CHAPTER

7

URBAN MOBILITY AND THE ENVIRONMENT

The increasing mobility experienced in cities all over the world brings enormous benefits to society and also provides the essential means by which a city can function effectively. The increasing urban mobility is manifested in three major forms: an increase in the number of trips made, an increase in the length of each trip, and – last but not least – an increasing motorization of urban people and goods movement. The environmental consequences of the increased motorization – and in particular the use of private motorized vehicles (cars and motorcycles) – are cause for major concerns, not only locally in the city, but also globally, as the transport sector is one of the major contributors to greenhouse gas emissions, the major cause of climate change.

In the past, it has often been argued that transport is an essential prerequisite for economic growth, at least for cities at an early stage in their development. It has also been argued that this relationship is not so important for cities in developed countries where there is already an extensive network of routes and where levels of accessibility are already high.[1] Recent debates have argued for prosperity without growth,[2] meaning that economic growth (and transport) needs to be more closely aligned with environmental and social priorities.

It is increasingly being acknowledged that urban development has to be based not only on economic growth, but also on social equity (and equal access) and environmental sustainability. Thus interventions in urban mobility systems should not only address the economic benefits of higher levels of accessibility (and mobility), but at the same time take account of the social and environmental implications of following particular policy pathways.[3]

The purpose of this chapter is to highlight environmental sustainability concerns within urban mobility systems. This includes the identification of environmental costs and a discussion of the means by which their impacts can be reduced. The chapter acknowledges that urban mobility will always use resources and generate externalities,[4] but its impact on the urban environment can be substantially reduced, so that it remains within acceptable limits and makes a strong contribution to other aspects of sustainability, including intergenerational concerns.

The first section of the chapter identifies the main environmental challenges facing urban mobility, focusing on oil dependence, greenhouse gas emissions, sprawl and human health concerns. This is followed by five sections that discuss the policy responses to these challenges. The second to fourth sections focus on reducing the number of trips made, reducing travel distances in cities and changing the modal split towards non-motorized and public transport. The fifth section discusses the potential of technology in reducing the negative externalities of motorization by addressing the efficiency and age of the vehicle stock, standards of fuels used and emissions from vehicles and alternatives to oil-based fuels, and the need for increased efficiency in the use of vehicles. The sixth section argues that, in practical terms, a combination of several approaches is likely to be most effective. This is followed by a section that (briefly) discusses international funding mechanisms to achieve environmentally sustainable urban mobility systems. The final section contains a brief summary and some major lessons for policy.

The environmental consequences of the increased motorization . . . are cause for major concerns, . . . as the transport sector is one of the major contributors to . . . climate change

ENVIRONMENTAL CHALLENGES IN URBAN MOBILITY SYSTEMS

Environmental concerns have, over the last few decades, become central to the debates about sustainable urban mobility. Yet, in practice, developmental objectives seem to take priority over environmental concerns. A key message underpinning the discussion in this chapter is the need to find the means by which both developmental and environmental concerns can be addressed at the same time, in mutually supporting ways.

Environmental concerns have . . . become central to the debates about sustainable urban mobility. Yet, in practice, developmental objectives seem to take priority over environmental concerns

Motorized urban transport relies almost entirely (95 per cent) on oil-based products for its energy supply

The transport sector accounts for about 22 per cent of global energy use

Motorized urban transport relies almost entirely (95 per cent) on oil-based products for its energy supply, primarily in the form of petrol and diesel.[5] The shift in urban transport technology toward motorization has thus led to a significant increase in the global consumption of such oil-based products. While 45.4 per cent of global oil supplies were used in the transport sector in 1973, this figure had increased to 61.5 per cent in 2010. Thus, while the total amount of oil used globally increased by 63 per cent during the 1973–2010 period, the consumption by the transport sector increased by 120 per cent.[6]

It has been estimated that the transport sector accounts for about 22 per cent of global energy use. The bulk of this (about two-thirds) is accounted for by passenger transport, while the rest is consumed by freight transport. As can be seen from Table 7.1, cars and motorcycles (the bulk of which is private motorized transport) account for nearly half of the energy consumption of the entire transport sector.

The dependence on an oil-based energy supply means that there has been a direct correspondence between the amount of energy used in the transport sector and the emissions of CO_2, the main transport-related greenhouse gas. CO_2 emissions from the transport sector have remained constant at about 23 per cent of total energy-related CO_2 emissions during the 1973–2009 period.[7] Given the considerable growth in urban travel demand globally (as the world's urban population is projected to increase by 40 per cent between 2010 and 2030),[8] mitigation technologies and practices are urgently required to achieve a significant global reduction in carbon-based energy use for urban transport.

There are, however, a number of other significant impacts of oil-based transport energy on both the natural environment and the built environment. This section focuses on these impacts and related environmental challenges. The environmental conditions of cities vary significantly – both between and within cities. Yet, many of the problems arising from the transport sector affect all urban residents (although, in many cities, the poor suffer disproportionally from many of the negative externalities of urban transportation) and impacts upon health and the quality of life in cities in general. Four major clusters of challenges are discussed below, namely: motorization and oil dependence; mobility and climate change; dependence on motorized forms of transport and urban sprawl; and human health concerns.

Motorization and oil dependence

Despite the many negative impacts arising from dependence on oil-based energy products in the transport sector, the sector is likely to remain a premium user of such products. There are many reasons for this, the most prominent of which are listed below:

- Oil-based products have the highest energy density of all fuels.[9] Thus, any change to alternative fuels (e.g. biofuels, solar, hydrogen or electricity) needs to be examined with caution in light of the quantity of such alternative fuels required to travel a given distance.
- There are currently no substitutes to oil-based products that are available in the quantities required.
- Considerable investments have already been made in the infrastructure supporting oil-based transportation (i.e. fuel stations and oil refineries).[10]

However, global supplies of oil are not unlimited, and they are often subject to political interference. The politically induced oil shortages of the 1970s and the rapid price increases during the last decade (Figure 7.1) have exemplified the potential consequences of reductions in oil supply, as a component of national energy security.[11] The urban poor in developing countries are especially hit hard by increased petrol prices. In 2011, Kenya experienced a shortage in petrol supply, followed by a rise of

Table 7.1

World transport energy use and CO_2 emissions, by mode

Mode of transport	Share of total energy use (2000) (%)[a]		Share of CO_2 emissions (2000) (%)[b]	
	Passenger transport	Goods transport	Passenger transport	Goods transport
Road transport	77.3		74.7	
Cars	44.5	–	42.5	–
Buses	6.2	–	6.3	–
Other (two- and three-wheelers, etc.)	1.6	–	2.4	–
Heavy trucks	–	16.2	–	23.5
Medium trucks	–	8.8		
Rail transport	1.5		2.3	
Air transport*	11.6	–	12.4	–
Sea transport*	–	9.5	–	10.6

Note: * Air and sea transport has been allocated to passenger and goods transport respectively for simplicity.

Sources: [a] Kahn Ribeiro, 2007, p328 (citing Fulton and Eads, 2004); [b] OECD/ITF, 2011b, p17.

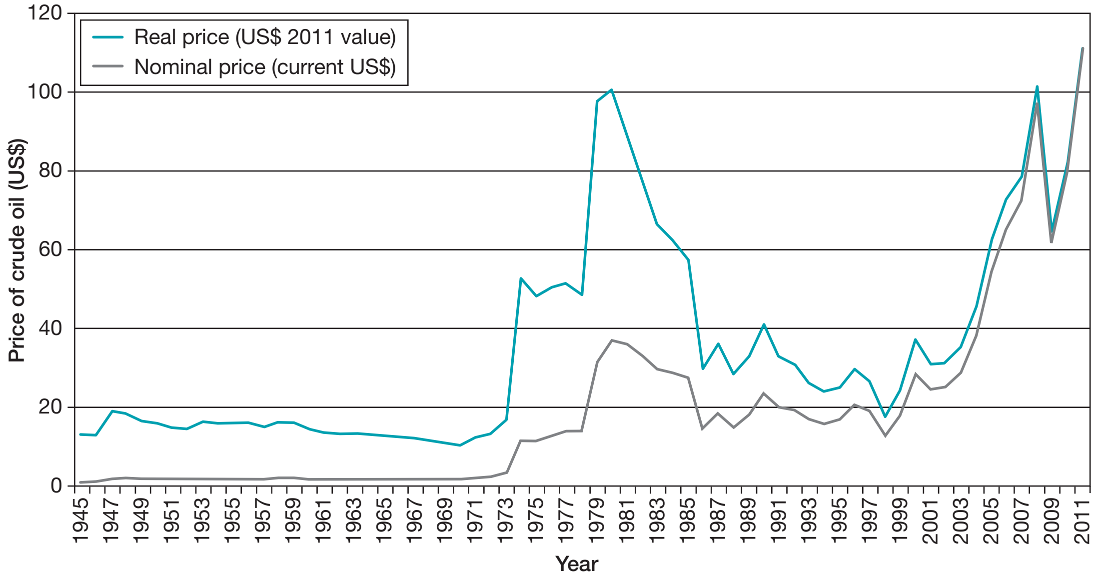

Figure 7.1
Crude oil prices (1945–2011)
Source: Based on BP plc, 2012.

30 per cent in petrol prices within a few months.[12] Car owners slowly decreased their number of trips; however the mounting prices had an immediate effect on public transport. Privately owned bus lines initially decreased the frequency of legs collecting passengers to maintain profitability, followed by the suspension of multiple public transport lines by owners, while at the same time demanding the government lower petrol prices. As a result, the urban poor living at the fringes of the city suffered the most, unable to travel long distances to earn a living.

In the short term, the transport sector is prepared to pay for the higher costs of energy, and most savings in the use of carbon-based energy sources will come from the use of more efficient technology within the conventional petrol and diesel vehicles. In the longer term, however, and irrespective of the wider environmental impacts, the transport sector needs to diversify its sources of energy and to de-carbonize the sources of fuel used.[13]

High and volatile prices have encouraged some countries to subsidize fuel prices to protect their own motorists from increasing world prices for petrol and diesel. Other countries impose various taxes on such commodities. Thus, the pump price for petrol varies considerably between (and also within) countries, from US$0.02 per litre in Venezuela to US$2.54 in Eritrea (Figure 7.2). The political rationale for subsidizing fuel prices varies dramatically from one country to another.[14] However, the perverse effect of fuel subsidies has been to encourage more car travel. And, it can be argued that fuel subsidies primarily benefit car owners. Targeted subsidies to public transport are a better alternative if the objective is to make transport more affordable to the urban poor. In general, fuel prices should not be subsidized for the sake of short-term political interest (Box 7.1), as it is important that the full environmental costs of fuels are paid by the user. This is known in international law as the ‘polluter pays principle’.[15] It has been estimated that ‘a universal phase-out of all fossil-fuel consumption subsidies by 2020 would cut global primary energy demand by 5%’, with savings predominantly in the transport sector.[16] If fuel subsidies are to be retained, it is often argued that it would be better to subsidize renewable energy sources, to encourage a shift away from fossil fuels.[17]

The transport sector needs to diversify its sources of energy and to de-carbonize the sources of fuel used

The perverse effect of fuel subsidies has been to encourage more car travel

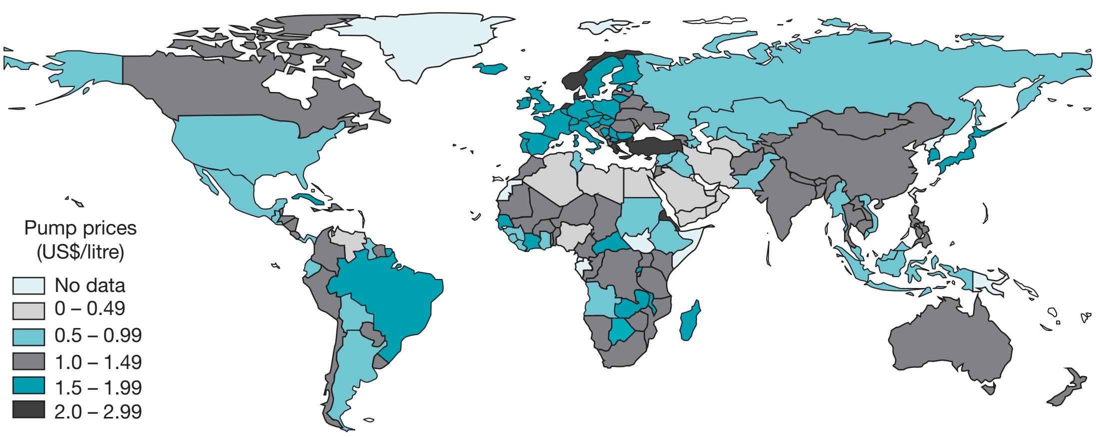

Figure 7.2
Worldwide retail prices of petrol (2010)
Source: http://data.worldbank.org/indicator/EP.PMP.SGAS.CD, last accessed 21 March 2013.

Box 7.1 Fuel subsidies

With high oil prices (over US$100 a barrel), many countries are not passing on these costs to users, as fossil fuels are needed for cooking, heating, electricity generation as well as powering engines and vehicles. The International Monetary Fund estimates the global bill for fuel subsidies reached US$250 billion in 2010, up from US$60 billion in 2003.[a] Some 40 per cent of this amount are subsidies for oil products (the rest being natural gas, electricity and coal).[b] Other sources quote even higher levels of fossil fuel subsidies, namely: '$523 billion in 2011, up almost 30% on 2010 and six times more than subsidies to renewables'.[c]

For oil-producing countries fuel subsidies are part of a social contract and can be managed. In Iran alone, the total value of oil subsides reached nearly US$25 billion in 2005.[b] But for non-oil producers it creates an additional fiscal burden and it means that investments in other sectors are delayed as foreign currency is used to pay for the oil. In India, it is estimated that fuel subsidies have added US$20 billion, or 1 per cent of GDP, to the national budget.[a]

Most of those that argue for the continuation of subsidies on fossil fuels argue that this is done to assist the poor. In practice, however, this is rarely the case; as 'only 8% of the subsidies to fossil-fuel consumption in 2010 reached the poorest 20% of the population'.[d] The figure is even lower for petrol and diesel, where only 6 per cent of the total subsidy went to the poorest 20 per cent of the population.[e]

For political reasons, 'Governments like to keep subsidies "off-budget" since "on-budget" subsidies are an easy target for pressure groups interested in reducing the overall tax burden. For this reason, subsidies often take the form of price controls that set prices below full cost, especially where the energy company is state-owned, or of a requirement on energy buyers to take minimum volumes from a specific, usually domestic, supply source. Subsidies may be aimed at producers, such as a grant paid for each unit of production, or at consumers, such as a rebate or exemption on the normal sales tax'.[f]

Sources: [a] Hook et al, 2011; [b] IEA, 2006, Figure 11.7; [c] IEA, 2012a, p1; [d] IEA, 2011c, p7; [e] IEA, 2011d; [f] UNEP, 2008, p9.

There is a significant potential to reduce . . . greenhouse gas emissions, by encouraging more people to use public transport

Cities make greater efficiency in their use of energy for transport than less densely populated locations, as more efficient public transport can replace the need to use a private car, and as distances are shorter. The relative energy efficiencies for different modes of transport in 84 cities are shown in Table 7.2. The occupancy rates for public transport vehicles are central to the interpretation of this table. The substantial differences in energy efficiency between cities in the different regions are partly due to the technology being used, but also to the occupancy levels. For example, China has high levels of efficiencies for all forms of public transport (except ferry), while the figures for the US are significantly lower. The general conclusion of the table, however, is that there is a significant potential to reduce energy use (and thus greenhouse gas emissions) by encouraging more people to use public transport.

Mobility and climate change

As a result of international policy concern during the 1970s and 1980s, the United Nations Framework Convention on Climate Change, also known as the

Table 7.2

Energy efficiency for urban transport, by mode of transport

Country/region	Transport energy use (megajoule per passenger kilometre)								Assumed occupancy rates for public transport in cities (%)
	Private vehicles	Public passenger transport							
		Total	Bus	Tram	Light rail	Metro	Suburban rail	Ferry	
World	**2.45**	**–**	**1.05**	**0.52**	**0.56**	**0.46**	**0.61**	**–**	**–**
US	4.6	2.63	2.85	0.99	0.67	1.65	1.39	5.41	10
Canada	5.0	1.47	1.50	0.31	0.25	0.49	1.31	3.62	15
Australia and New Zealand	3.9	1.49	1.66	0.36	–	–	0.53	2.49	10
Western Europe	3.3	0.86	1.17	0.72	0.69	0.48	0.96	5.66	17
High-income Asia	3.3	0.58	0.84	0.36	0.34	0.19	0.24	3.64	25
Eastern Europe	2.35	0.40	0.56	0.74	1.71	0.21	0.18	4.87	–
Middle East	2.56	0.67	0.74	0.13	0.20	–	0.56	2.32	–
Latin America	2.27	0.76	0.75	–	–	0.19	0.15	–	–
Africa	1.86	0.51	0.57	–	–	–	0.49	–	–
Low-income Asia	1.78	0.64	0.66	–	0.05	0.46	0.25	2.34	–
China	1.69	0.28	0.26	–	–	0.05	–	4.90	–

Notes: The table is based on data from a sample of 84 cities in different regions. '–' implies 'data not available'.

Sources: Newman and Kenworthy, 2011a (citing Kenworthy, 2008).

Climate Convention, entered into force in 1994. Its ultimate objective is to stabilize global greenhouse gas concentrations in the atmosphere at a level that will prevent human interference with the climate system. In order to achieve this, many developed countries committed (through the Kyoto Protocol) to reduce their overall greenhouse gas emissions by at least 5 per cent below 1990 levels by 2012.[18] Although some countries have managed to meet their commitments, many other countries (primarily those that did not commit to reductions) have increased their greenhouse gas emissions dramatically. Global emissions of CO_2 have increased by nearly 50 per cent between 1990 (20.97 billion tonnes)[19] and 2010 (30.6 billion tonnes).[20]

Globally, the CO_2 emissions from the transport sector have increased by 85 per cent from 3.593 billion tonnes in 1973 to 6.665 billion tonnes in 2007.[21] With respect to the targets of the Kyoto Protocol, the emissions have increased by over 47 per cent during the 1990–2007 period.[22]

There is considerable variation in the amounts of CO_2 produced by different countries and regions. A similar variation applies to the emissions from the transport sector. As can be seen from Table 7.3, the transport emissions per capita in North America are more than four times the global average, and more than double that in other OECD countries. The CO_2 emissions from transportation are much lower in developing countries. The emissions in most of Asia and Africa are about a third or a quarter of the global average, the notable exception is the Middle East, where the transportation emissions per capita are similar to those in Europe. Even more striking: while the overall CO_2 emissions per capita in the US are some 2.5 times higher than in China, the CO_2 emissions per capita from transportation in the US are 12 times as high as in China.

As indicated in Table 7.1, road and maritime freight accounts for about 25 per cent and 10.6 per cent of the CO_2 emissions, respectively. Aviation accounts for another 12.4 per cent, while the emissions from rail transport are insignificant. The remaining 52 per cent of CO_2 emissions are being produced from passenger road transport.[23] For all parts of the world, more energy (and CO_2 emissions) per capita is used in private than in public transport; in Africa the ratio is 3:1, while it is 50:1 in the US.[24]

At the city level, there is considerable variation in energy use between cities. For example, more than half the total energy consumption in Mexico City and Cape Town is transport based,[25] while the levels in many European cities (for example, London and Paris) are about a quarter.[26] This reflects the differences between cities in terms of their structure, their urban form, their densities, their levels of sprawl, the importance of public transport and the balance between energy use in transport and other sectors.

Globally, the CO_2 emissions from the transport sector have increased by 85 per cent from . . . 1973 to . . . 2007

Figure 7.3 shows variations in CO_2 emissions from passenger transport across cities in various parts of the world. The emissions are highest in US, followed by Canadian and Australian cities, with emissions in the range of 2–7.5 tonnes per capita. Most European cities have emissions in the range of 1–2 tonnes per capita. Most developing country cities, however, have significantly lower emissions. To provide a specific example: the mobility patterns of each resident of Atlanta, US, produce about 150 times as much CO_2 emissions as those of a resident of Ho Chi Minh City, Viet Nam. Figure 7.3 also shows that, in most cities, the emissions from public transport are insignificant compared to those from private motorized transport.

In most cities, the emissions from public transport are insignificant compared to those from private motorized transport

Nearly one-half of the world's cities are located on the coast or along major rivers. These locations have in the past been subject to occasional flooding, but these risks have increased as a result of more frequent storm surges and high winds, accentuated by global warming and sea-level rise. The vulnerability of these cities to flooding has thus been substantially

Table 7.3

CO_2 emissions levels overall and for transport (2009)

	Total CO_2 emissions		CO_2 emissions from transport		
	Total ($MtCO_2$)	Per capita (tCO_2)	Total ($MtCO_2$)	Per capita (tCO_2)	% of total emissions
World	**28,999**	**4.29**	**6,544**	**0.968**	**22.6**
OECD countries:					
North America	6,180	13.27	1,940	4.166	31.4
Asia and Oceania	2,099	10.00	418	1.996	19.9
Europe	3,765	6.85	957	1.742	25.4
Non-OECD countries:					
Africa	927	0.92	233	0.230	25.1
Asia (excl. China)	3,153	1.43	492	0.223	15.6
China	6,877	5.14	476	0.356	6.9
Middle East	1,509	7.76	329	1.689	21.8
Europe	2,497	7.46	346	1.032	13.9
Latin America	974	2.16	339	0.751	34.8

Source: Based on IEA, 2011a.

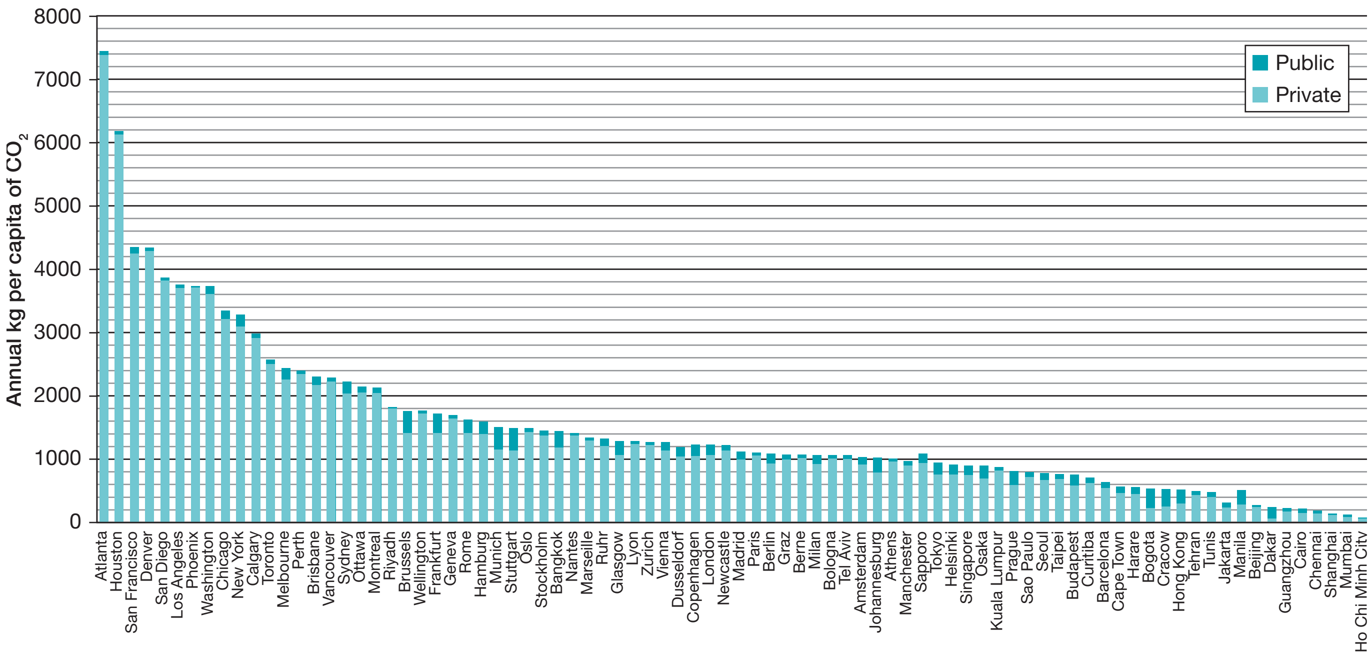

Figure 7.3

Per capita emissions of CO_2 from (private and public) passenger transport in 84 cities (1995)

Source: Kenworthy, 2003, p18.

increased, and some have taken action to reduce the potential impacts. However, some 40 million people are still exposed to a 1 in 100 year coastal flood event, and this will rise to 150 million in 2070.[27] A recent survey of 90 cities indicates that severe flooding and storm-water management is among the top three challenges facing cities.[28] Transport is central to the functioning of cities, and it is often the transport system that is initially affected by flooding and high temperatures. Yet, it is that same transport system that is required to provide access to the locations that have become isolated as a result of flooding. Furthermore, when urban transport infrastructure fails this can have far-reaching economic consequences, as people cannot get to work and goods cannot be distributed.[29]

There is . . . an immediate need for cities to take action to protect the existing transport infrastructure from the impacts of climate change

There is thus an immediate need for cities to take action to protect the existing transport infrastructure from the impacts of climate change. This includes continuous maintenance, but may also require additional investments in drainage, erosion control and protective engineering structures. At the same time, cities all over the world should integrate planning for climate change with general land-use planning to reduce vulnerability for new developments. This should include limitations on developments in flood-prone locations. The infrastructure itself can be designed to be more resilient to high temperatures (e.g. buckling of rail, effects on metallic bridges, etc.), and should be raised above the levels of the surrounding countryside to allow passage during flooding. Furthermore, drainage systems should be designed with a capacity to move flood waters away from the infrastructure.[30] Moreover, improvements to existing, or development of new, transport infrastructure should take into account the requirements of the whole urban population, including vulnerable and disadvantaged groups (see Chapter 6).[31]

Dependence on motorized forms of transport and urban sprawl

Increasing levels of motorization have, in most cities, resulted in lower densities and decentralization, with the second-round effect that suburban living has generally encouraged the ownership of a car. Motorization also exacerbates congestion, which can have the knock-on effect of increasing travel times on public transport, thus further encouraging travel by private cars. While, in many cities, buses tend to be unreliable (due partly to congestion),[32] the car seems to offer more control as alternative less congested routes can be used, giving the driver greater flexibility. For those with access to a car, mobility levels increase and many also want to live in lower density developments. This gives rise to urban sprawl. This in turn makes it difficult to provide alternatives to the car.[33] Such development has been common in locations where land is available and cheap.[34]

For [the poorest and most vulnerable] groups, urban sprawl often leads to social isolation

However, not everyone can afford a private car, leading (in many cities) to a social stratification of urban transport systems. The poorest and most vulnerable groups (including women, children, youth, elderly and disabled persons) cannot afford to (or are unable to use) private cars.[35] For these groups, urban sprawl often leads to social isolation.[36]

In addition to more space being taken up by low-density developments, transport systems in such settlements also use substantial amounts of space for roads, railways, car parks and other associated infrastructure. The loss of agricultural land and the changing local climate resulting from greater amounts of land being allocated to urban development (and motorized transport) mean that there may be increased fragmentation of natural habitats, reductions in biodiversity and impacts on local ecosystems as roads act as barriers.[37] An Australian study found that energy use in suburban households was 50 per cent higher than those in the urban centre, and this was explained primarily by greater car use and longer journeys.[38] Other countries (for example, China) now have the problem of loss of productive land as cities spread and as car ownership levels increase. In Hyderabad (India), which more than doubled its population between 1980 and 1999,[39] the urban land take increased from 9 per cent to 24 per cent of the total land available (1980–1999). This resulted in a 24 per cent reduction of the agricultural land area.[40]

Human health concerns

The increased motorization of urban transport is also causing serious challenges to human health. This section summarizes the main physical health concerns related to air and noise pollution, reduced physical activity, as well as issues related to community severance, open spaces and mental health. Road traffic accidents, which are perhaps the most prominent human health concern from urban mobility, are discussed in Chapter 6, as part of the discussion on urban safety and security.

■ *Air pollution*

The impacts of air pollution on air quality and human health are gaining increasing attention by residents and local governments alike.[41] Worldwide, it has been estimated that 'a record 3.2 million people died from air pollution in 2010, compared with 800,000 in 2000'.[42] The impacts of transport-related air pollution affect all urban residents, but there is substantial evidence that it affects the poor and vulnerable groups more than others. In fact, the social groups that are most seriously impacted are often not those that cause the pollution.[43] The main groups of local air pollutants – nitrogen oxides, volatile organic compounds, carbon monoxide and particulate matter (as well as some other pollutants) – are described in Box 7.2.

Trucks and other freight carriers emit disproportionate amounts of pollutants in cities. Even

An Australian study found that energy use in suburban households was 50 per cent higher than those in the urban centre, and this was explained primarily by greater car use and longer journeys

Box 7.2 Air pollutants

Nitrogen oxides (NO_x) when combined with other air pollutants can lead to respiratory difficulties and reduced lung functions, particularly in urban areas (where densities lead to higher concentrations). In the 32 member countries of the European Environment Agency, transport emissions of NO_x have reduced by 32 per cent (1990–2008) through the introduction of catalytic converters, but this reduction has been offset by some growth in traffic.[a] In many developing countries the add-on technology is not mandatory and traffic has been growing at a rapid rate.

Volatile organic compounds comprise a wide variety of hydrocarbons and other substances (e.g. methane and ethylene) that result from the incomplete combustion of fossil fuels. When combined with NO_x in heat and sunlight, hydrocarbons and volatile organic compounds generate low-level ozone, a main contributor to photochemical smog. Their impact has a measurable effect on respiratory functions and as an irritation, but these levels are declining as technologies improve.[b]

Carbon monoxide (CO) is an odourless and almost colourless gas, which is very toxic as it interferes with the absorption of oxygen. This in turn can lead to increased morbidity and can affect fertility and general levels of health. The transport sector is a major contributor as carbon monoxide comes principally from the incomplete combustion of fuel.[b]

Particulate matter consists of very small particles (under 10 microns in diameter: PM_{10}), that come mainly from diesel fuels, tyre particles and road dust. They can cause cancer, worsen heart and breathing problems for sensitive groups and may lead to premature mortality for all urban residents.
Among 59 cities in Asia, Africa and Latin America, only two meet standards for PM_{10}, while 46 of the cities exceeded the standard by more than twice (WHO standard is 90 milligram per cubic metre).[c] Cities in developing countries are most at risk, partly due to minimal enforcement. In Beijing, China, the government shut down '103 heavily polluting factories and took 30% of government vehicles off roads to combat dangerously high air pollution . . . but the . . . air remained hazardous despite the measures' in January 2013. The reason was that the amount of $PM_{2.5}$ (particles with a diameter of less than 2.5 microns) reached more than 500 milligram per cubic metre, on a scale where 300 is considered hazardous, while the WHO recommends a daily level of no more than 20.[d] Similar high levels have also been reported in other Asian cities, such as New Delhi, India.[e]

Other pollutants – such as lead (Pb), ammonia (NH_3) and sulphur dioxide (SO_2) – have transport links but are less important than the four listed above, as they are being reduced through the switch to different and 'cleaner' fuels and new designs for catalytic converters. However, many cities still allow the use of leaded petrol, despite the known dangers for children and their mental development.

Sources: [a] EEA, 2011a; EEA, 2011b; [b] EC, 2006; [c] World Bank, 2007; [d] Reuters, 2013; [e] Stainburn and Overdorf, 2013.

In developed countries, about 130 million people are exposed to unacceptable noise levels

The perceived danger of walking and cycling is a strong disincentive to non-motorized transport

The links between health and non-motorized transport need to be emphasized through education programmes and the involvement of doctors

Community severance divides and fragments communities, and is often a result of heavily used transport infrastructure forming a barrier so that people cannot cross the road or rail track

though they make up less than 10 per cent of road traffic in most European cities, large commercial vehicles can cause half of all nitrogen dioxide emissions, about a third of particulate matter, and more than 20 per cent of greenhouse gas emissions.[44]

■ Noise pollution

Noise and vibration are often cited as nuisances to people living in urban areas, but it is often the peak or unexpected noises that are most problematical. In developed countries, about 130 million people are exposed to unacceptable noise levels over 65dB(A), and 400 million to inconvenient levels of over 55dB(A).[45] In some 'quiet' countries (parts of Scandinavia) only 5 per cent of residents are exposed, while up to 30 per cent of residents in 'noisy' cities can be exposed.[46] Prolonged exposure to noise can lead to anxiety, depression and insomnia.[47] Vibration is caused by all vehicles, but it is heavy trucks that cause most intrusion and this again affects sleep, increasing levels of stress and anxiety.[48] Noises from horns are common in many cities, and car alarms also cause nuisance to residents. In Moscow, around three-quarters of the population live in areas with levels of transport noise that exceed WHO standards.[49]

■ Human health and physical activity

There are also major health effects resulting from the lack of physical activity that accompanies increased motorization. The perceived danger of walking and cycling is a strong disincentive to non-motorized transport.[50] As more people travel by motorized transport, the risks to vulnerable road users increase, and, as a result, fewer people walk and cycle. There is growing evidence of the links between physical inactivity and weight, and of the impacts that these two factors have on the risk of diabetes, heart disease, colon cancer, strokes and breast cancer.[51] Food-energy intake has not decreased in line with reductions in physical activity, and many countries are experiencing an epidemic in obesity.[52]

According to the Global Burden of Disease Study, overweight and obesity accounts for 36 million disability adjusted life years (DALYs) lost, with physical inactivity accounting for a further 32 million DALYs.[53] In the UK, about 66 per cent of adults do not get enough exercise, and the majority of the population is now overweight or obese.[54] The links between health and non-motorized transport need to be emphasized through education programmes and the involvement of doctors. Copenhagen, Denmark, is often cited as a good example of a cycling city as there are numerous initiatives, both private and public, to promote cycling.[55]

In a study of 30,000 people over a 14 year period, it was found that cycling to work reduced the risk of mortality at a given age by 39 per cent relative to those that did not cycle, and over half of cyclists (54 per cent) cite speed and convenience as their main reason for cycling, meaning that their journey times were reduced.[56]

■ Community severance, open spaces and mental health

Community severance divides and fragments communities, and is often a result of heavily used transport infrastructure forming a barrier so that people cannot cross the road or rail track. It adversely affects the quality of life, the level of activities on the street and the amount of social interaction within communities. It is particularly important for young people who are trying to socialize, and who often come to the understanding that the urban space surrounding them belongs to motorized vehicles rather than people.[57]

The reallocation of space from people to cars means that roads are widened and the space available for non-motorized modes is reduced. Furthermore, the expansion of roads often competes with open and green spaces (as well as squares and other spaces that allow people to spend time together). These spaces are important for the quality of life, and for their role in providing the 'lungs' of the city. Much of these spaces are open to the public and can be used for recreational and sporting activities, as well as providing habitat for wildlife and for absorbing carbon.[58]

There is also evidence that traffic congestion can impair 'health, psychological adjustment, work performance and overall satisfaction with life'.[59] Research indicates that job satisfaction and commitment declines with increased road commuting distance (but not with public transit use), and that perceived traffic stress is associated with both lower general health status and depression.[60] According to the 2011 IBM commuter pain survey, 42 per cent of respondents stated that their stress levels (due to congestion) had increased and 35 per cent reported increased anger.[61] Additional environmental effects of traffic congestion include pedestrian/vehicle conflicts on congested streets, which cause safety concerns and traffic delays, visual intrusion caused by elevated roads, bus stations, etc., and distorted city image, which disturbs liveability and reduces tourism potential.[62]

REDUCING THE NUMBER OF MOTORIZED TRIPS

There are many opportunities to reduce the need to travel by motorized transport. One is to travel by non-motorized means instead (i.e. walking or cycling).[63] Cycling can be encouraged for many shorter trips (i.e. normally less than 10 kilometres), provided that the infrastructure is available, including space to securely

Box 7.3 A successful bicycle sharing system, Changwon, the Republic of Korea

The city of Changwon is working towards becoming Korea's leading 'eco-rich city', by improving the quality of life through sustainable mobility and non-motorized transportation. As a part of this effort, the 'Nubija' bicycle sharing system was introduced on 22 October 2008, with 20 parking stations (where bikes can be checked out and returned) and a total of 430 bicycles.

The system has since increased steadily, and by 2011 there were 163 parking stations (with 3300 bicycles). At that time, the membership of the scheme had reached 76,579, who ride an average of 4396 kilometres per day. By early 2012 it was reported that the number of parking stations had reached 230.

The bicycle sharing system has led to annual emissions reduction of more than 4000 tonnes of CO_2 by 2011. Other outcomes have been reduced energy consumption, lower levels of air pollution and better public health.

Sources: ICLEI, 2010; ICLEI and Changwon City, 2011; Rhee and Bae, 2011; Sociecity, 2011; Changwonderful, 2012.

leave the bicycle. More imaginative innovations are the cycle hire schemes that are now a feature of many cities (see for example Box 7.3), where old technology (the bicycle) has been matched up with the new technology (smartcards), so that bikes can be used on demand, either free for an initial period or for a reasonable charge. Another good example is that of Paris, France, which has introduced a popular bike sharing scheme (*vélib*) and aims to increase the city's network of bike lanes to some 700 kilometres by 2014.[64] The co-benefits are manifest for the user (healthy and fast) and for the transport system (less space is used). However, it should be noted that the potential for increased bicycle use is related to age and (dis)ability, as well as prevalent cultural constraints, that may, for example, limit the use of bicycles by women.

Unfortunately, in many cities of developing countries the promotion of cycling as an alternative to motorized travel is fraught with danger, due to lack of dedicated bicycle lanes, forcing riders into a rather uneven competition for road space with motorized vehicles. There are some positive developments though. The City of Buenos Aires, Argentina, for example has since 2010 developed a 94-kilometre network of protected bike lanes, and introduced a bike-share programme featuring more than 22 stations and over 850 bikes. The City intends to expand its bike lane network to 130 kilometres by 2013.[65] Similarly, the two Egyptian cities of Fayoum and Shebin El Kom are planning the construction of 14 kilometres of cycling tracks and improved sidewalks on major streets.[66]

Another means to reduce the number of trips is through trip-chaining, where several activities are undertaken on one tour (from home back to home) rather than as a series of several individual trips. This again reduces overall distance travelled, but needs to be matched by the location of destinations in close proximity to each other and by mixed-land uses.[67]

The most effective way of reducing the number of trips (at least in theory) is that a specific trip is no longer made as it has been replaced by a non-travel activity or substituted through technology, for example internet shopping (Box 7.4). For many years now there have been debates over the potential for teleworking, teleactivities and teleconferencing,[68] and the more recent advent of mobile technology has opened up many new possibilities.[69] Although there is a large substitution potential, the relationships seem to be symbiotic with a greater opportunity for flexibility in travel patterns, as some activities are substituted, while others are generated, and some replaced by fewer longer distance journeys.[70]

The introduction of new technology has extended to mobile phones, and these have become available worldwide, often changing lives through allowing social and business communications. It is unclear about the implications for travel, but the effects are likely to be positive for the environment, as less carbon-based energy will be used.[71] Conventionally, the impacts of mobile phones have been grouped into three categories: incremental (improving the speed and efficiency of what people already do), transformational (offering something new) and related to production (selling mobiles and related services). The impact of mobile phones has been most profound in developing countries, where telephone communications in the past were reserved for the rich.[72]

The most effective way of reducing the number of trips . . . is that a specific trip is no longer made as it has been replaced by a non-travel activity or substituted through technology

Box 7.4 Internet shopping

Sainsbury's is the third largest chain of supermarkets in the UK. Sainsbury's Online is the internet shopping brand, where customers choose their grocery items online and items are delivered to customers from a local store (165 stores operate an online service) by van. This service is available to nearly 90 per cent of the UK population.

In 2005, Sainsbury's Online tested Smith Electric Vehicles in its home shopping delivery applications in and around Central London. The year-long trial proved so successful that Sainsbury's placed an order for eight vehicles in 2007 and a further 50 in 2008. Each zero emission van will reduce emissions by 5 tonnes of CO_2 per year.

Source: London, undated.

REDUCING TRAVEL DISTANCES IN CITIES

Urban spatial structure (or urban form)[73] is important in determining transport mode and distance travelled, as it links the spatial distribution of population and jobs within the city to the pattern of trips. Thus, urban planning has a major role to play in organizing spatial activities in cities so that they are in close proximity to their users. Two important factors are at work here. First, if travel distances are reduced then accessibility is improved as activities can be undertaken with less travel. Second, if travel distances are short, then it becomes more attractive to walk and cycle – particularly if space is allocated for exclusive rights of way – and to use public transport, and this in turn reduces the energy use and the environmental impacts of transport.

Urban planning has a major role to play in organizing spatial activities in cities so that they are in close proximity to their users

Such an approach implies that the available street space in cities can be optimized for the highest number of users. An increased focus on urban planning means that the city operates more efficiently, but it also increases equity as services and facilities become accessible to the entire population. Optimization of street space, however, is not only a matter of urban planning. Efficient traffic engineering design, supply and demand management, enforcement of traffic law and efficient governance at the city level are necessary requisites for introducing and sustaining urban transport services and facilities in developing countries.

Regardless of the form of the city, it is important to develop around highly accessible public transport nodes so that the attractiveness of these areas is fully realized

Many cities in developing countries are growing rapidly, driven by inward migration and population growth. This implies a considerable potential for urban planning to keep travel distances as short as possible. Peripheral sprawl needs to be discouraged as it uses valuable agricultural land, because it increases travel distances and makes the provision of public transport more difficult. The arguments for high urban densities are strong on both transport and land take reasons, and cities should be encouraged to build upwards (higher buildings) and not outwards (suburban sprawl).[74]

Regardless of the form of the city, it is important to develop around highly accessible public transport nodes so that the attractiveness of these areas is fully realized. These areas integrate land use and transport through the promotion of high-density development around accessible points and interchanges on the public transport network, facilitating walking and cycling and increased use of public transport systems. Development needs to include mixed uses, covering housing, jobs, schools, shops, health facilities, educational services (e.g. crèches) and recreational opportunities, so that all activities can take place in one location. Such developments are particularly important for women, who often have quite complex travel patterns.[75]

Transport development areas often become the new mega nodes within cities where people meet to carry out their business and social activities, and they consequently promote social cohesion. These public transport interchanges can thus become the new commercial hubs for cities, for example in Canary Wharf, London (Box 7.5) and Shin Yokohama (Japan). Singapore (Table 7.4) has also constructed public housing close to the metro stations, and this allows lower income people access to both housing and transport.[76] Such public transport interchanges can often be financed by developers, as has been the case in Hong Kong, Singapore, Frankfurt and London.

Apart from the major contribution that transport development areas can play in encouraging sustainable mobility in cities, they are seen as central to the urban regeneration process that involves the creation of new city places and spaces, and there is usually strong community involvement so that the benefits can be widely distributed across all social groups.

Box 7.5 Transport accessibility to Canary Wharf, London, UK

Canary Wharf is a major business and financial district located in the eastern part of London. It contains around 1.3 million square metres of office and retail space and a workforce of around 93,000 people (in 2009). It is home to global or European headquarters of numerous major banks, professional services firms and media organizations.

Construction began on the old docks area in 1988 as part of a major urban regeneration programme. A key element of the planning was to ensure high-quality access by public transport through the extension of the Jubilee Line metro, the new Docklands Light Railway, improved bus services, river boat services and cycle routes. There is little parking available, but a substantial amount of residential development has taken place in the riverside areas surrounding Canary Wharf.

A survey was carried out in June/July 2009 within the local areas and Canary Wharf to measure the movement of people throughout the area and in particular those travelling to Canary Wharf. During the survey period only 5.1 per cent of workers at Canary Wharf travelled by car, down from 6.2 per cent in 2007. Cycling has increased in popularity across London and Canary Wharf is no exception. Nearly 4 per cent of workers cycled to work in 2009, up from 2.9 per cent in 2007.

Use of public transport, including the Jubilee Line and the Docklands Light Railway, continues to increase, especially from areas east of Canary Wharf, reflecting the area's rapid regeneration and the increased number of Canary Wharf-based workers living in East London. About 90 per cent of all people coming to Canary Wharf do so by public transport.

Source: Canary Wharf Group plc, undated.

Table 7.4

Planning and development measures taken in New York City and Singapore

New York City (population 8.2 million in 790km²)	Singapore (population 5 million in 700km²)
Background information: Manhattan (population 1.6 million) covers 53km² and has 35 per cent of the total regional jobs, with the Midtown having 2160 jobs per hectare.	**Background information:** Singapore has a compact urban structure supported by high-quality public transport.
Measures: • Strict zoning with 'floor area ratio' 11–15.[a] • Mixed zoning – office, commercial, recreational and housing. • Transit system operational throughout 24 hours. • Parking spaces taxed by municipality, and most parking is provided privately and off-street. • Increasing the subway network to 337 kilometres – transit density of 56 kilometres per million population. • Encourage walk and cycle – 21 per cent trips in New York City are walk and cycle and a further 55 per cent by mass transit. • Ensure the working environment is intellectual, fertile and innovative.	**Measures:** • Restraint on car ownership, use and costs through quota system, electronic road pricing, fuel taxation and parking controls. • Public housing areas some located at metro stations to give easy access to employment. • Some decentralization to regional centres to reduce travel distances. • Reductions in need to travel and dependency on car though providing high-quality alternatives. • Rail network to double from 138 kilometres to 278 kilometres by 2020 (US$14 billion) – transit density of 51 kilometres per million population (2020).

Note: [a] The floor area ratio refers to the ratio of floor space to the land area of the development – so a ratio of 11 means that 11,000 square metres of floor space can be built on a piece of land measuring 1000 square metres.

Source: Based on Bertaud et al, 2009.

CHANGING THE MODAL SPLIT

Transport policy has often been strongly orientated towards maintaining and increasing the levels of public transport use in the city. However, success has been limited, as other factors have intervened, such as increases in incomes and growing urban populations. These factors have meant that the car and the motorcycle have become dominant. It is important to the quality of life and to the environment that as much urban travel as possible is undertaken by non-motorized and public transport, as these modes are the most environmentally efficient. In many European cities up to 60 per cent of all trips are made by walking, cycling or public transport. A survey of 26 cities in four EU countries indicated that the proportion of trips by car ranges from 17 to 73 per cent. The interesting point to note from this survey is the variability in modal shares, and that there does not seem to be any direct relationship between population density (or size) and the prevalence of specific transport modes.[77] However, high-capacity public transport systems, such as BRT, can offer a viable alternative to car dependence in cities of developing countries (see Box 7.6).

It is essential that the full cost of the energy used in transport, including all externalities, is reflected in the price.[78] Real cost increases reduce the amount of energy used (and thus the greenhouse gases emitted) and reduce travel distances (as they encourage more local travel) and the greater use of non-motorized and public transport. This full economic price could be based on the carbon content of the fuel, but it also needs to include a number of other external factors.[79] There are three basic groups of strategies that can be used to encourage modal shift to more energy-efficient forms of transport, namely: regulatory measures, pricing measures and investments in public transport.[80]

It is important . . . that as much urban travel as possible is undertaken by non-motorized and public transport, as these modes are . . . most environmentally efficient

Regulatory measures can place limitations on the numbers of vehicles on the road at any given time or day. Limitations can also be placed on the number of new vehicles that can be registered in the city. For example, both Beijing and Singapore use a quota system. In Singapore, the Land Transport Authority allocates quotas for each vehicle category according to the current traffic conditions and the number of vehicles taken off the roads permanently (Table 7.4). The vehicle quota for a given year is administered through the monthly release of 'certificates of entitlement' and the certificates are allocated

Regulatory measures can place limitations on the numbers of vehicles on the road at any given time or day

Box 7.6 Promoting sustainable transport solutions in Eastern African cities

The 'Sustainable Transport Solutions in East African Cities' project (SUSTRAN) aims to reduce growth in private motorized vehicles, thus reducing traffic congestion and greenhouse gas emissions in the cities of Addis Ababa (Ethiopia), Kampala (Uganda) and Nairobi (Kenya). The project – which is implemented by UN-Habitat in collaboration with UNEP with financial support from the Global Environment Facility – includes support for the design and implementation of transport corridors featuring BRT, non-motorized transport and travel demand management measures. It also supports regional capacity building, including city-to-city learning. While collaborating with local metropolitan and transport authorities, the project has promoted the active involvement of current transport operators and other stakeholders. By 2035, it is projected that this initiative will have led to a reduction in greenhouse gas emissions amounting to more than 2.5 million tonnes.

Source: http://www.unhabitat.org/SUSTRAN, last accessed 6 August 2013.

Very few cities have introduced pricing as a mechanism to limit the numbers of cars coming into the central area

through an auction.[81] In Bogotá, Colombia, the *pico y placa* (Box 7.7) limits the numbers of vehicles on the road on a given day by allowing odd and even number plates to be used on alternative days.[82] However, this latter type of measure may encourage higher income-residents to buy a second car, often with an older, less efficient engine (thus leading to increased emissions).

Parking regulations are important as this relates to the allocation of space in cities by price and time of day, and it covers both on-street and off-street locations (Box 8.5). As part of the congestion charging scheme in London, UK (introduced in 2003), parking availability was reassessed both within the pricing area (to reduce it) and outside the area to encourage commuters to leave their cars at home.[83] Many cities have also introduced park-and-ride schemes where drivers leave their cars at the periphery and continue their journeys into the centre by public transport. A recent survey of 45 schemes in Europe found rather uneven implementation, but where deployment had taken place there was strong public support, as traffic levels and levels of pollution had been reduced.[84]

Pricing measures include electronic road pricing (Singapore), congestion charging or cordon pricing (London, UK, and Stockholm, Sweden),[85] and parking pricing to reflect the value of the space used. But very few cities have introduced pricing as a mechanism to limit the numbers of cars coming into the central area, and even in those cities that have introduced schemes, it has only covered a small part of the city. In addition, fuel prices are often taxed, although the levels vary considerably from country to country, as it relates both to the levels of duty imposed and the additional national and local taxes imposed.[86] Some countries have tried to use fuel duty escalators, so that the real price of petrol and diesel increase over time to reflect the full economic costs, but this has proved unpopular with the oil industry, car manufacturers, as well as motorists.[87] All of these measures have primarily been introduced to raise revenues[88] and to address congestion issues, even though it has been acknowledged that there are also environmental benefits.[89]

Public transport fare subsidies can have social objectives in increasing the mobility of low-income

Box 7.7 TransMilenio: Supporting sustainable mobility in Bogotá, Colombia

The first two phases of the TransMilenio BRT system in Bogotá, Colombia, were completed by 2003, and it has a total of 84 kilometres of median busways, about 25 per cent of which is completely segregated from other traffic. The final phase (of another 100 kilometres, which was due to be completed in 2012) has been delayed due to unresolved political issues (including plans to construct a metro).

By 2011, the BRT system included some 1190 articulated buses, 10 bi-articulated buses, 114 access stations (with prepayment), 6 terminals and 4 intermediate integrated stations. In addition there were 448 feeder buses, running on 61 feeder routes with 420 line-kilometres. TransMilenio is frequently cited as a 'good practice' BRT project, and it carries some 1.7 million passengers per weekday, with 43,000 passengers moving each hour in one direction. The uniqueness of Bogotá's system is the 'transformation of a busway corridor with severe pollution, safety problems and aesthetically displeasing into a new BRT system with significantly lower travel times, lower noise and fewer greenhouse gas emissions'.[a]

By drastically reducing existing travel times and acting on the radial corridors connecting residential areas to the central business district, TransMilenio has done much to reinforce the attractiveness of the city centre. Public acceptance of the project is over 70 per cent, but there have been complaints about overcrowding and the time taken for interchange from the feeder lines. Furthermore, many people still lack access to the system as the network does not extend to the locations where the poor are living. In 2005, the population located in the more remote parts of the city accounted for 65 per cent of the total population, as the land there was cheaper and thus more affordable for low-income people. In fact, land-use value increases around the TransMilenio corridors have been estimated to be close to 20 per cent.

While the TransMilenio system has played an important role in contributing to more sustainable mobility system in Bogotá, it is worth noting that it was introduced as part of wider policy package, which also included the following components:

- Development of 285,500 square metres of walkways, green spaces, road dividers, sidewalks and shaded promenades, with 11 metropolitan parks, 3149 neighbourhood parks and 323 smaller scale parks.
- Construction of 350 kilometres of bikeways contributed to an increase in bicycle use from 1 per cent in 1995 to 7 per cent in 2010, when there were a total of 1498 bike parking locations.
- In addition, the introduction of the *ciclovia* system implies that some 120 kilometres of main roads are closed to motor vehicles for seven hours every Sunday, so that streets can be used by people for walking, cycling, jogging and meeting each other.
- Peak and license plate (*pico y placa*) restrictions during peak hours (6–9 am and 4–7 pm) using plate numbers for 40 per cent of the private cars.
- Fees and taxes: 20 per cent petrol surcharge (revenue allocated to public transport infrastructure and road maintenance) and car-free weekday in February (approved by popular vote).

Sources: Bocarejo and Tafur, 2011; Hidalgo and Carrigan, 2010; Hidalgo et al, 2007; Rodriquez and Targa, 2004; [a] Estupiñán and Rodriquez, 2008, p299.

households, but it is important that such subsidy goes to the identified user. It is also important to make sure that the quality of the public transport fleet is maintained at a high environmental standard, and that operators are given an incentive to invest. But subsidies have much wider impacts on livelihoods, as illustrated by a study of public transport in Sub-Saharan Africa:

> 'Subsidies and other forms of compensation can help formal public transport but an integrated framework and a level playing field are also needed for all types of transport to flourish. Financial mechanisms should be put in place to support the system, integrating the different types of collective transport rather than allowing profits to be scooped up by the informal sector with no regard for the burden of costs they might place on local governments and society as a whole. This can include trust funds, better credit facilities, land-value capture and other sources of revenues that can be used to help build sustainable low-carbon transport systems that will allow Africa to flourish and develop economically.'[90]

As noted above, subsidization is a form of incentive to encourage people to change their behaviour, and it can also apply to cars. For example, incentives can be given to encourage the purchase of more efficient cars and electric vehicles, where purchase prices are subsidized, or where preferential parking is given, or exemption from paying the congestion charge is given. All three of these incentives have been introduced in the UK.[91]

Investment in public transport and public transport infrastructure are both central to make sure that priority is given to this transport mode, as it allows the greatest number of people to be carried most efficiently. Public transport has to share space on congested roads with other traffic, and this reduces its efficiency. Trams have provided one effective means to introduce 'clean' transport that has a clear priority through control (traffic signals) and exclusive tracks.[92]

More recently, BRT is seen as a flexible and cheap means to invest in high-quality public transport with a separate right of way.[93] As discussed in Chapter 3, BRT potentially offers a high-capacity, relatively inexpensive and flexible form of public transport in many cities. BRT systems have good environmental credentials and can be introduced in a variety of different forms. Box 7.7 looks at how BRT can be combined into part of an integrated set of measures that have the potential to change perceptions of public transport.

TECHNOLOGICAL INNOVATION AND VEHICLE EFFICIENCY

This section presents technological and other policy responses related to increasing the efficiency of motorized vehicles and the use of the best available technology. This implies that the use of carbon-based fuels should be substantially reduced and cleaner low-carbon fuels should replace them for all forms of motorized transport (freight and passenger). As noted earlier in this chapter, the amount of CO_2 produced by motorized vehicles is directly related to the amount of fuel used, and there is considerable potential for reductions.[94]

However, it should be remembered that efficiency gains must be set against the growth in traffic,[95] as this often outweighs those gains. The discussion below focuses on four main issues, namely: the efficiency and age of the vehicle stock, standards of fuels used in vehicles, the potential of alternative fuels, and vehicle occupancy.

It is here important to note that there is a substantial potential for technological 'leapfrogging'. Thus there is no reason why cities in developing countries have to follow the same high-motorization (and high-pollution) pathway as that followed in developed countries. Rapid urbanization in many developing countries thus presents an opportunity to invest in the low-carbon city transport system of the future. That having been said, it is important to note that this cannot be undertaken without substantial financial support from the developed countries. This means that effective mechanisms need to be established, such as the fuel security credits being tested by the Asian Development Bank,[96] or initiatives under the clean development mechanism of the Kyoto Protocol.[97]

Public transport fare subsidies can have social objectives in increasing the mobility of low-income households, but it is important that such subsidy goes to the identified user

Investment in public transport and public transport infrastructure are both central to make sure that priority is given to this transport mode

Efficiency gains must be set against the growth in traffic, as this often outweighs those gains

Efficiency and age of the vehicle stock

The scale of any emission reduction is dependent on a set of factors such as the efficiency and turnover rate of the vehicle stock, the distance driven by each vehicle, and the tendency to buy larger and heavier vehicles. New vehicle technology has reduced the fuel use per unit of power by 50 per cent over a 15 year period (1990–2005), yet most of that potential saving has been negated by the overall increase in power and weight, particularly in the US. Thus the net effect has been no change.[98]

The introduction of new technologies does not, however, lead to immediate cuts in emissions. The efficiency of any single vehicle on the road is always lower than that of the newest technology. In general, this implies that overall emissions depend on the average age of the vehicle fleet in any particular country (or city). And, in the countries with the oldest

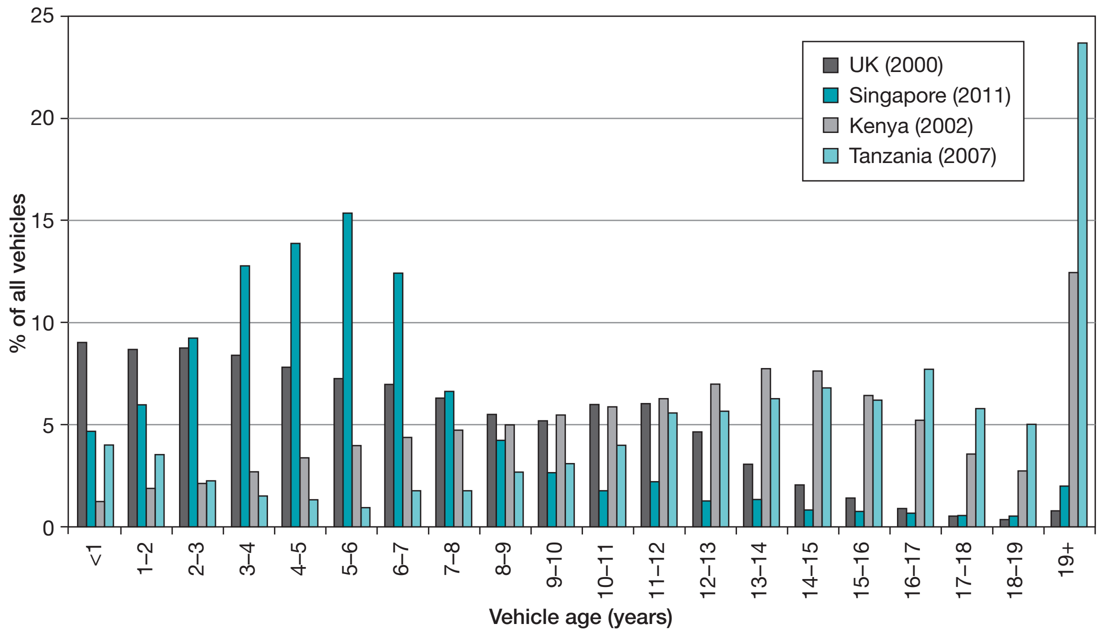

Figure 7.4

Vehicle age distribution, selected countries

Sources: Based on data from Kollamthodi et al, 2003 (citing DTLR Vehicle licensing statistics 2000); Government of Singapore, 2011; University of California at Riverside, 2002; UNEP, 2009 (citing data from Tanzania Revenue Authority).

Developed countries are exporting their less efficient and more polluting vehicles to developing countries

vehicle fleets, maintenance becomes a central issue. In general, the average age of vehicles in developed countries is lower than in developing countries, where the average age of vehicles can be more than 15 years[99] (Figure 7.4). There are some exceptions however, such as Brazil, which is one of the few developing countries with its own car manufacturing industry.[100] Some of the vehicles in developing countries operate for more than 40 years. These older vehicles are responsible for a disproportionately high percentage of air pollution, despite their relatively low numbers:

> 'The main reasons for the persistence of old technology include the high cost of new vehicles, the relatively low maintenance and support cost for older technology, and a lack of government fleet renewal incentives (including inspection and maintenance regimes).'[101]

However, there are examples, even from developing countries of successful schemes of upgrading the vehicle fleet. In Cairo, Egypt, for example, the government has initiated a scheme to renew the taxi fleet. The project started in 2007 with the introduction of 100 new air-conditioned (and metered) taxis, fuelled by CNG. In 2009, through a joint scheme with five car companies, three banks, advertising agencies (who were given the right to place advertisements on the taxis) and owners of scrapping yards, the scheme was launched at full scale. By 2013, a total of 43,000 old taxis had been replaced.[102]

Most developing and transitional countries – with the major exceptions being Brazil, India and China – do not have their own car manufacturing industry. The majority of developing countries are thus relying on imported vehicles. And, due to the cost of new vehicles, many of the imported vehicles are second-hand. In effect, developed countries are exporting their less efficient and more polluting vehicles to developing countries. Over the period 2005–2008, for example, 2.45 million vehicles were imported to Mexico from the US and Canada (with an average age of 11.4 years). The vehicles exported from the US to Mexico had higher emissions levels of hydrocarbons (4 per cent higher), carbon monoxide (4 per cent higher) and nitrogen dioxide (22 per cent higher) than the average vehicle in the US. Yet, the emissions of these vehicles were still lower than that of the existing fleet in Mexico.[103]

In order to address the issue of this 'dumping' of polluting vehicles, a number of countries have introduced technology- or age-restrictions on imported vehicles. In Kenya, for example, only models that are eight years old or less can be imported.[104] In Belarus, the government discourages the import of older cars through high import duties.[105]

Standards of fuels used and emissions from vehicles

The emission of pollutants from motorized vehicles is related to three main factors: the quality of the fuel, the fuel efficiency of the vehicle stock and the capture of pollutants before they escape from the vehicle. These are discussed in more detail below.

Considerable progress is being made in improving the quality of fuel used and the efficiency of the conventional petrol and diesel internal combustion engine, so that the typical car is now some 35 per cent more efficient than it was ten years ago. This improvement can be directly translated into reductions in CO_2 emissions.[106] The EU has introduced legislation (2009) for a reduction of the greenhouse gas intensity of fuels by up to 10 per cent by

2020 – a 'low carbon fuel standard'. This will be achieved through the greater use of renewable energy in electric vehicles, and the use of biomass sources, such as bio ethanol that is already mixed with fuel (5 per cent).[107]

Even though diesel vehicles produce less CO_2 per unit of distance travelled, their increasing dominance in the vehicle fleet (both passenger and freight) has been negated by the greater distances travelled. Diesel vehicles also tend to have larger emissions of other pollutants, such as nitrogen oxides and particulate matter (Box 7.2). As a result, the WHO has recently stated that diesel exhaust causes cancer, and has called for tighter emission standards, comparing the risk of exhaust to second-hand cigarette smoke.[108]

In India, the fuel quality standards for transport fuels are legislated under the environmental Protection Act (which follows the EU specifications). New specifications have been introduced in two phases, first applied in 13 major cities[109] and then followed by nationwide implementation. India has used unleaded petrol nationwide since 2000.[110]

Reductions in the sulphur levels in diesel have major effects on emissions, as many developing countries have very high sulphur levels[111] in diesel fuels. Reducing sulphur to very low levels[112] also reduces the emissions of particulate matter, and it enables emission control technologies that provide even greater emission reductions (i.e. diesel oxidation catalysts and diesel particulate filters).[113] For petrol vehicles, low sulphur levels[114] in fuel improve the performance of catalytic converter systems that are standard in developed countries. Low sulphur levels are now being introduced in most developing countries as well, through the importation of new and second-hand cars.[115]

Governments are increasingly looking towards vehicle manufacturers to improve the fuel efficiency of the vehicle stock. Many governments are now setting more challenging mandatory targets for fuel efficiency in new vehicles, and this single action will substantially reduce CO_2 and other emissions from the transport sector.[116] The EU tried, unsuccessfully, to introduce voluntary agreements with the vehicle manufacturers during the last decade. It is only recently (2009) that mandatory targets have been set. However, the fact that good progress has already been made towards these targets may suggest that the targets are not tough enough. Figure 7.5 shows that there is a clear downward trend in the emissions of CO_2 from new vehicles and the fleet-wide mandatory targets set by the EU will be a benchmark for other manufacturers.

Governments are increasingly looking towards vehicle manufacturers to improve the fuel efficiency of the vehicle stock

Many pollutants can be filtered out through the use of catalytic converters, particulate traps and other technologies, although this means that additional costs are imposed on vehicle owners. It is, however, also important to ensure that the filters are working effectively, and this again relates to regular maintenance and testing of vehicles. Catalytic converters do not work when engines are cold, and so for many short journeys the pollutants are not being filtered out. Regulations in Europe have gradually been tightened up so that emissions levels for all vehicles (including freight vehicles) conform to EU standards.[117] These standards are also being adopted elsewhere, for example in Russia[118] and China.[119] The US and Japan have their own emissions standards that have been tougher than those in the EU until 2000, but all three have since followed essentially the same path and are converging towards zero emissions for all pollutants.

It takes a considerable time before [the] full benefits [of emission standards] are realized, as existing older vehicles have to be scrapped and replaced by new vehicles

Due to the fact that the emission standards only apply to new vehicles, it takes a considerable time before their full benefits are realized, as existing older vehicles have to be scrapped and replaced by new vehicles.[120] Despite the clear intentions to reduce

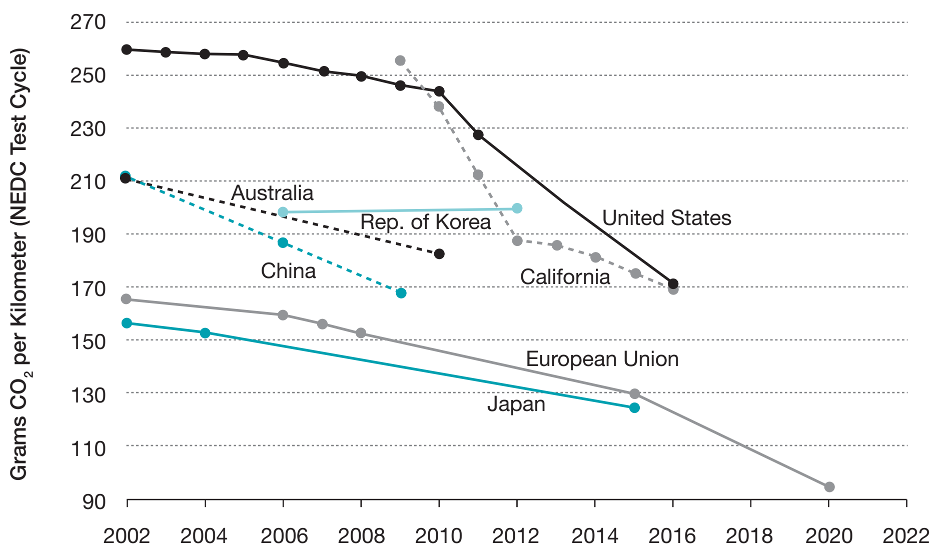

Figure 7.5

Actual and projected greenhouse gas emissions from new passenger vehicles, by country and region

Note: Solid lines are enacted; dotted lines are proposed or contested.

Source: UNEP, 2009.

key emissions from vehicles, in practice it will take 10–15 years to work its way through the entire vehicle stock in developed countries. In developing countries, with their considerably older vehicle stock it will take even longer.

The belief that add-on technology can 'solve' the air quality issue is too simple

Add-on technology (principally the catalytic converter), cleaner fuels and more efficient and lighter vehicles have helped reduce the levels of pollutants from petrol engine vehicles by 80 per cent. There are, however, questions about whether the technology is working efficiently and the rate of change in the existing vehicle fleet, particularly in those cities with the most rapid increase in levels of car ownership. Furthermore, there are still concerns over whether the same levels of air quality improvement can be achieved in diesel vehicles.[121] And, the problem of particulates is still present as this results from fuels (diesel), from tyres and from other sources, and this is much harder to control (and is a particular problem for freight trucks in urban areas).

In the near future, it is unlikely that any alternative fuel can replace the established oil-based sources of fuel, as they cannot be produced (or distributed) in the quantities required

The belief that add-on technology can 'solve' the air quality issue is too simple. As noted above, there are important limitations relating to whether the catalytic converters are working, whether diesel emissions can be controlled effectively, the time taken for all vehicles to be fitted, and the slow switch to alternative fuels. When set against the growth in car ownership and use, the catalytic converter really only gives a maximum of ten years 'breathing space' before pollution levels start to rise again. In the US, for example, the catalytic converter has been compulsory since 1979, and the full benefits have already worked their way into the entire car fleet. The CO_2 problem has not been addressed, as reduction in fuel use is the only means to reduce such emissions.[122]

Alternative fuels

In order to reduce the dependence on oil – and to reduce the emissions of greenhouse gases and other pollutants – there has been much debate over the introduction of alternative fuels in the transport sector. However, while searching for alternatives, it is important to keep in mind the fact that both petrol and diesel have very high energy densities,[123] and that there have already been substantial investments in support infrastructure in most countries (e.g. fuel stations). Thus, alternatives need to have a high energy output and they must be produced cleanly and cheaply, and in sufficient quantities.

The most positive developments have come from hybrid vehicles that combine conventional internal combustion engine with electric vehicle technology

In the near future, it is unlikely that any alternative fuel can replace the established oil-based sources of fuel, as they cannot be produced (or distributed) in the quantities required. This means that all alternative fuels are likely to be niche markets. However, these may in turn develop to mass-market options in the longer term. In situations where there is less established supporting infrastructure (e.g. in developing countries), the introduction of new fuels may happen earlier. This provides an opportunity to initiate new solutions to urban motorization in developing countries. This is already evident in some countries through the use of BRT and electric vehicles (including e-bikes).

In terms of policy, the EU seeks to halve the use of conventionally fuelled cars by 2030, to phase such cars out of cities by 2050, and to achieve carbon-free goods movement in cities by 2030. The EU believes that technological innovation will play a major role in this process, combined with regulations and standards being set by individual governments, demand management, road pricing and local city-level controls.[124]

The public discussion related to alternative fuels started with a focus on ***greater efficiency*** within existing internal combustion engines. As discussed above, efficiency levels have improved substantially, and a further halving of CO_2 emissions is expected over the next ten years (Figure 7.5). Public debate has since moved onto ***biofuels*** and ***hydrogen***. However, the potential of biofuels has been restricted by the conflicts arising from increasing food prices, as increasing production of energy crops has led to reduced areas of agricultural land producing food crops.[125] The production of liquid fuels from sugar, biomass and cellulose also requires huge amounts of water. Likewise, the potential of hydrogen as a clean fuel has been questioned because of the energy required in its production (often from carbon products, such as oil or coal), and because of issues related to the storage and distribution of the hydrogen.[126]

More recently, the ***electric vehicle*** has emerged as a more suitable alternative for urban transport. Such vehicles include hybrid electric vehicles, plug-in hybrid electric vehicles[127] and other electric vehicles (including battery-driven vehicles). Increased use of such vehicles would solve many of the local pollution problems. However, the energy still has to be generated (often from coal), and there are issues relating to the recharging infrastructure, the use of materials and the need for a lifecycle approach to energy use and emissions.[128]

The most positive developments have come from hybrid vehicles that combine conventional internal combustion engine with electric vehicle technology, as this allows both electric power at low speeds and a combination of internal combustion engine and electric power at higher speeds. In such hybrid vehicles, the conventional engine is supported by a battery that can be recharged while the vehicle is being used. Greenhouse gases and other pollutants are still being emitted, but these vehicles provide a direct substitute for the conventional car, but use only about 60 per cent of the fuel. Over the lifetime of the car it is likely that there are cost savings to

Box 7.8 Sustainable transport in Hangzhou, China

The city of Hangzhou (population 8.1 million in 2009) seeks to build a highly integrated and low-carbon intensive transport network that consists of metro, BRT, cycle and walking, water transport and electric vehicles. A key element of this strategy is the world's largest public bicycle programme. In 2009, some 67 per cent of all trips were by foot, cycle and electric bike. This accounted for 9.6 million out of 14.4 million trips made each day – the CO_2 emissions per trip are 250 grammes (about a third of the level in London). The sustainable transport strategy includes the following elements:

- A metro system of 69 kilometres (2011), to be extended to 278 kilometres by 2050.
- Nine BRT routes, with a further ten planned for 2020.
- Smart card operated systems for buses, taxis, bicycles and other forms of public transport.
- Seamless connections and zero interchange strategies for public transport transfers.
- Central city divided into eight walking areas with pedestrian priority.
- Free public bicycle service (for first hour or more if using public transport), with 17,342 bikes and 800 service points (June 2009).
- 1130 kilometres of bike routes by 2020.
- Subsidy for electric cars up to US$18,000 or about 50 per cent of purchase price and free charging initially.
- Four electric vehicle charging stations, 38 sub charging and battery swap stations and 3500 charging posts by 2012.
- Plans for 1100 electric vehicles to be used by the public sector, and electric buses and taxis are being tested.
- Electric bikes are cheap and flexible, costing US$150–300. The running costs are 2 per cent of those of a car, averaging at US$2.25 per 100 kilometres. In 2007 there were 600,000 electric bikes in Hangzhou.

Sources: Banister and Liu, 2011; Keirstead and Brandon, 2011.

the user, as the higher purchase prices are compensated for by lower fuel costs.

China has introduced a series of policies aiming to facilitate electric vehicle industrialization and commercialization, including pilot projects, standard announcements and purchase subsidies. In the industrial sector, a group of car manufacturers has announced mass production plans for electric vehicles.[129] In some cities, electric vehicles are beginning to make a significant impact in terms of their share of public transport and public service vehicle fleets. This includes delivery vehicles, buses and other services (e.g. taxis). In June 2010, six cities were chosen to implement electric vehicle purchase subsidies with a maximum of US$9000 per vehicle in the private car market.[130] One of these 'electric' transport cities is Hangzhou, where a variety of measures have been combined to achieve an innovative and environmentally beneficial transport pathway (Box 7.8).

Although, worldwide, most attention has been given to technological innovation for the private car, there is also considerable potential within cities to use electric power and hybrid technologies for public and freight transport. London, UK, for example, had more than 300 hybrid buses in operation by December 2012,[131] and similar initiatives are currently underway in Latin America (Box 7.9). Electric trucks have been used for local deliveries (Box 7.4) and hybrid vehicles have become more commonly used by global companies (Box 7.10). These vehicles are intensively used, and they can be recharged and maintained at the company's own sites.

There is . . . considerable potential within cities to use electric power and hybrid technologies for public and freight transport

Occupancy (load) factors

The range of technological solutions that can be used to address the issues of improved vehicle efficiencies and reduced levels of CO_2 emissions are extensive. However, technology cannot provide the whole

Box 7.9 The Hybrid and Electric Bus Test Programme, Latin America

The Hybrid and Electric Bus Test Programme was launched in June 2011 by the C40 Cities Climate Leadership Group in partnership with the Clinton Climate Initiative. In five participating cities – Bogotá, Curitiba, Rio de Janeiro, Santiago de Chile and São Paulo – the programme seeks to reduce the carbon footprint of public transportation and develop a market for fuel-efficient, low-carbon buses in Latin America.

Supported by the Inter-American Development Bank, the programme brings together cities, bus technology companies and local transport operators to test bus technology performance in city-specific driving conditions and duty cycles. Ultimately, the programme aims to catalyse the deployment of up to 9000 buses across Latin American cities over the next five years, with annual CO_2 emission reductions of 475,000 tonnes.

The programme compares hybrid diesel-electric technology and conventional diesel technology. Promising findings show that hybrid technology is at least 32 per cent more fuel efficient and produces fewer local air pollutants and greenhouse gases than conventional diesel buses; while electric buses have zero on-road emissions and are 250 per cent more fuel efficient than normal diesel buses.

Source: Manuel Olivera, Director, C40-CCI Hybrid and Electric Bus Test Programme (personal communication, 8 October 2012).

Box 7.10 Hybrid trucks

A number of global delivery companies (FedEx, DHL, TNT and UPS) have tested hybrid delivery trucks and these are slowly beginning to be introduced into their fleets. FedEx together with Eaton Corporation have developed a diesel hybrid electric vehicle delivery truck and launched a pilot project with 20 hybrid electric vehicle diesel trucks (in 2004). The Eaton truck is a medium weight pick-up delivery truck that operates in urban areas with many short stops for collection and delivery. By 2009 FedEx had a fleet of 264 hybrid electric trucks, and they have covered more than 4 million miles of service (2004–2009), reducing fuel use by more than 570,000 litres and CO_2 emissions by 1521 metric tonnes.

Source: FedEx, undated.

Urban residents can live in a car-free environment, provided that: the right transport links are established . . .; there are local facilities and services; and there are sufficient reasons for not owning a car

solution to the environmental impacts of urban mobility. Improved vehicle standards, better fuels, alternative fuels and innovation can all make an important contribution, but effective policy actions here need to be combined with strategies to reduce the need to travel, the distances travelled and the modes of transport used (see below).

Underlying all strategies, however, is the importance of vehicle occupancy (freight and passenger), and the efficiency figures illustrate the importance of occupancy (or load) (Box 7.11). Fully laden vehicles (public and private, freight and passenger) are far more efficient than empty ones. This also reduces environmental impacts, improves the quality of the urban area and contributes to reducing congestion.

'High-occupancy vehicle' lanes or car-pool lanes have been introduced in some cities (primarily in developed countries) to increase vehicle occupancies. Vehicles that travel in a high-occupancy vehicle lane must carry at least one (sometimes two) passengers in addition to the driver. Some high-occupancy vehicle lanes are in operation only during certain hours. Outside of those hours, they may be used by all vehicles.[132] High-occupancy vehicle lanes have also been introduced in some developing countries. On such example is South Africa where such lanes have been introduced to facilitate bus transport in particular.[133] According to critics, however, few buses are using these lanes – primarily because the lanes are on the wrong side of the road with respect to loading and off-loading of passengers, forcing buses to constantly change lanes – and, due to lack of controls, these lanes are now used primarily by private cars.[134]

THE COMPOSITE SOLUTION

The preceding sections have presented a number of examples of interventions to enhance environmentally sustainable urban mobility systems. Each of the examples has illustrated the impact of specific types of policies. In most cases of successful implementation, however, it is not a single policy that has been introduced – but rather a package of measures. Such 'packages' are more likely to gain public acceptance, and they allow a mixture of policies that may be seen as disadvantageous to individual users, but promote overall welfare gains to society (see for example Box 7.7). Yet, while policy packaging can certainly support effective and efficient policy-making (not least through enhancing interventions' implementation and the *ex-ante* mitigation of unintended effects), the packaging process requires a deep and holistic appreciation of policy subsystems, together with a structured approach, if its benefits are to be genuinely realized.[135]

To promote the environmental argument it is important to consider a wide range of effects that contribute co-benefits. For example, health can be viewed in three main ways, as less motorized traffic or 'cleaner' vehicles improve local air quality, as slower travel leads to improvements in road safety and as non-motorized transport has direct health benefits. In addition, these improvements are likely to have a positive effect on climate change through reductions in CO_2 emissions. All these factors lead to important co-benefits that need to be included in all environmental evaluation.

In order to achieve the EU 2050 target of zero carbon emissions from transport in cities[136] some communities have started moving towards the 'car-free city'. One such community is Vauban (in Freiburg, Germany). It was constructed on a scale that facilitates movement by local public transport, walking and cycling (Box 7.12). Vauban offers one example of how many of the different elements outlined in this chapter can be brought together into a coherent set of proposals. Based on this experience it seems that urban residents can live in a car-free environment, provided that: the right transport links are established (i.e. to the main station and the city

Box 7.11 Freight loads and emissions standards

New regulations in many cities restrict access to the city centre based on the age and load of the vehicle:

- In Amsterdam (the Netherlands), a truck may make deliveries in limited access zones if it meets the following four conditions: it must be less than eight years old, meet the Euro II standard, have a maximum length of 10 metres, and load or unload at least 80 per cent of its merchandise in the central city.
- In London, the Low Emission Zone (set up in 2008) prohibits trucks older than the Euro III standard to enter the metropolitan area (the area surrounded by the M25 highway, totalling 1580 square kilometres).
- In Tokyo, since 2003, the most polluting diesel vehicles have been prohibited from the city centre.

Source: World Bank and DfID, 2009, p23.

Box 7.12 Car-free living: Vauban, Germany

Vauban is a small community of 5500 inhabitants and 600 jobs, 4 kilometres south of the town centre of Freiburg (Germany). It was started in 1998 as 'a sustainable model district' on the site of a former military base. Although the Vauban community itself is small, it is mixed with considerable levels of involvement of the local people in helping to decide priorities and alternatives (the Forum Vauban). The guiding mobility principle has been to try to reduce the use of the car, but giving residents the flexibility to use a car where necessary. This is matched by high-quality public transport, walking and cycling facilities.

Within Vauban, movement is mainly by foot and bicycle, and there is a tram link to Freiburg (2006). Cycling is the main mode of transport for most trips and most activities, including commuting and shopping. The town is laid out linearly along the tracks so that all homes are within easy walking distance of a tram stop. The speed limit on the district's main road is 30 kilometres per hour, while in the residential area cars should not drive faster than 'walking speed' (5 kilometres per hour). About 70 per cent of the households have chosen to live without a private car (2009), and the level of car ownership (and use) has continued to fall. In the past, more than half of all households owned a car, and among those who are now living car free, 81 per cent had previously owned one and 57 per cent gave up their cars on or immediately after moving to Vauban.

The transport network in Vauban adopts a complex combination grid, with three types of streets: collector roads, local streets and pedestrian/bicycle paths. As indicated in the drawing, most local streets are crescents and *cul-de-sacs*. While they are discontinuous for cars, they connect to a network of pedestrian and bike paths that permeate the entire neighbourhood. In addition, these paths go through or by open spaces adding to the enjoyment of the trip.

Furthermore, most of Vauban's residential streets lack parking spaces. Vehicles are allowed to drive in these streets (at walking pace) to pick up and to deliver, but are not allowed to park, and enforcement is based on social consensus. Each year, households are required to sign a declaration indicating whether they own a car. If they do, they must buy a space in one of the multi-storey car parks on the periphery (at an annual cost of €18,000 in 2008).

The implementation of the traffic concept in Vauban meant that new laws were needed to accommodate the current building regulations in the federal state of Baden-Württemberg. The Association for Car-free Living in Vauban (*Verein für autofreies Wohnen*) was founded as a legal body for the implementation of the concept. For those that want the occasional use of a car, the car sharing company Freiburger Auto Gemeinschaft offers cars for occasional use by residents of Vauban, and they are parked in the community car park. Those in the car-sharing scheme have access to the shared cars and they also receive a one-year free pass for all public transportation within Freiburg, as well as a 50 per cent reduction on every train ticket for one year.

Sources: Forum Vauban, 1999; Scheurer, 2001; Nobis, 2003; Melia, 2006 and 2010.

centre of Freiburg); there are local facilities and services; and there are sufficient reasons for not owning a car (e.g. limited and costly parking).

Similarly, in order to improve public transport, a series of policy interventions are necessary to create a positive overall experience. This includes investments in new infrastructure (including vehicles, routes and maintenance), electronic ticketing (smart cards), 24-hour availability and the feeling of safety and security. Another essential requirement is organizational change that allows seamless travel and short interchanges between modes (including both route and fare integration). Furthermore, high levels of public transport occupancy[137] and use permits, lower fares and extensive networks for all users are central to sustainable urban mobility. All these factors increase the efficiency of transport in the city, and in turn result in environmental and other co-benefits (e.g. safety, health and noise). Complementary actions include the slowing down of urban traffic, the allocation of space to public transport, strong parking controls and road pricing. All of these interventions are likely to maximize the use of public transport.

In addition to prioritizing public transport, investment in separate cycle and pedestrian networks would strengthen the commitment to promoting non-motorized transport. The available transport space in the city should be determined and allocated based on prioritization of low-carbon transport, demand management and the identification of priority users (and uses). However, it is important to keep in mind that measures to encourage modal shift must be combined with strategies to make the best use of the 'released space' so that there is a net reduction in motorized traffic.[138] Such an approach introduces the much wider notion of the street, as road space is no longer considered only as a road but as a space for people, green modes and public transport. Creative use of that space at different times

The available transport space in the city should be determined and allocated based on prioritization of low-carbon transport, demand management and the identification of priority users (and uses)

Table 7.5

GlaxoSmithKline – 2010 corporate responsibility report

Freight transport	Employee transport
• Switching transport mode from air to sea. • Optimizing its European road freight network by improving vehicle load configuration to maximize use of the available capacity and using fewer trucks. • Warehousing improvements – lower stock levels. • Reducing the number of external warehouses to cut travel between sites and the warehouses. • Installing intelligent lighting controls and energy efficient lighting. • Consolidation of refrigerated storage units. • Using energy efficient forklift truck charging.	• Green travel plans are in operation at a number of sites to encourage employees to reduce the environmental impact of their travel by sharing vehicles, using public transport or by cycling to work. • The distance flown on company business fell by more than 200 million kilometres and nearly 85,000 fewer single flights were made in 2010 compared to 2009. • Significant investment has been made in videoconferencing systems, with over 500 videoconference rooms in 68 countries. Other technology includes teleconferencing, desktop and personal videoconference units and web conferencing. In 2010, there was a 40 per cent increase in the use of videoconferencing compared to 2009.

Source: GlaxoSmithKline, 2011.

of the day or days of the week means that new uses can be encouraged (e.g. street markets and play zones).

The experience of GlaxoSmithKline, one of the largest pharmaceutical companies in the world, exemplifies how private-sector companies can reduce their greenhouse gas emissions, and thus contribute to more environmentally sustainable urban transport. The fact that such initiatives are also of financial benefit to the company should provide additional encouragement for other companies to reduce some of the negative environmental externalities of their operations. Table 7.5 outlines measures implemented by GlaxoSmithKline in 2010 with respect to the company's freight and employee transport. However, more recent data indicate that the company's total transport emissions grew by 8.4 per cent in 2011, thus cancelling out the gains made in 2010.[139]

The existing carbon market is not appropriate for the transport sector, and a separate sector-based mechanism may be required

FUNDING MECHANISMS FOR ENVIRONMENTALLY SUSTAINABLE URBAN MOBILITY SYSTEMS

While Chapter 8 contains a more elaborate discussion of funding for urban transport investments, it is appropriate here to make a brief reference to global financial options that are directly related to environmental sustainability. So far, the mechanisms devised to address such funding have not been effectively used in cities or in the transport sector. Out of the 6660 clean development mechanism projects registered by 1 April 2013, only 28 were related to transport.[140] Another ten projects were under validation, or in the process of being registered.[141] The clean development mechanism is one of the three flexible mechanisms under the Kyoto Protocol. The clean development mechanism enables the implementation of emissions reduction projects in developing countries to earn 'carbon credits', which can then be sold internationally (thus being rewarded for having reduced emissions). By purchasing such carbon credits, developed countries can meet parts of their emissions reduction targets (by paying for the right to pollute).[142]

Unfortunately, such carbon emissions trading favours the cheaper projects, which may not have the greatest potential to reduce greenhouse gas emissions over the longer period. Most transport projects are expensive as they require up-front investment or the development of new fuels and technologies. Apart from the scale of change needed in the transport sector, the emissions are diffuse and hard to measure, as is the reliable baseline and the need to define project boundaries so that a consistent monitoring framework can be established. Thus, the existing carbon market is not appropriate for the transport sector, and a separate sector-based mechanism may be required.

Alternatively, there could be a greater role allocated to cities to reduce greenhouse gas emissions in transport and to adopt national appropriate mitigation actions[143] for city-scale application. Certainly, there is a strong case to integrate existing funding mechanisms available for climate change mitigation – such as the Global Environment Facility (GEF),[144] the environmental fiscal reform[145] and official development assistance – in the clean development mechanism.[146]

Furthermore, there may be considerable potential for emerging cities and countries to follow a less carbon-intensive pathway when it comes to transport. The Sustainable Fuel Partnership,[147] for example, is examining the rationale behind a new market mechanism to provide energy incentives for improving energy security in the Asia-Pacific region by treating energy security as a public good that can be valued and translated into a cash flow, and thereby to correct market inefficiencies. This will be achieved through 'fuel security credits' that are designed to reduce actual oil use and to invest in transport projects that are less energy intensive, to examine means by which trips can be avoided, to encourage mode shift to public and non-motorized transport, and to improve technologies.[148]

There are also considerable overlaps between many general development programmes – funded through official development assistance – and global public goods programmes, including climate change mitigations strategies such as public-sector investments in clean transportation.[149] Furthermore, although it is currently not mentioned specifically, there should be considerable scope to include funding for sustainable urban mobility – particularly in developing countries – in the discussions on innovative development financing mechanisms currently being explored in the global economic arena.[150] Thus, both of these sources of funding could be drawn upon to finance environmentally sustainable urban mobility systems.

CONCLUDING REMARKS AND LESSONS FOR POLICY

When sensitively planned and appropriately supported by sustainable infrastructure, compact cities are the world's most efficient settlement pattern. Urban density reduces the overall spatial footprint of development and allows for greater preservation of natural areas. It also allows for more efficient use of transport infrastructure, which reduces emissions and resource use. However, current trends in motorization and oil dependence – and the increased dependence on private motorized transport – pose major challenges to the development of environmentally sustainable urban mobility systems, namely:

- greenhouse gas emissions: the main cause of global climate change, which could have catastrophic impacts on urban transportation systems;
- urban sprawl: leading to increasing trip lengths and thus increased dependence on the private car to meet individual mobility needs;
- air and noise pollution, and decreased physical activity: have major negative impacts on the health of urban residents;
- road traffic accidents: are among the leading causes of premature deaths in cities all around the world;
- community severance: where major transport infrastructure disrupts neighbourhoods and serves as physical barriers to human interaction.

To address these challenges, there is a need for policy interventions that encourage change in five major areas, namely: a reduction of the number of motorized trips made (i.e. telecommuting, online shopping or a shift to non-motorized transport); reduced travel distances in cities (i.e. changes to the urban form); changes in the modal split (i.e. encouraging public transport); technological innovations that reduce the negative externalities of motorized transport (i.e. more efficient fuels and reduced emissions); and increased vehicle efficiency (i.e. higher occupancy rates).

Most policy interventions may be grouped in three categories: regulatory measures; pricing measures; and investments in public transport and public (and non-motorized) transport infrastructure. Regulatory measures may be used to limit the number of cars on the roads at any particular time, or to restrict the number of parking places in inner-city areas, both of which may encourage a modal shift towards public transport. Such measures may also be used to reduce emissions from motor vehicles to encourage the use of more energy-efficient vehicles, and to encourage more efficient use of infrastructure and vehicles, for example through the introduction of dedicated high-occupancy vehicle lanes.

There is a need for policy interventions that encourage . . .: a reduction of the number of motorized trips made . . .; reduced travel distances in cities . . .; changes in the modal split . . .; technological innovations that reduce the negative externalities of motorized transport . . .; and increased vehicle efficiency

Pricing measures may be used to discourage the use of private motorized transport – in the form of electronic road pricing, congestion charging, parking pricing, fuel taxes, etc. – or to encourage the use of more energy-efficient vehicles – for example sales duties related to engine size. Similarly, such measures may also be used in the form of subsidies to encourage the use of public transport (fare subsidies) and to encourage the purchase of more efficient vehicles (subsidies on low-emission fuels, vehicle purchase prices, exemptions from congestion or parking charges, etc.).

Investments in public transport, and infrastructure for public and non-motorized transport, may also play a major role in encouraging shifts to more sustainable modes of transport. Improved connectivity, increased capacity, enhanced quality and reduced travel times for such modes are major factors encouraging city residents to reduce their reliance on the private car.

However, the perhaps most effective approach (at least in the longer term) to reduce the environmental impact of urban mobility is to reconsider the urban spatial structure. As discussed in Chapter 5, urban form plays an important part in determining both transport mode and distance travelled, as it links the spatial distribution of population and jobs (as well as other destinations) to the pattern of trips. Through increased (population and job) densities and mixed-use developments, urban planning may play a major role in organizing spatial activities in cities so that they are in close proximity to their users. Well-planned, densely populated settlements can reduce the need for private motorization and decrease travel distances, thus making it more attractive to walk and cycle. Furthermore, urban planning based on transit-oriented development (or similar approaches) helps to maximize urban densities around transport nodes and encourages a modal shift to public transport. Such an integration of land-use and transport planning is a core component of a strategy to create environmentally sustainable urban mobility systems.

The perhaps most effective approach . . . to reduce the environmental impact of urban mobility is to reconsider the urban spatial structure

To ensure successful implementation of environmental policies, . . . public acceptability should be a major concern

While the above interventions are discussed separately in the report, it is essential to consider them as components of a package of measures. Such 'packages' are more likely to be publicly acceptable, as they allow a mixture of policies, some of which may be seen as disadvantageous to individual users, yet as a package they may be seen as supporting the public good. To ensure successful implementation of environmental policies, some of which may involve radical change, public acceptability should be a major concern. Communities and other stakeholders should thus be involved in all phases of policy development, including initial discussions, decision-making and implementation.

The strategic planning of the city, and the role played by transport systems, needs to be balanced by actions taken at the neighbourhood level, in a supportive government environment at all levels. It is at the neighbourhood level that cycling and walking become important modes of transport – for access to employment and other services and facilities – and these complement the need to travel longer distances by public transport to other parts of the city. City-wide decisions need to take account of the requirements of the population and businesses – i.e. to ensure access to destinations – so that movement can take place in an efficient and environmentally sustainable manner.

NOTES

1 Banister and Berechman, 2000.
2 Jackson, 2009.
3 Perrels et al, 2008.
4 Such externalities include the costs that are imposed by one set of users on other users and on society more generally, and where these costs are not paid by the polluter (Maddison et al, 1996).
5 Carpenter et al, 2008, p439; Banister, 2005.
6 IEA, 2012b. See Figure 1.5.
7 IEA, 2009. See also UN-Habitat, 2011; and Barker et al, 2007. For details on how these emissions distribute across modes, see Table 7.1.
8 UN, 2012a.
9 Energy density is the amount of energy per unit volume of fuel (Savage, 2011).
10 With respect to this last point, this indicates that developing countries may more easily find alternatives to oil-based transport, as these may have lower levels of investment in 'conventional' transport infra-structure. This might be seen as an opportunity for developing countries to make the transition to a low-carbon transport system.
11 Gilbert and Perl, 2010.
12 Afrique en ligne, 2011.
13 Banister et al, 2011. This is so despite recent development in terms of the extraction of unconventional oils, which have the potential to dramatically increase oil supply in short and medium term (Gordon and Tsay, 2013).
14 See for example UNEP, 2008.
15 See for example Principle 16 of the 'Rio Declaration on Environ-ment and Development', http://www.unep.org/Documents.Multilingual/Default.asp?documentid=78&articleid=1163, last accessed 30 January 2013. The removal of subsidies is necessary, but not sufficient, to ensure payment of the full environmental costs of fuels.
16 IEA, 2010, p569.
17 See IEA, 2010, pp571–572.
18 UN-Habitat, 2011, pp17–20.
19 IEA, 2011a, p13.
20 IEA, 2011b.
21 Yet, as noted earlier in this chapter, emissions from the transport sector have remained constant at about 23 per cent of total CO_2 emissions.
22 OECD/ITF, 2011b.
23 OECD/ITF, 2011b, Table 4.
24 UITP, 2001.
25 UN-Habitat, 2008.
26 UN-Habitat, 2008.
27 Nicholls et al, 2008.
28 LSE cities et al, 2013.
29 UN-Habitat, 2011.
30 For a more elaborate discussion on this, see UN-Habitat, 2011.
31 Due to the limited access to private modes of transport of the urban poor, evacuation plans should provide sufficient (and free) public transport services in case of evacuation.
32 BRT systems seem to provide an answer to the congestion problem, as these buses travel in dedicated lanes.
33 Banister, 2007.
34 See Chapter 5.
35 See Chapter 6.
36 Lucas, 2009. This issue is discussed at more length in Chapter 6.
37 Banister, 1998.
38 Perkins and Hamnett, 2002, p11.
39 From 2.5 million to 5.3 million (UN, 2012a).
40 From 42 per cent to 31 per cent of total land area (Ernst, 2011).
41 See for example the attention paid to air pollution ahead of the 2008 Olympic Games in Beijing China (UNEP, 2007a).
42 Vidal, 2013; citing Lim et al, 2012.
43 Walker, 2012.
44 EC-Environment, 2011.
45 UN, 1997. See also EEA, 2001. The WHO noise standard for traffic areas is 70 dB (Berglund et al, 1999, p65).
46 OECD, 1991.
47 OECD, 1991.
48 OECD, 1991; UN, 1997.
49 Suchorzewski, 2011.
50 Woodcock et al, 2007; Roberts and Edwards, 2010.
51 Bull et al, 2004.
52 Woodcock et al, 2007 and 2009.
53 James et al, 2004; WHO, 2009, Table A4.
54 Overweight and obesity increase with age. In England, the percentage of adults who are obese has roughly doubled since the mid-1980s (Oxford University, 2007).
55 See for example http://www.copenhagenize.com/, last accessed 6 February 2013.
56 Andersen et al, 2000.
57 Vasconcellos, 2011, p351.
58 Gehl, 1996; Gehl and Gemzøe, 2001.
59 Ontario College of Family Physicians, 2005, p3.
60 Ontario College of Family Physicians, 2005.
61 IBM Corporation, 2011.
62 Huzayyin, 2011.
63 This option is discussed in more detail in the section below on 'Changing the Modal Split'.
64 Pineau, 2010. See also Chapter 6.
65 Paula Bisiau, Director for Sustainable Transportation, City of Buenos Aires (personal communication, 8 October 2012).
66 Sustainable Transport Project for Egypt, 2011.
67 The relationship between travel behaviour and urban form is discussed in more detail in Chapter 5.
68 Banister and Stead, 2004.
69 Larsen et al, 2006.
70 Lyons and Kenyon, 2003.
71 See for example Hampshire et al, 2012; Porter, 2012.
72 Castells, 2000; Etzo and Collender, 2010. See also Economist, 2009.
73 See Chapter 5.
74 Glaeser, 2011.
75 Chew, 2011.
76 Chew, 2011.
77 ADONIS, 1999.
78 See note 4 above, and Chapter 8.
79 See the discussion above in the section on 'Environmental Challenges in Urban Mobility Systems'.
80 Note that governance issues are also important for effective implementation (see UN-Habitat, 2011, p108; and Chapter 9 below).
81 Barter and Dotson, 2011.
82 The *pico y placa* in Bogotá was introduced in 1998, and was later replicated in Medellín in 2005. A similar system (*hoy-no-circula*), which restricts drivers from using their vehicles one weekday per week, was introduced in Mexico City in 1989 (Gallego et al, 2011).
83 Banister, 2003.
84 Dijk and Montalvo, 2011.
85 US Department of Transportation, 2006.
86 See also the discussion on fuel subsidies in the section on 'Motorization and oil dependence' above.
87 The UK introduced such a scheme in 1993, but it was abolished in 2000 due to public discontent (Politics.co.uk, undated).
88 See discussion in Chapter 8.
89 Anas and Lindsay, 2011.
90 UITP, 2010, p22.
91 Office for Low Emissions Vehicles, 2011. Many other countries have introduced similar measures, see http://en.wikipedia.org/wiki/Government_incentives_for_

plug-in_electric_vehicles (last accessed 30 January 2013).
92 Hall and Hass-Klau, 1985. See also Bauer et al 2006; Dresdner Verkehrbetriebe AG, 2011.
93 Wright, 2010. See also Chapter 3 above.
94 See the section above on 'Motorization and oil dependence'.
95 Including increases due to the 'rebound effect', which implies that environmental policies do not achieve all of their stated aims, as people tend to travel more if they think that they are doing it more efficiently (Herring and Sorrell, 2008).
96 ADB, 2010a.
97 See the section below on 'Funding Mechanisms for Environmentally Sustainable Urban Mobility Systems'.
98 Schipper, 2011.
99 UNEP, 2009.
100 The average age of all motor vehicles in Brazil in 2010 was 8.7 years (Kliment, 2011), comparable to countries such as Switzerland: 8.2 years (Federal Statistical Office, Switzerland, 2012); and the Netherlands, 8.6 years (Central Bureau of Statistics, Netherlands).
101 UNEP, 2009, p17.
102 Huzayyin and Salem, 2013. Personal communication with Professor Ali Huzzayin, Cairo University, Egypt, March 2013.
103 Davis and Kahn, 2011.
104 Kenya Revenue Authority, undated.
105 UNEP, 2009.
106 UNEP, 2009.
107 See also the section on 'Alternative fuels' below.
108 Gallagher, 2012.
109 The 13 cities are Delhi, Mumbai, Kolkata, Chennai, Bangalore, Hyderabad, Ahmedabad, Pune, Surat, Kanpur, Agra, Lucknow and Sholapur.
110 ACFA, 2010.
111 Often more than 5000 parts per million.
112 i.e. 50 parts per million and less.
113 UNEP, 2007b, p8.
114 i.e. 500 parts per million and less.
115 UNEP, 2007b, p9.
116 The Obama administration in the US is suggesting a fuel-economy standard of 23 kilometres per litre average for an automaker's whole fleet by 2025, boosting the price of a new vehicle by at least US$2100 (Healey, 2011).
117 See DieselNet, 2012a and 2012b.
118 Regional Environmental Centre for the Caucasus, 2008.
119 An et al, 2011.
120 See also the previous section on 'Efficiency and age of the vehicle stock'.
121 Bleviss et al, 1996.
122 Banister, 1998.
123 See the section on 'Motorization and oil dependence' above.
124 EC, 2011.
125 The potential of biofuels may improve, subject to the successful development of 'second generation biofuels' – which seek to utilize local 'biomass consisting of the residual non-food parts of current crops, such as stems, leaves and husks that are left behind once the food crop has been extracted, as well as . . . non food crops' (http://en.wikipedia.org/wiki/Second_generation_biofuels, last accessed 6 February 2013).
126 Evenson, 2004.
127 A hybrid electric vehicle is a vehicle that uses both an electric motor and a petrol engine to power the vehicle. A plug-in hybrid electric vehicle is a hybrid electric vehicle that is capable of storing energy from the grid in onboard batteries.
128 The conventional approach has been to look at energy use and emissions from a 'tank-to-wheels' perspective only, i.e. only the energy used and the carbon emissions produced from the use of the vehicle itself (i.e. the petrol or the electricity from the onboard battery). A lifecycle approach implies a 'well-to-wheels' approach, i.e. all energy used and carbon emissions produced from the source of the energy to the final user (Graham and Reedman, 2010).
129 Liu, 2012.
130 Banister and Liu, 2011 (RMB60,000).
131 Transport for London, undated b.
132 Ministry of Transport, Ontario, 2007. For an overview of some cities that have introduced high-occupancy vehicle lanes, see http://en.wikipedia.org/wiki/High-occupancy_vehicle_lane, last accessed 30 January 2013.
133 De Vries et al, 2010.
134 Debra Roberts during the eighth meeting of the HS-Net Advisory Board, 20 November 2012.
135 Givoni et al, 2013.
136 See the section above on 'Alternative fuels'.
137 See the section above on 'Occupancy (load) factors'.
138 Banister and Marshall, 2000.
139 GlaxoSmithKline, 2012.
140 These 28 projects were categorized as follows: BRT (13 projects); motorbikes (4 projects); modal shift from road to rail (7 projects); more efficient vehicles (1 project); regenerative braking for railways (i.e. that the kinetic energy from braking is recovered and later reused) (1 project); biodiesel for transport (1 project); and cable cars (1 project) (UNEP Risø Centre, 2013).
141 UNEP Risø Centre, 2013.
142 See UN-Habitat, 2011, p20.
143 'National appropriate mitigation actions' (NAMAs) are a set of actions and policies that can be undertaken by countries as part of a commitment to reduce greenhouse gas emissions.
144 Under GEF, by 2011, there had been 45 'sustainable transport and urban systems' projects funded over 20 years, accounting for 6 per cent of total projects (GEF, 2011, p5). Within the country programmes, the Clean Technology Fund has allocated about 14 per cent of investment to transport, as of December 2011 (CIF, 2011, p14).
145 See World Bank, 2005.
146 Bertaud et al, 2009.
147 ADB, 2010a.
148 'The credits will give a value to the fuel security benefit arising from improvements in fuel consumption. Trading in the credits could help developing countries to access additional funds to carry out policies and technologies that may not otherwise meet investment requirements from a traditional cost–benefit analysis . . . Accounting for fuel consumption is far easier than accounting for greenhouse gas emissions . . . and, as with carbon emissions, reducing a tonne of oil-equivalent is less costly in Asia than in Europe or North America' (IntellAsia.Net, 2011).
149 UN, 2012b, p7.
150 See, for example, the discussions of the United Nations High-level Panel on Financing for Development and the Leading Group on Innovative Financing for Development (UN, 2012b).