissions that are attributable to transport, are needed to quantify potential health benefits of transport interventions.

7.6 Conclusions

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 and local health benefits, along with the longer-range climate change mitigation potential, political interest and will can be bolstered. The experience of cities such as Bogotá shows how knowledge and political will can support far-reaching, health-enhancing and climate-friendly transport policies. While the global climate benefits of emission reduction measures take many years to become apparent, health co-benefits are more immediate and local, helping to foster local support. The sooner such measures are implemented, the better for health – and the better for climate as well.

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PUBLIC HEALTH AND ENVIRONMENT

Many strategies to reduce climate change have large, immediate health benefits, while others may pose health risks or tradeoffs. Examined systematically, a powerful new set of measures to improve health and promote sustainable development emerges.

WHO's *Health in the Green Economy* series reviews the evidence about expected health impacts of climate change mitigation in key economic sectors. The series identifies how investments and policies in areas such as housing, transport, and energy could yield significant health "co-benefits" and help prevent the growing burden of noncommunicable diseases. Exploring development options from this health perspective can help policymakers to better identify "win-win" strategies.

Opportunities for synergies are identified in this report for the transport sector.

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