Technologies for Climate Change Mitigation - Transport Sector

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Technologies for Climate Change Mitigation

– Transport Sector –

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ENERGY, CLIMATE AND SUSTAINABLE DEVELOPMENT

Technologies for Climate Change Mitigation

– Transport Sector –

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Abbreviations

ASEAN	Association of Southeast Asian Nations
BRT	Bus Rapid Transit
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CUSP	Curtin University Sustainability Policy Institute
DAT	Development Assisted Transit
DME	Di-methyl Ether
EJ	Exa-joules
EV	Electric Vehicles
FFC	Full Fuel Cycle
GHG	Green House Gas
GJ	Giga-joules
IPCC	Intergovernmental Panel on Climate Change
LPG	Liquefied Petroleum Gas
MJ	Mega-joules
NGO	Non Governmental Organisation
NOx	Oxides of Nitrogen
OECD	Organisation for Economic Cooperation and Development
p km	Passenger kilometre
PUC	Pollution Under Control
SPM	Suspended Particulate Matter
TOD	Transit Oriented Development
UITP	International Association of Public Transport
UNEP	United Nations Environment Programme
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
VOC's	Volatile Organic Compounds
WBCSD	World Business Council for Sustainable Development

Preface

When it comes to carbon dioxide emissions, the transport sector is a heavyweight. In 2006, transport contributed 23 percent of global CO_2 emissions, and substantial increases are projected, particularly in developing countries. Due to the sector's complex nature, policy makers in developing countries face some exceptionally difficult challenges. For one, infrastructure development and soft technologies can be as effective as hard technologies for curbing transport sector emissions, if not more so. Also, up until now transport has not received as much attention as other sectors, like energy, and therefore relevant technical information is hard to find in the public domain. This information gap makes it that much more difficult to develop meaningful mitigation planning.

Many of the countries participating in the Technology Needs Assessment project have identified transport sector for mitigation efforts. This guidebook is intended to help countries achieve that goal. Measures explored in this book show that it is possible for transport systems to meet both people's and the environment's needs, without sacrificing one for the other.

A broad range of transport options are covered this book, including rural, urban, motorised and non-motorised transportation, and a wide variety of applicable emissions-reducing policies and measures are explored. The guidebook proposes cycling and mass transit approaches, as well as ideas for improving motorised transport technologies. Newer developments, like high-density, mixed-use schemes built around rail nodes, or rapid bus service are also examined in detail.

The guidebook is divided into five chapters, each supplemented with a rich list of references. Our hope is that this comprehensive approach has resulted in a valuable tool for policy makers and transport planners, as well as anyone else interested in the topic.

A number of internationally recognized experts addressed the wide-ranging issues and options discussed in this guidebook, and their names and affiliations are noted in relevant chapters. These experts provided invaluable comments and suggestions and their contributions are greatly appreciated.

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We greatly appreciate the contributions made by the authors of a number of the sections in Chapter 3, most of whom did this work on a *pro bono* basis. They are named at the start of their sections. As well, the three reviewers of the guidebook's first draft, Todd Litman, Dario Hidalgo and Jorge Rogat, made many useful suggestions which have helped us, we hope, to improve the manuscript.

Finally, we are grateful to UNEP Risoe Centre, for bringing out this guidebook.

Editors
Robert Salter
Subash Dhar
Peter Newman

Executive Summary

The options outlined in this guidebook are designed to assist you in the process of developing transport services and facilities in your countries and localities – transport that better serves people's needs and enhances their lives while at the same time producing fewer greenhouse gas emissions. This is a new challenge, as previously improving transport generally led to increased greenhouse gases.

The challenge now is to provide transport that:

- is cheaper, more extensive and better quality
- reduces pollution, congestion, traffic accidents and other threats to health and wellbeing
- is accessible to all
- supports economic development
- reduces greenhouse emissions overall.

This can be achieved if:

- mass transit, walking and cycling are supported and encouraged, and integrated in a way that allows seamless multimodal travel, including networks of taxis, auto-rickshaws and small buses.
- the mass transit services – including trains, buses and light-rail – are frequent, extensive, attractive, comfortable, affordable and faster than alternatives, with features like integrated ticketing and real time information accessible through mobile phones and other sources
- private vehicle use and air travel are discouraged through pricing and other demand management measures, and through the availability of better alternative modes
- there is support for the adoption of cleaner, lower carbon fuels and technologies and better maintenance practices for all transport modes, including private vehicles, water transport, auto-rickshaws and freight vehicles
- the overall need for travel is reduced through the development of denser localities with more mixed land use and better access to mass transit (which reduces overall travel in ways that will be explained)
- travel space is better managed to give higher priority to more sustainable transport modes, to promote safety, and to prevent traffic from adversely affecting residents and businesses.

As you address these issues, the Guidebook can help you by:

- providing data on energy use and greenhouse gas emissions for different transport modes in different parts of the world, and showing how to calculate greenhouse savings from various policy options
- setting out in some detail fifteen sets of technologies and practices to better meet people's transport needs while reducing greenhouse emissions

- describing how these technologies and practices can be implemented, with attention to planning, local research, consultation, governance, ownership, capacity-building and funding (from both traditional and new carbon-related funding sources)
- providing additional sources of information to enable detailed follow up.

Through consideration of these measures you will be better equipped to address the challenges of making your country's transport both more low carbon and more able to serve people's needs.

1. Introduction and Outline

This guidebook is designed to assist you as you contribute to the development of transport in your country or locality. It provides transport options that not only minimise greenhouse gas emissions, but also offer a host of other economic, social and environmental benefits, of which the following are some.

In terms of economic benefits, these options can:

- save money spent on transport by both individuals and society
- save time
- reduce dependence on imported fossil fuels
- reduce health costs and absenteeism resulting from traffic accidents and illness caused by vehicle pollution and lack of exercise
- provide better transport for all levels and sectors of society, so that all people can access jobs, markets, services and education, and thereby participate economically
- contribute to urban consolidation and reduce costs for the provision of urban infrastructure
- provide the transport necessary for effective and efficient twenty-first century economies.

In terms of social benefits, these measures can:

- reduce traffic congestion and noise and make localities more attractive and pleasant places in which to live and work
- promote better physical and mental health by encouraging and enabling people to exercise more, by reducing road accidents and respiratory diseases caused by pollution, and by creating a less stressful environment
- contribute to greater equality by ensuring that all levels of society have access to the necessary transport to meet their needs
- enhance community connectedness by promoting transport modes that have been shown to increase local interaction.

In terms of environmental benefits, as well as reducing greenhouse gas emissions, these transport options can:

- reduce local level pollution
- lessen urban sprawl
- reduce overall fuel use and in particular the use of unsustainable fuels
- decrease the use of other finite resources.

Transport is central to the life of a society. It gets people to jobs and schools, to shops and health services. It moves farm produce to markets, raw materials to factories, office supplies to businesses and merchandise to shops. It brings together family and friends to socialise and help one another. The options described in this guidebook can enable the transport systems of developing countries to play their part in the attainment

of national goals: to develop economies, to create jobs, to reduce poverty and inequality, to produce more food, to improve health and education, and in general to ensure that citizens can live healthy and satisfying lives.

Box 1.1: What's in a name?

There is no entirely satisfactory way of referring to the two main categories of nations in the world. One is referred to as the developing world, the Third World or the South, to name just some expressions, while terms to describe the other include the developed world, the industrialised world, and the North. We have chosen to use the terms developing and developed to refer to these two groups of nations, mainly because these are the most commonly used terms. But we have done so not without misgivings, because they imply that the developed world has attained a state of development that developing countries are heading towards, when in fact all nations need to develop towards something better and more sustainable. So our use of these terms should be understood in this context.

At the same time, ensuring that transport is sustainable is a key challenge faced by the whole world. In particular, we need to make sure that carbon dioxide and other greenhouse gases in the atmosphere are reduced, so that humans and other species can have viable lives on this planet into the future[1], and emissions from transport comprise 23% of global energy-related carbon dioxide emissions.[2] Recent reports are now suggesting that, unless greenhouse emissions are greatly reduced, up to a billion people could lose their homes before the end of the century.[3] This cannot be allowed to happen. Both developed and developing countries need to act, but the developed world has been responsible for most of the greenhouse emissions generated so far, and it is recognising that it therefore has a responsibility to fund emission-reduction measures in the developing world. A number of funding mechanisms now enable this to occur.

A range of policy options

This guidebook enables you to choose the technologies and practices that best suit the conditions of your country or locality. The options it presents cover the many different kinds, modes and purposes of transport within different locations, including:

- urban and rural transport
- short and long trips
- transport of passengers and goods
- land, water and air transport
- individual and mass transport
- motorised and non-motorised forms of transport
- low and high technology transport.

The guidebook describes a range of measures through which transport can meet people's needs while being low-carbon at the same time. In broad terms, these measures address how you can:

- develop high quality, sustainable transport modes – mass transit modes such as trains, buses and light-rail, as well as cycling and walking facilities, and water transport where appropriate

- assist people to reduce their need for transport overall, and especially for private motorised transport, through the development of communities that have denser, more mixed land use and are close to well-integrated transit, walking and cycling routes
- further reduce the use of private vehicles through pricing and other demand management measures
- support the development and use of more efficient and lower carbon technologies and fuels for private vehicles
- ensure that vehicles using conventional technologies are in reasonable operating condition
- implement realistic strategies that reduce carbon emissions while ensuring good transport provision in the areas of air transport, auto-rickshaws, and the different freight modes
- manage travel space in a way that gives fair and safe access to all transport modes, that gives priority to the most sustainable ones, and that avoids adverse effects on residents
- in general terms, work towards a situation in which all sections of society have access to affordable, efficient, sustainable, good quality transport options that enable them to meet their needs.

In recent years there has been a dramatic increases in the number of urban metros in China, India and the Middle East, yet such technologies were once considered to be just for wealthy Western cities. At the same time many wealthy cities have turned to the bicycle to rescue them from excessive car use. More and more, there are not developed world solutions and developing world solutions to the challenge of providing effective, sustainable transport but, rather, universal solutions. Environmental, social and economic imperatives the world over require us to shift to mass transit, walking and cycling, to electric and other more sustainable private vehicle technologies, and to denser, more mixed-use localities. But different countries and regions are moving to these solutions from different pre-existing sets of circumstances. The developed world, for example, needs to overcome its car dependence, its low urban densities and highly segregated land use patterns. The developing world, on the other hand, tends to already have denser, more mixed-use urban areas, less car dependence, and greater use of public transport, so in many ways its transport is more sustainable to begin with. However, it often faces significant problems of traffic congestion, air pollution and inadequate provision and quality of transport infrastructure and services.

Some questions to consider

While there can be broad similarities, each country's solutions will be somewhat different, with the differences determined not only by existing circumstances, but also by that country's future needs and preferences. Thus, this guidebook gives you options, so that you can select the transport modes, technologies and practices that best suit the circumstances and needs of your locality. In order to select from these options, you may want to consider the following questions:

- What additional transport developments does your country or locality need? Which localities and regions most require additional transport? Which sections of society require it? Which modes of transport are lacking? How well serviced are rural areas?
- Aside from reductions in greenhouse gas emissions, in what ways would transport and related improvements benefit people in your locality or nation? By providing faster services? Less expensive services? Services in new areas? By reducing local pollution or traffic congestion? If you are clear about this then you know where the emphasis should be in the design and promotion of services.
- What forms of transport are feasible in light of particular urban features, for example, the density of cities, or space available for train lines or bus rapid transit (BRT) lanes?

- What geographical features have an impact on transport modes and routes, for example, the presence of waterways, or the environmental vulnerability of certain areas?
- What costs of new transport modes will be borne by government? By business? By transport users? Are these costs affordable for the different stakeholders? What sources of funds are available to help meet these costs?
- What has worked well in other parts of the country? In other countries with similar conditions?
- How possible and important, is it to locally manufacture vehicles and vessels, or to locally maintain them?

You also need to consider questions about the best technologies to adopt, and how quickly you should do so. Should your country 'leapfrog' to the most technologically advanced solutions, which may be more expensive, or opt for cheaper, more established technologies? Are their emerging technologies that have immediate application? Should you focus exclusively on moving large numbers of people efficiently, via mass transit, or give some attention to supporting the development of sustainable private vehicles, which also offer flexibility? Should you support the development of particular engine technologies and energy sources and, if so, which ones? Some offer greater travel range, while others offer greater energy efficiency. Particular fuels are more available in some countries than in others. Should you favour local technology solutions or more globally available solutions? How can government encourage people to shift to low carbon transport options?

Thus, in addressing these sorts of questions and selecting the most appropriate solutions, your country or locality will arrive at its own unique mix of transport modes, technologies and practices.

Focusing on what you can do and need to do

This guidebook focuses on things that you and other leaders actually have the capacity to do in order to improve transport provision and reduce transport greenhouse gas emissions. For example, in the section of Chapter Three on domestic air transport, it does not focus on improvements to aircraft engine technology and aerodynamics, because these are not things that most countries have much control over. Rather, it focuses on the provision of alternatives to domestic air flights, on changes to airports to make them more energy efficient, and on the provision of public transport to and from airports. These are all measures that your nation or city has the capacity to implement.

The guidebook provides solutions not only for today's transport problems in the developing world, but also for possible problems in the future. For example, excessive car use may not be, today, the issue in developing countries that it is in developed ones, but increasing economic growth in many parts of the developing world is driving up private vehicle demand and posing real challenges for the future. Unless countervailing measures are taken, increasing numbers of cars will worsen problems of congestion, noise, safety, air pollution and greenhouse emissions as well as making cities unattractive to investors and thus driving development elsewhere. Thus, the guidebook contains a range of measures such as car-pooling, car-sharing, behaviour change programs, congestion taxes, and transit oriented developments – measures that may not be commonly applied in developing countries at the moment, but will be increasingly needed to stem the anticipated growth of private vehicle use.

The challenge to improve transport systems very often involves changes in technology, but appropriate transport solutions do not always mean adopting the very latest technology. They may involve continued, expanded or revived use of existing, even traditional, technologies. China has recently initiated the world's fastest train service between Hangzhou and Shanghai, while the town of Castelbuono in Sicily has started using donkeys in its narrow streets to collect garbage. Both are appropriate, efficient, sustainable transport

solutions, meeting a need within a particular set of circumstances. We don't have to assume that the new must always be better than and replace the old. In this guidebook transport modes like walking, cycling and the use of simple boats are advocated as highly desirable forms of transport in many situations. Another existing, fairly low-technology transport solution, the use of auto-rickshaws as urban taxis, is given attention because its existence has been threatened in recent years, and yet it has the potential, if properly regulated and uses cleaner – even electric – technology, to provide a flexible, low-cost, relatively sustainable form of passenger transport in urban areas, especially if integrated into a network that supports mass transit.

There is an emphasis in the guidebook on urban transport, but this reflects the complexity of transport challenges in urban settings rather than any idea that rural transport is less important. On the contrary, adequate transport in rural areas, where most residents of developing nations still live, is perhaps more vital because of the potential for rural populations to be isolated from jobs, education, health and other services, markets and sources of household, farming and small business supplies. The guidebook therefore gives some attention to specific rural transport needs and how they can be met, for example, in the Chapter Three sections on Mass transit and Water transport.

It is one thing to favour the adoption of particular transport technologies and practices, but quite another to actually implement them. This requires finance, research, planning, capacity building, coordination between different sections of government, and management of the implementation and operation of the particular transport initiative. The guidebook deals with these matters as well.

What's in the chapters that follow

The remaining chapters of this guidebook cover the following areas.

Chapter Two provides information on the energy use and greenhouse gas emissions of the various transport modes, looking at differences in regions, nations and cities across the developing and developed worlds, and at the emission reductions that can be achieved by adopting particular technologies, practices and modes.

Chapter Three is the largest chapter in the book. It contains fifteen sections, each focusing on a particular transport mode, group of modes, or set of practices that can bring about more low-carbon outcomes while improving transport services. The sections have been grouped in the following way:

- **Sections A-D** – Increasing use of low carbon modes: In this group are the most sustainable modes of transport – walking, cycling and mass transit (trains, buses and light-rail). Three sections describe how these modes can be developed and made more efficient, pleasant and sustainable, and better integrated with other modes. A further section in this group deals with how travellers can be encouraged and assisted to move toward mass transit options through information provision, integrated ticketing systems, and behaviour change programs.
- **Sections E-F** – Reducing overall travel: Two sections describe how the number and length of trips people take can be reduced. One of these deals with transit oriented developments – which are new high-density, mixed-use developments built around rail nodes, often with rapid bus services as well. The other section describes how such an approach can be adopted on a broader scale to reduce the amount of travel people do: through changes to urban areas so that they are denser, with more mixed land use and greater self sufficiency; through increased mass transit, walking and cycling, which also reduce overall travel; and through increased use of information and communications technology in place of trips.

- **Sections G-L** – Making current modes more low carbon: Six sections describe how modes of transport that currently generate significant greenhouse gas emissions can produce fewer emissions through reduced use, better technology, improved operating standards, and better traffic management. These modes include cars, trucks, motorbikes, motor scooters and three-wheeler taxis. There are separate sections for private vehicle demand management, improved vehicle operating standards, traffic management, electric vehicles, vehicle technologies and fuels more generally, and motorised three-wheeler taxis.
- **Section M –** Moving goods: Another section deals with freight transport, and gives particular attention to rail and water-based freight, to multimodal freight trips, to logistics technology for managing vehicle movements, and to non-motorised freight for smaller, more localised deliveries.
- **Sections N-O –** Lower carbon air and water transport: The two final sections move away from land-based transport to cover air and water transport. Air transport is a global issue, but steps can be taken locally to reduce the number of air trips and to reduce greenhouse gas emissions associated with air transport, including those generated at airports and on trips to and from airports. Water transport is under-recognised, but is vitally important for many regions and sectors of society. The section presents a range of ways of making it more sustainable, more efficient, and more able to meet social and economic needs, whether transporting passengers or goods.

Chapter Four then looks at how these transport solutions can be implemented: at sources of finance, including new funds derived from a price on carbon; at the roles of government, business and the community sector; at the need for integrated approaches, and for capacity building in order to introduce, operate, maintain and administer particular transport modes and technologies; and at how planning, local research, public consultation, piloting of new solutions, legislation, enforcement, promotion, education, and periodic review can all enhance the effectiveness of transport solutions.

Finally, **Chapter Five** reiterates how the different elements of change – the technologies, practices, planning and governance mechanisms and other measures – all fit together to enable your country or locality to adopt low carbon transport that better meets people's needs.

Effective, low-carbon transport solutions for developing countries is a large, complex subject, and this guidebook cannot possibly provide more than a fraction of the necessary ideas and information. That is why there are many suggested further readings – mostly available online – and much of this material is produced by, or describes, organisations that you can make contact with to find out more. UNEP also collaborates with UNDP for an online site that you can read and contribute to: http://climatetechwiki.org/.

The provision of effective, low-carbon transport for all is a critical task in the twenty-first century. But all the solutions exist somewhere in the world. The transport modes exist. The engine and fuel technologies exist. The urban designs exist. The systems for smoothly integrating transport modes exist. Ways of persuading travellers to adopt more sustainable transport modes exist. Mechanisms for financing new forms of transport and for building local capacity to install, maintain and operate them exist. The challenge is to learn from these existing examples and to adapt them to suit local circumstances and needs. May the guidebook help you in meeting this challenge.

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1 Climate change is now considered irreversible, but we can avoid the situation becoming much worse. See http://www.noaanews.noaa.gov/stories2009/20090126_climate.html

2 IPCC (2007) Climate Change 2007: Mitigation of Climate Change, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate, Cambridge University Press, Cambridge, see 'Transport and its infrastructure'.

3 M New, 'Four Degrees and Beyond', papers from Tyndall Centre for Climate Change Research, Oxford University, 2010

2. Evaluating the Transport Sector's Contribution to Greenhouse Gas Emissions and Energy Consumption

Peter Newman* and Jeff Kenworthy**

The transport sector accounts for 22 per cent of global energy use.[1] Passenger transport accounts for about two thirds of energy usage, with freight accounting for roughly one third[2] (Table 2.1).

Table 2.1: World transport energy use by mode

Sr. No.	Mode	Energy use (EJ)	Share
A	**Road**	**59.40**	**77.3%**
i)	***Passenger Transport***		
	Cars	34.20	44.5%
	Buses	4.76	6.2%
	Other (motorbikes, rickshaws, etc.)	1.20	1.6%
ii)	***Freight***		
	Heavy trucks	12.48	16.2%
	Medium trucks	6.77	8.8%
B	**Rail - passenger & freight transport**	**1.19**	**1.5%**
C	**Air - passenger transport**	**8.95**	**11.6%**
D	**Shipping - freight transport**	**7.32**	**9.5%**
	Total	**76.85**	**100.0%**

Source: Based on data from World Business Council for Sustainable Development, Mobility 2030 Report: Meeting the Challenges to Sustainability, WBCSD, 2004.

Virtually all energy for transport comes from petroleum based fuels.[3] According to the Intergovernmental Panel on Climate Change (IPCC) in 2004, the global transport sector was responsible for 23 per cent of world energy-related CO_2 emissions.[4] Hence reducing these emissions from transport must be an important part of climate change mitigation programs both at local and national levels. According to the 2007 IPCC Fourth Assessment Report, the growth rate of greenhouse gas emissions in the transport sector is the highest among all the energy end-user sectors.[5]

There has been exponential growth in private car ownership, with the 200 million cars in operation in 1970 reaching 850 million in 2006,[6] and much of the pressure of this growth is being felt by cities.[7] The growth in cars is faster in developing countries where growing per capita incomes are boosting car ownership.

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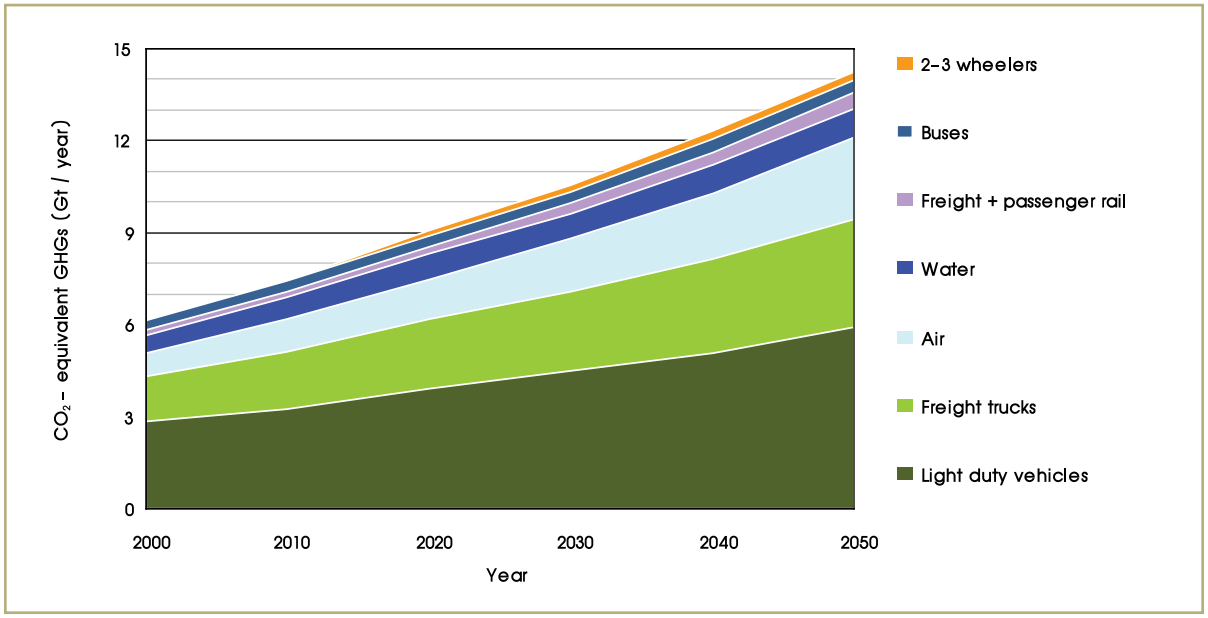
Despite significant advances in energy productivity, current rates of energy reduction for various transport modes, such as cars and aeroplanes,[8] are not keeping pace with the rapid growth of these modes. As can be seen in Figure 2.1, in 2001 cars (light duty vehicles) and freight trucks accounted for the majority of total transport CO_2 emissions, some 74 per cent, with air travel close behind.[9] Hence, both at local and national levels, strategies to reduce the environmental impact from the transport sector will need to include a strong focus on both light duty vehicles and trucks.

Figure 2.1: Transport-related well-to-wheels CO_2 emissions



Source: Based on data from World Business Council for Sustainable Development, Mobility 2030 Report: Meeting the Challenges to Sustainability, WCBSD, 2004.

However, recent studies suggest that the challenge of reducing private vehicle use may not be quite as great as this data would indicate. The numbers of cars manufactured worldwide dropped from 69 million units in 2007 to 59 million in 2009.[10] There have also been reductions in car use per capita and rapid increases in transit in many cities across eight industrial countries, especially the US and Australia which have traditionally been the most car dependent and car using.[11] This research also suggests that there may be serious limits to private vehicle growth due to the sheer lack of space in developing city streets.

Notwithstanding these hopeful signs, it is still vitally important to reverse the growth in transport-related greenhouse gas emissions in a way that is cost-effective and at the same time supports community needs and aspirations, and the Guidebook sets out to assist in this process. Achieving such reductions will require transport agencies to estimate the greenhouse gas savings that can be anticipated from each suggested measure. Box 2.1 sets out the basic steps in calculating greenhouse emissions from energy.[12] The rest of this chapter helps to show how to estimate greenhouse savings, and the broad factors that are involved in addressing these transport issues.

BOX 2.1 Basic data for calculating greenhouse gases – CO_2 (e) – from transport

To estimate the greenhouses gases from transport it is necessary to have good transport data, which is sometimes unavailable. Basic surveys of car users and data from public transport operators needs to be supplemented by data on the operations of other transport modes such as auto-rickshaws, motor-bikes, push-bikes and pedestrians. Information about vehicle fuel use by mode can be obtained from energy statistics (e.g., from oil companies who usually disaggregate data for cities and rural areas) or it can be assessed and calculated from transport data. To convert transport energy to transport greenhouse gas emissions involves using conversion factors that are provided for fuels and electricity by the Intergovernmental Panel on Climate Change (IPCC). However, the variations in fuels for electricity mean significant variations in greenhouse gases. Table 2.2 below sets out CO_2 emissions for different modal values calculated for 46 different cities based on real transport data. Table 2.3 shows the variations in conversion factors for different places.

Table 2.2: Conversion of energy to CO_2 (eq) for each mode in a study of 46 global cities

Transport Mode (fuel)	Measured Average Vehicle Efficiency (MJ/km)	Measured Average Vehicle Occupancy (passengers)	Average Fuel Efficiency: MJ/pass km	CO_2 (eq): g/pass-km
	X	Y	A = X/Y	= A x Emission co-efficient
Car (Petrol)	4.51	1.48	3.05	219.6
Bus (Diesel)	20.89	12.74	1.64	118.1
Heavy Rail (electric)	13.62	30.96	0.44	2.6 – 182.2
Heavy Rail (diesel)	40.23	27.97	1.44	103.7
Light Rail/Tram (electric)	20.62	26.06	0.79	4.7 – 327.1

Source: Jeffrey R Kenworthy & Felix B Laube, An International Sourcebook of Automobile Dependence in Cities 1960-1990, University Press of Colorado, Boulder, 1999.

CO_2 Emission Conversion Factors: petrol/diesel 72 g/MJ; for electricity use the low and high values from table 2.3.

Note: occupancies are for 24 hour car, bus and train use, not peak, which is higher in transit and lower in cars. Rail is per wagon and not per train.

Table 2.3: CO_2 emissions per megajoule of traction energy (1990)

Fuel/Grid	CO_2 emissions g/MJ	Fuel/Grid	CO_2 emissions g/MJ	Fuel/Grid	CO_2 emissions g/MJ
Petrol, Diesel	72	Malaysia	241	Sweden	11
LPG	65	Philippines	164	Switzerland	6
Electricity:	6 – 414	Singapore	292	UK	230
Canada	66	Thailand	260	Australia (WA)	282
USA	206	Austria	104	Aust. (NSW)	265
China	232	Belgium	110	Aust. (Vic)	414
Hong Kong	292	Denmark	278	Aust. (Qld)	287
Indonesia	231	France	36	Aust. (SA)	253
Japan	190	Germany (W)	184		
South Korea	146	Netherlands	195		

Source: Jeffrey R Kenworthy & Felix B Laube, An International Sourcebook of Automobile Dependence in Cities 1960-1990, University Press of Colorado, Boulder, 1999.

Note: The factors in Australia primarily vary because of the vast differences in the quality of the coal in each State. The cities researched for this table are: Adelaide, Brisbane, Canberra, Melbourne, Perth, Sydney, Boston, Chicago, Denver, Detroit, Houston, Los Angeles, New York, Phoenix, Portland, Sacramento, San Diego, San Francisco, Washington, Calgary, Edmonton, Montreal, Ottawa, Toronto, Vancouver, Winnipeg, Amsterdam, Brussels, Copenhagen, Frankfurt am Main, Hamburg, London, Munich, Paris, Stockholm, Vienna, Zurich, Hong Kong, Singapore, Tokyo, Bangkok, Jakarta, Kuala Lumpur, Manila, Seoul and Surabaya.

How do cities vary in their transport greenhouse emissions?

There is enormous variation in levels of transport fuel consumption and emissions across the world's cities. Unless otherwise stated, the data in this chapter are drawn from the Millennium Cities Database for Sustainable Transport compiled over three years by Kenworthy and Laube (2001) for the International Union of Public Transport (UITP) in Brussels. The database provides data on 100 cities on all continents. Data summarised here represent averages from 84 of these fully completed cities in the USA, Australia and New Zealand, Canada, Western Europe, Asia (high and low income areas), Eastern Europe, the Middle East, Latin America, Africa and China.[13]

Figure 2.2 below shows how the greenhouse gas emissions from passenger transport vary across cities in developed and developing countries. US cities top the list with 4000 to 7500 g of CO_2 per person while the cities in developing countries come at the bottom with less than 50 g of CO_2 per person. In order to see more clearly how this varies, the data are sorted into regional groupings of cities in Tables 2.4 and 2.5, and are discussed further in these groups in sections below.

Figure 2.2: Per capita emissions of CO_2 from passenger transport in 84 cities (private and public transport)

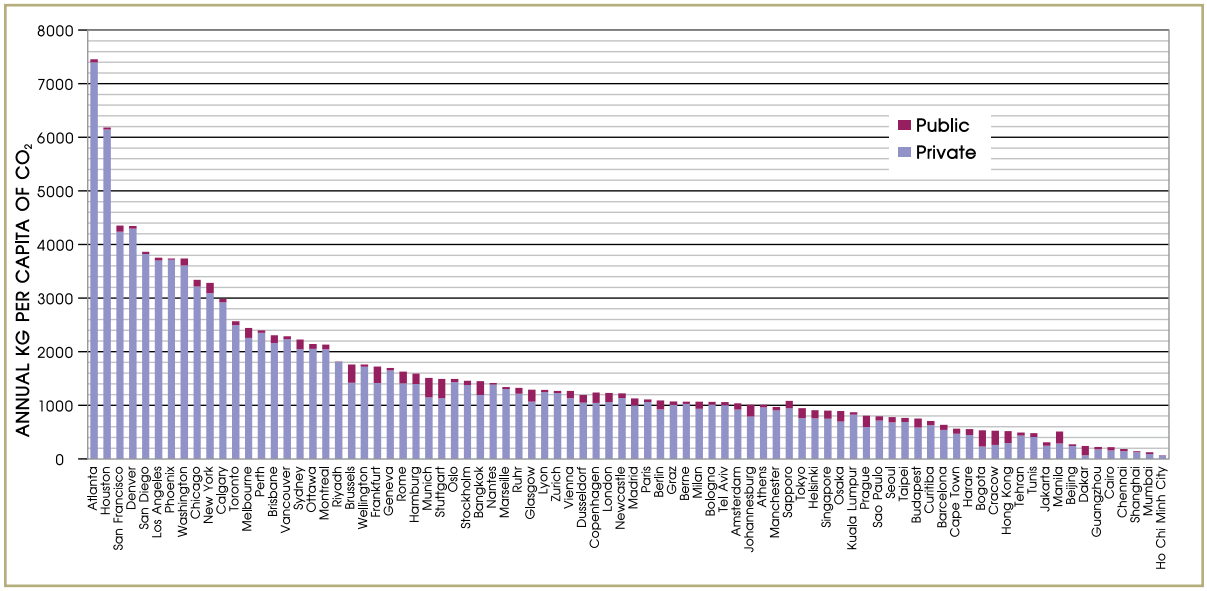


Table 2.4: Greenhouse gas emissions from transport per capita in low income cities

Greenhouse Indicators	Unit	EEU	MEA	LAM	AFR	LIA	CHN
Total passenger transport CO_2 emissions per capita	kg/ person	694	812	678	592	509	213
Total private transport CO_2 emissions per capita	kg/ person	480	761	524	443	441	180
Total public transport CO_2 emissions per capita	kg/ person	214	51	154	149	96	33
Percentage of total passenger transport CO_2 emissions from public transport	%	30.8	6.2	22.7	25.2	18.8	15.5

Key to abbreviations: EEU Eastern Europe; MEA Middle East; LAM Latin America; AFR Africa: LIA Low Income Asia; CHN China.

Table 2.5: Greenhouse gas emissions from transport per capita in high income cities

Greenhouse Indicators	Unit	USA	ANZ	CAN	WEU	HIA
Total passenger transport CO_2 emissions per capita	kg/ person	4,405	2,226	2,422	1,269	825
Total private transport CO_2 emissions per capita	kg/ person	4,322	2,107	2,348	1,133	688
Total public transport CO_2 emissions per capita	kg/ person	83	119	74	134	162
Percentage of total passenger transport CO_2 emissions from public transport	%	1.9	5.3	3.1	10.6	19.7

Key to abbreviations: USA United States; ANZ Australia and New Zealand; CAN Canada; WEU Western Europe; HIA High Income Asia.

How does transport greenhouse vary by mode?

Greenhouse gas is emitted from transport through the burning of fossil fuel energy so the analysis below is all about how these fuel patterns vary and why. Each city has a different set of conditions that impact on the final emissions – from the source of fuel used to make electricity to the technologies used for private transport and the number of people per private or public vehicle. These variations can also be seen across the various city types as set out above and detailed in Tables 2.6 and 2.7.

Table 2.6: Energy efficiency by mode in low income cities (in MJ/p km)

Transport Energy Indicators	EEU	MEA	LAM	AFR	LIA	CHN
Energy use per private passenger vehicle km	2.35	2.56	2.27	1.86	1.78	1.69
Energy use per public transport passenger km	0.40	0.67	0.76	0.51	0.64	0.28
Energy use per bus passenger km	0.56	0.74	0.75	0.57	0.66	0.26
Energy use per tram passenger km	0.74	0.13	-	-	-	-
Energy use per light rail passenger km	1.71	0.20	-	-	0.05	-
Energy use per metro passenger km	0.21	-	0.19	-	0.46	0.05
Energy use per suburban rail passenger km	0.18	0.56	0.15	0.49	0.25	-
Energy use per ferry passenger km	4.87	2.32	-	-	2.34	4.90

Source: J Kenworthy, 'Energy Use and CO_2 Production in the Urban Passenger Transport Systems of 84 International Cities: Findings and Policy Implications', in P Droege (ed), Urban Energy Transition, Ch 9, pp 211-236, Elsevier, 2008.

Table 2.7. Energy efficiency by mode in high income cities (in MJ/p km)

Transport Energy Indicators	USA	ANZ	CAN	WEU	HIA
Energy use per private passenger vehicle km	4.6	3.9	5.0	3.3	3.3
Energy use per public passenger vehicle km	26.3	14.9	22.0	14.7	14.4
Energy use per bus passenger km	2.85	1.66	1.50	1.17	0.84
Energy use per tram passenger km	0.99	0.36	0.31	0.72	0.36
Energy use per light rail passenger km	0.67	-	0.25	0.69	0.34
Energy use per metro passenger km	1.65	-	0.49	0.48	0.19
Energy use per suburban rail passenger km	1.39	0.53	1.31	0.96	0.24
Energy use per ferry passenger km	5.41	2.49	3.62	5.66	3.64

Source: J Kenworthy, 'Energy Use and CO_2 Production in the Urban Passenger Transport Systems of 84 International Cities: Findings and Policy Implications', in P Droege (ed), Urban Energy Transition, Ch 9, pp 211-236, Elsevier, 2008.

In general,[14] mass transit modes are less greenhouse emitting than private modes such as cars and motorcycles. Energy consumed per passenger km in public transport in all cities is between one-fifth and one-third that of private transport, the only exception being in the US cities where large buses dominate public transport and only manage to pick up thinly spread passengers in suburbs designed principally around the car. In US cities, public transport energy use per passenger kilometre is 65% that of cars, and public transport vehicles there have the highest use of energy per vehicle kilometre of all cities (26 MJ/km, with most other regions under about 16 to 17 MJ/km, or as low as10 MJ/km in African cities).

Examining the overall modal energy consumption of motorised transport in cities (private and public transport combined), as shown in Tables 2.6 & 2.7, Canadian cities are the least efficient at 3.5 MJ per passenger km, followed closely by US cities at 3.2 MJ per passenger km. This reflects the large vehicles in use in North American cities, especially sports utility vehicles, their low use of motorcycles and their high levels of private (as opposed to public) mobility. Private vehicles in US and Canadian cities consume about 5 MJ/km, whereas for most other regions the figure is under 4 or even 3 MJ/km, despite generally worse levels of congestion in these latter areas. Australian cities average 2.4 MJ per passenger km for their total motorised passenger transport system.

In contrast, energy consumption in developing country cities where incomes are lower ranges between 0.9 (for China) and 2.0 MJ per passenger km. In all these lower income cities energy-efficient transport has a more significant role, some have high use of motorcycles and many operate fleets of mini-buses, which are relatively energy-efficient (especially with high passenger loadings).

Modal energy use can be examined on a per vehicle km or per passenger km basis. The former is an indication of the energy and technology used in the vehicle, and of the environment in which it operates (the congestion level, etc). In the case of rail modes, the data are reported on a per wagon km basis, not train km. Energy use per passenger km is an indication of the mode's efficiency in carrying people, based on the kind of loadings that the mode achieves in different cities. Tables 2.6 and 2.7 contain these data for buses, trams, light rail (LRT), metro systems, suburban rail and ferries. Not all modes are present in some regions and the averages for a particular mode are taken from the cities in the region where the mode is found. All energy data are based on end use or actual delivered operating energy.[15]

It is difficult to discuss the energy use per vehicle kilometre for public transport modes in any detail because of the huge variety of vehicle types, sizes, ages and occupancy rates that lie behind the averages. A few general points can be made, however:

- As with cars, buses in US and Canadian cities are the most energy consumptive (between 24 and 29 MJ/km, compared to an average of 16 MJ/km in all other regions and only 10 MJ/km in Chinese cities).
- Big differences occur in vehicular energy use in suburban rail operations depending on whether higher consumption diesel systems are present.
- In 24 of the 29 cases where rail modes are represented in the two tables the energy use per vehicle km for the rail systems is lower than that of the respective bus system in the region.
- Ferries clearly have the highest use of energy per km due to the frictional forces involved in operating through water. However, there is a huge variation based on vessel size (e.g. double-deck ferries in Hong Kong and small long tail boats in Bangkok) and speed of operation. The average operational energy use across the nine regions where ferries exist is 277 MJ/km, but figures range from 846 in US cities to only 25 in low-income Asian cities.

More meaningful results can be obtained from energy use per passenger km because this takes into account vehicle loadings and is a more effective measure of success in public transport operations. It is also the only way to fairly compare public and private transport modal energy use. These data are summarised for all the cities in the sample in Table 2.8 below.

Table 2.8: Energy efficiency by mode (MJ per pass.km) averaged over 84 global cities incorporating actual occupancies

Mode	Energy Efficiency (MJ per pass.km)
Car	2.45
Bus	1.05
Metro	0.46
Suburban Rail	0.61
Light Rail	0.56
Tram	0.52

The key insights from the above data are:

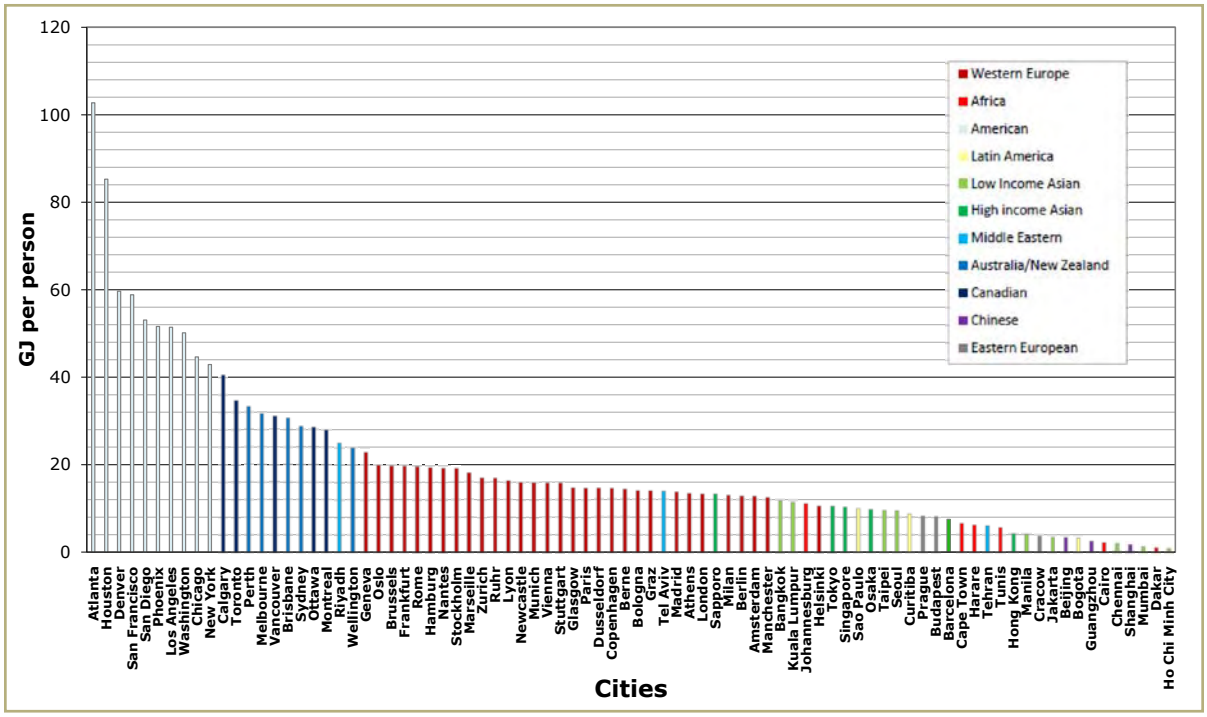
- Except for trams and light rail in Eastern European cities, rail modes use less energy than buses per passenger km in each region.
- There is, on average, not a huge difference in energy consumption between the different rail modes, and on average, rail systems in cities use about half the energy of buses per passenger kilometre.
- Urban rail modes, taken together across regions, are on average 4.6 times less energy consuming than the average car (0.54 compared to 2.45 MJ/passenger km).
- The above averages do, however, mask some exceptional energy performance by specific rail modes in particular regions. For example, light rail in low-income Asian cities and metro systems in Chinese cities consume only 0.05 MJ/passenger km. This is 57 times more efficient than an American urban bus and 76 times more efficient than a Canadian car per passenger km. These high efficiencies are mainly due to some exceptional loading levels on Chinese systems.

In policy terms, rail modes are clearly the most energy-efficient, they have the greatest potential to run on renewable energies and should be prioritised in urban transport infrastructure development where cities are facing a coming oil crisis. They are also best suited to serving dense nodes and linear strips of urban development and thus fit well with increasing urban densities, discussed later in the chapter. New low cost BRT systems can also fit this pattern, though they are not electric and there are sometimes practical and political problems fitting them into street systems that are already overcrowded. This is often the rationale for building rail over or under streets, as well as the extra speeds, despite the extra cost.

Patterns of transport energy use

We have so far seen that the level of per capita CO_2 emissions and per capita energy consumptions vary across the 84 cities surveyed. The extreme variation in transport fuel used by private and public passenger motor vehicles is outlined for these 84 cities in Figure 2.3.[16]

Figure 2.3: Private passenger transport energy use per person, 1995



These data show:

- US cities dominate in their oil consumption and car use with a significant difference between Atlanta with 103 GJ/person, Houston with 75 GJ/person and New York with 44GJ/person. (Note: 1 GJ of fuel equals 28.8 litres of gasoline equivalent).
- Australian, Canadian and New Zealand cities follow this with 30 to 40 GJ/person.
- All European cities use less than 20 GJ/person and reach as low as 12 GJ/person in Helsinki. Eastern European cities are even lower: between 5 and 10 GJ/person, with Cracow lowest at 2GJ/person.
- Wealthy Asian cities (Sapporo, Taipei, Tokyo, Osaka, Seoul, Hong Kong and Singapore) are also extremely low with 5 to 10 GJ/person.
- Cities in developing countries are scattered throughout this array but, apart from Riyadh and Tel Aviv, are less than 8 GJ/person and are mostly no more than a few GJ/person.
- The developing cities to the right of the graph (Jakarta, Beijing, Bogota, Guangzhou, Cairo, Chennai, Shanghai, Mumbai, Dakar and Ho Chi Minh City) are hardly measurable on the same scale as those to the left.

The variation is seen dramatically by comparing US and European cities; Atlanta uses 103 GJ per person of fuel in transport whereas Barcelona uses 8 GJ. Yet these cities have very similar levels of per capita wealth. The difference lies in their urban form and transport infrastructure priorities which result in very different choices exercised by the people in these cities. An overview of patterns for the 84 cities in terms of share of public transport, share of non motorised transport and final energy consumption can be seen in Figure 2.4.

Figure 2.4: Proportion of motorised passenger kilometres on public transport, 1995

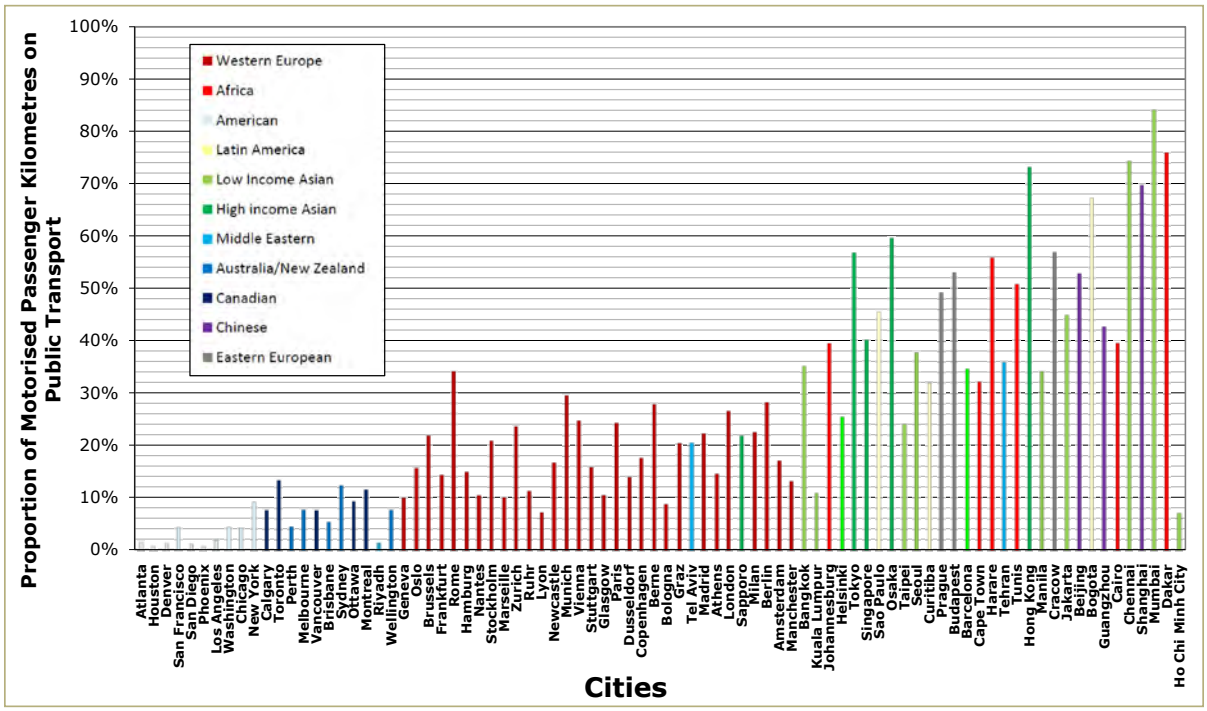


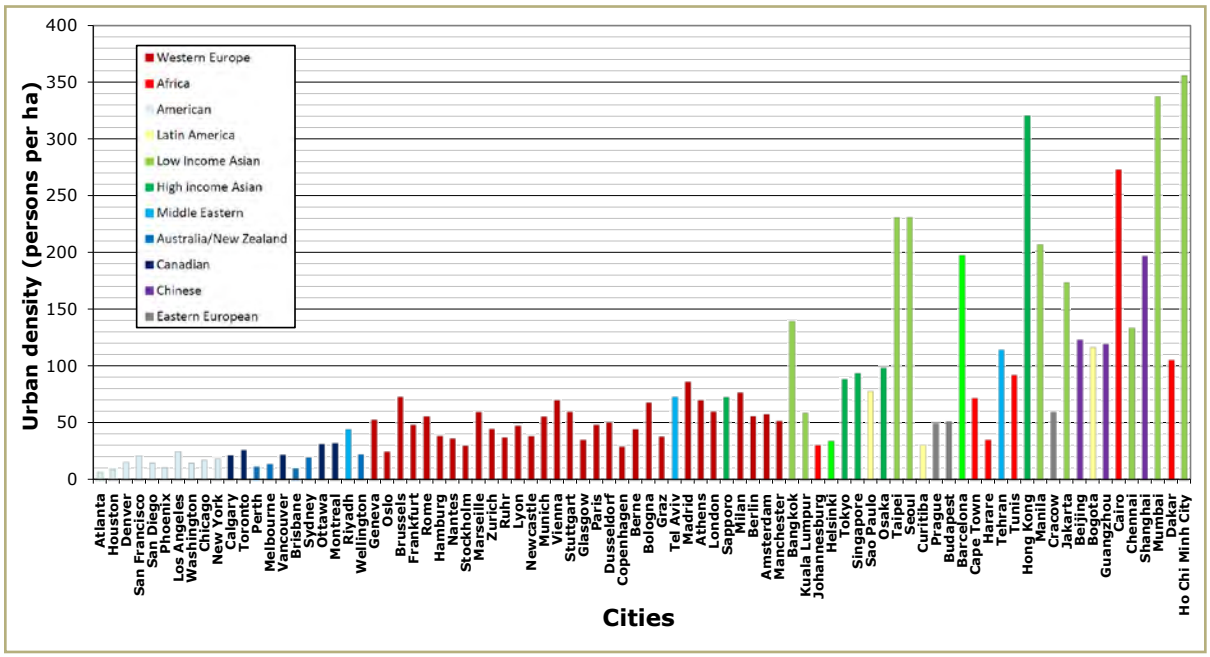
Figure 2.4 sets out the variations in the use of public transport as a proportion of all motorised transport used in the 84 cities, It shows a very large spread across these cities:

- US cities to the left of the graph, like Atlanta, Denver, San Diego, Houston and Phoenix, have tiny levels of transit at less than 1% of motorised transport, with Washington, San Francisco and Chicago at 5% and the best US city, New York, with 9%.
- Australian, Canadian and New Zealand cities are just a little better, varying between 5% in Perth to 12% in Sydney and 14% in Toronto.
- European cities mostly have around 20% transit with Barcelona and Rome at 35% though some are not so good, such as Glasgow, Marseille and Geneva at 10% and Lyon at 8%. Eastern European cities are all around 50% transit.
- The wealthy Asian cities are very high in transit (apart from the new Japanese city of Sapporo at 21% and Taipei at 25%) with Singapore and Seoul at 40%, Tokyo and Osaka at around 60% and Hong Kong 73%.
- The developing cities are highly scattered with Mumbai at 84% winning the transit prize, Dakar, Chennai and Shanghai at around 70%, Beijing and Tunis at around 50%, Tel Aviv 20%, Kuala Lumpur 11%, Ho Chi Minh City 8% and Riyadh at 1%.

None of these patterns seem to follow per capita wealth levels. Some cities invest in transit and others don't.[17]

The other indicator of significance is density of population in people per hectare (ha) of developed urban land (Figure 2.5). These data are related to the above transportation patterns with higher density cities having the more transit and less car use, and lower density cities have more car use and less transit. In particular Atlanta has a density of 6 people per ha and Barcelona a density of 200 per ha, which explains the huge variation in energy use between cities of similar wealth.

Figure 2.5: Urban density, 1995 (persons/Ha)



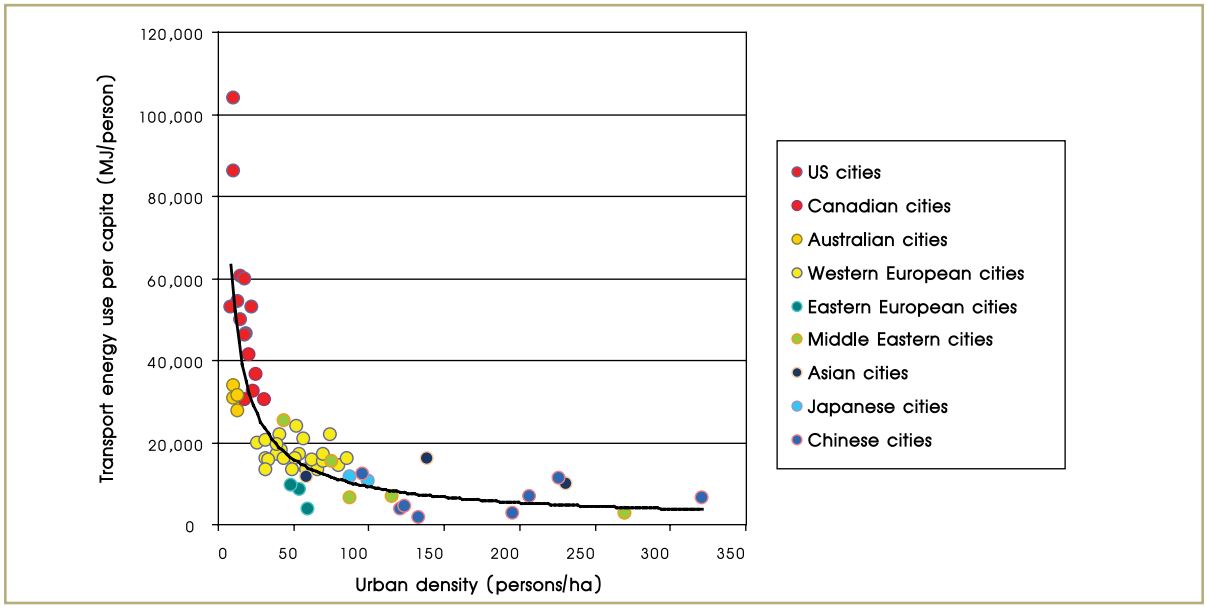
In Table 2.9 below the patterns of density are summarised in the regional groups of cities and are also related to the amount of walking and biking (called Non-Motorised Transportation or NMT).

Table 2.9: Percentage of trips using non-motorised transport and urban population densities for regional groups of cities

	US cities	Aust NZ cities	Cana-dian cities	W.Eur cities	Asian High Income cities	E.Eur cities	M.East cities	Latin Amer cities	Africa cities	Asian Low Income cities	China cities
%NMT	8.1	15.8	10.4	31.3	28.5	26.2	26.6	30.7	41.4	32.4	65.0
Density /ha	14.9	15.0	26.2	54.9	150.3	52.9	118.8	74.7	59.9	204.1	146.2

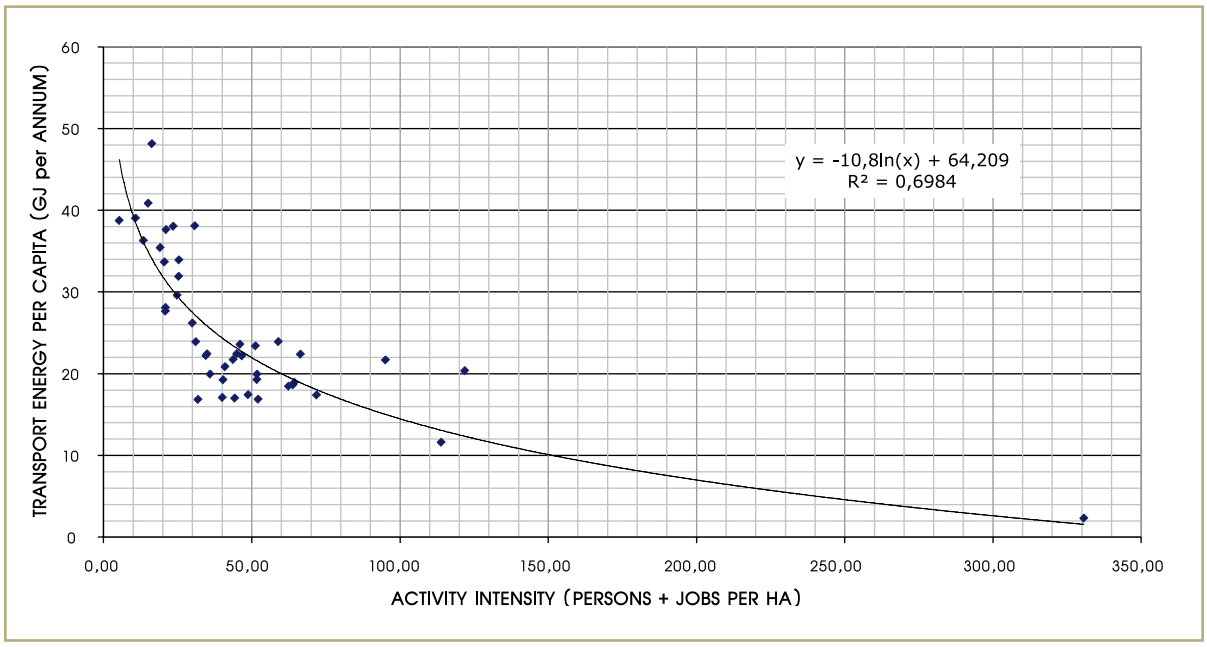
This relationship between transport energy use and density is also apparent within cities. Figure 2.7 shows the same pattern in relation to transport energy and density (of population and jobs) across Sydney's suburbs. The density of activity is very high in the centre and there the fuel use is similar to Asian cities, the inner suburbs are like Western European cities and the outer suburbs are like cities in USA. This also shows that it is not income driving these patterns as Sydney, like all Australian cities, declines uniformly in wealth from the centre out.

Figure 2.6: Urban density versus private passenger car travel per person



Source: The authors acknowledge Michelle Zeibots for creating the original graph upon which this was based.

Figure 2.7: Total transport energy use versus activity intensity in Sydney, 2002



Calculating greenhouse gas savings from sustainable low carbon policies

The Guidebook details different technologies and practices that, if implemented, can lead to greenhouse reductions. However calculations of potential greenhouse gas savings need to be considered carefully in each situation. Such savings may end up lower than expected for the following reasons:

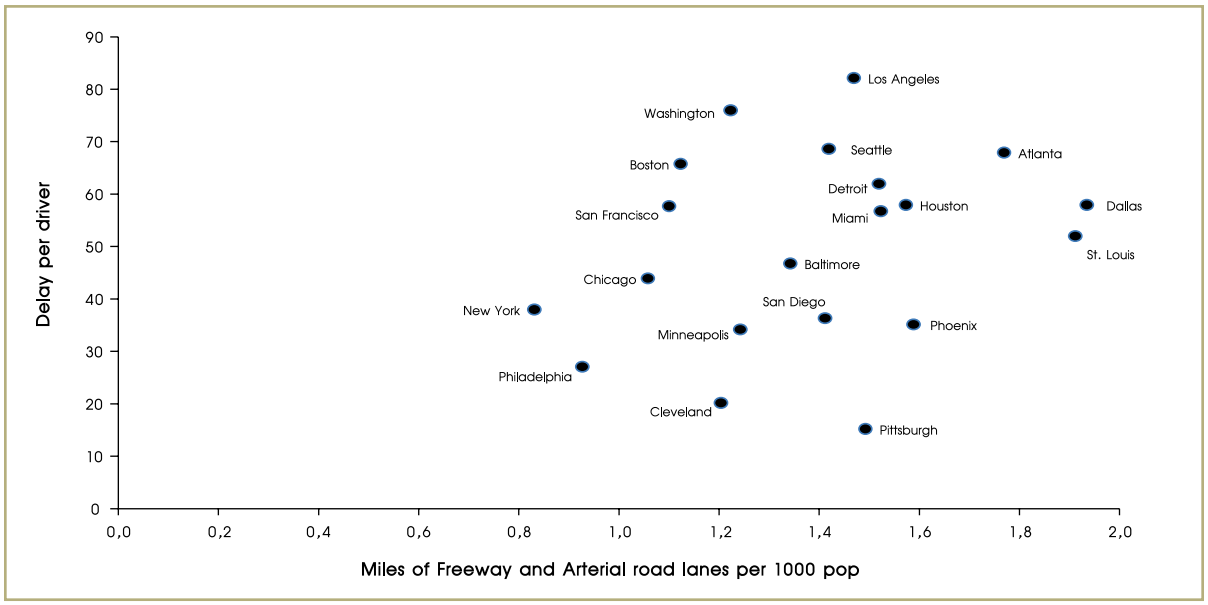
Drivers may use the savings from driving fuel efficient vehicles to simply drive more. This is called the Jevons Effect after the nineteenth century economist who predicted that more efficient coal-fired electricity would mean more coal was needed, not less.

Drivers may pass over fuel efficient vehicles and choose others instead (for example, SUVs, which have virtually cancelled out global fleet fuel efficiency savings over 20 years).

The construction of freeways, flyovers and other road works, intended to achieve smoother, less stop-start traffic flows and hence to save time, fuel and emissions, just encourages more vehicles onto the roads, thus increasing the vehicle kms that generate emissions, and ultimately seeing increasing congestion levels and stop-start traffic again as a result.

Looking at this last point in more detail, traditional traffic planners sometimes use oversimplified benefit-cost analyses to justify the large capital cost of freeways and flyovers based on time and fuel savings. However evidence does not support this contention.[18] Figure 2.8 below shows how the provision of freeways does not save time.

Figure 2.8: Miles of freeway and delay are not correlated in US cities

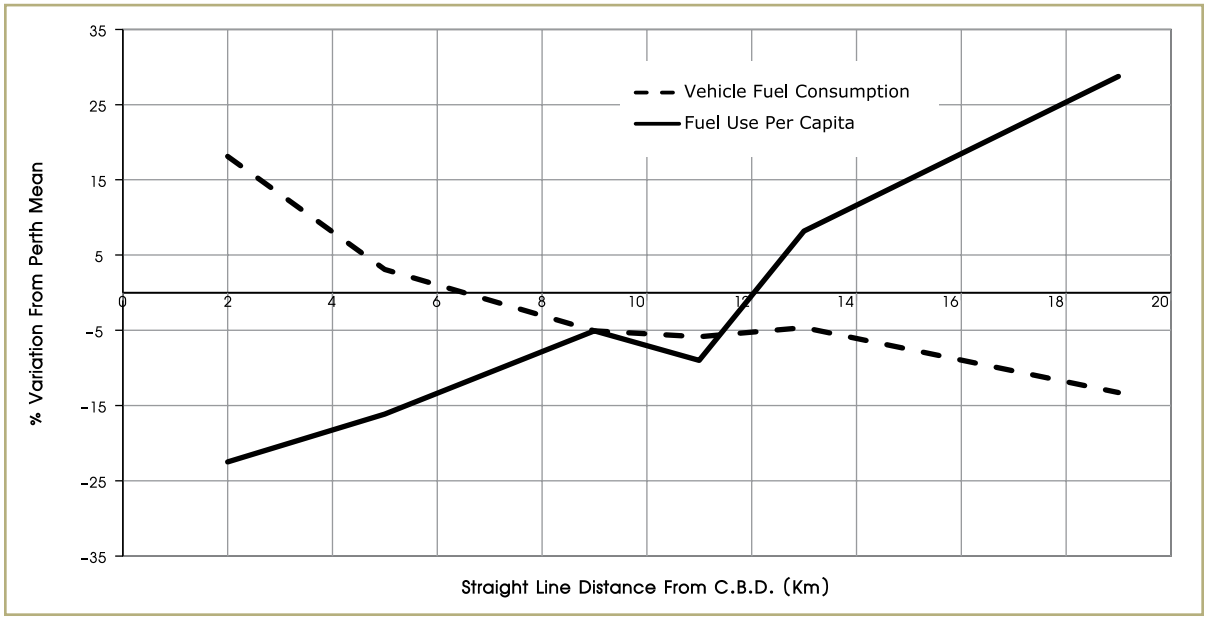


Data Source: Texas Transportation Institute. Emmerson Richardson, Integrated Transport Planning: Affordable and Supportable Solutions for Perth Communities, Sinclair Knight Merz Technical Paper, Perth, undated, http://www.skmconsulting.com/Site-Documents/Technical-Papers/Intergrated%20transport%20planning.pdf, viewed 27 Feb 2011.

While it is true that congested driving causes vehicles to run very inefficiently, the data shows that reducing congestion actually leads to more fuel being consumed. In order to understand this it is necessary to understand the trade-off between making travel per km more fuel efficient and making cities more fuel efficient. Figure 2.9 shows that as traffic congestion lessens with distance from the CBD in Perth, vehicles do become more fuel-efficient but their fuel savings are less than the extra fuel they consume in driving more. This can be further seen in the conceptual diagrams of Figure 2.10 that shows how linear assumptions about freeing up traffic are not able to explain the fuel consumption story. This is because the building of road infrastructure affects the level of road use and in turn the land use patterns of a city. As a

result, and contrary to the road planners' expectations, congestion leads to less fuel use and freeing traffic leads to more fuel use.

Figure 2.9: The trade-off between fuel efficient vehicles and fuel efficient cities as demonstrated in Perth, Western Australia



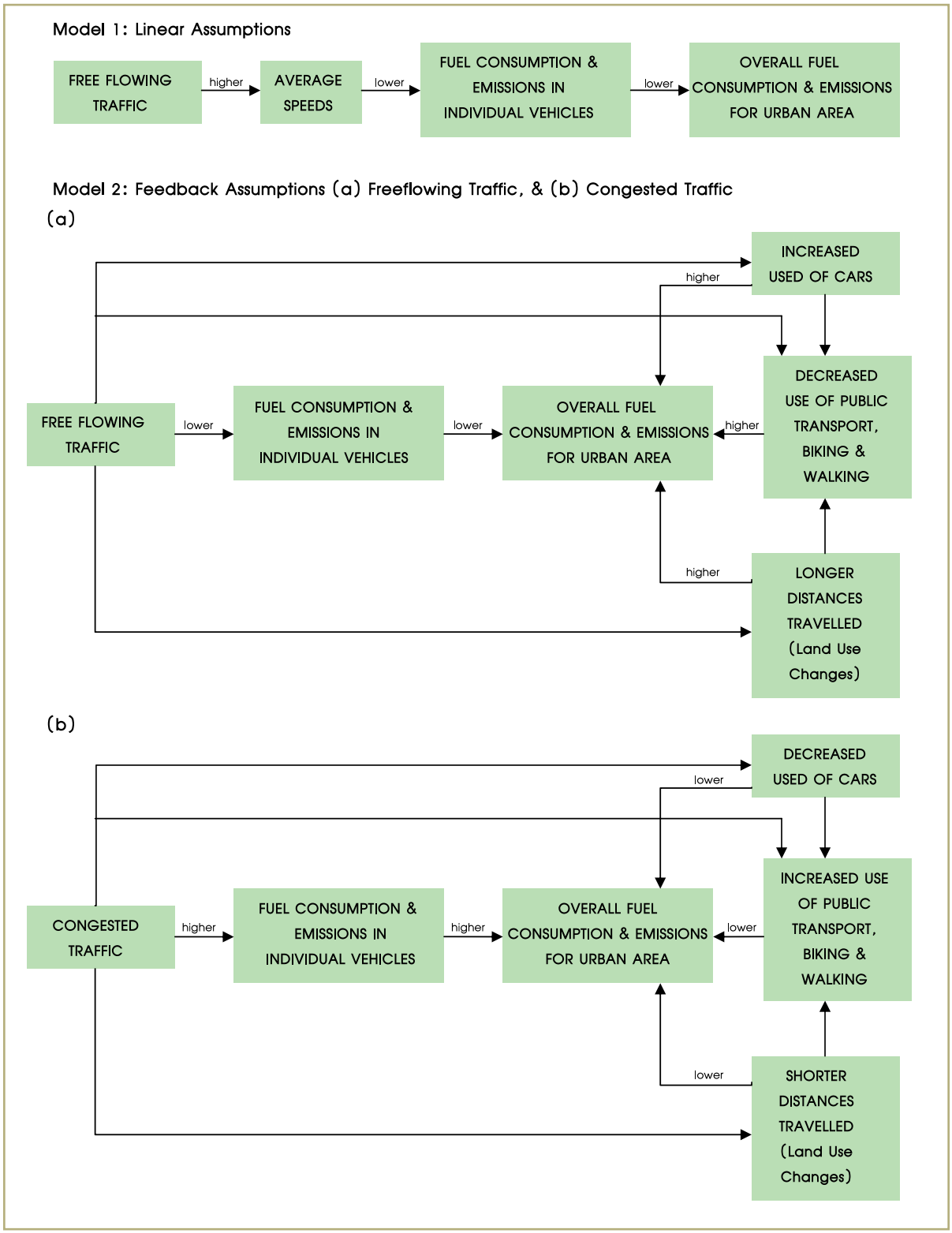
Data Source: P Newman & J Kenworthy, Cities and Automobile Dependence: An International Sourcebook, Gower, Aldershot, 1989.

Figure 2.10: Model 1 and Model 2 show how the simple linear assumptions of traditional road planners in Model 1 do not take into account the feedback loops that are generated by both congested and free-flowing traffic that are set out in Model 2. The phenomenon of increased road capacity increasing road usage is now described as 'induced traffic' and despite being a simple supply-demand issue continues to be neglected in the benefit-cost ratio calculations relating to major roads across the world.[19]

Figure 2.11 summarises this contentious issue. It shows that cities with higher congestion have lower fuel use and cities with less congestion use more fuel. As suggested this appears to be because, although vehicles in lesser congested cities are moving more efficiently, they are being used much more and for longer distances than in cities with more congestion, while in these less congested cities greener modes are being used less.[20] Finding a better balance between freeing congestion and saving fuel by facilitating better usage of sustainable transport needs to be the goal – as set out in Chapter 3. This usually means charging more for fuel, parking or road use and using this money to build alternatives to car use, as described in Box 2.2.

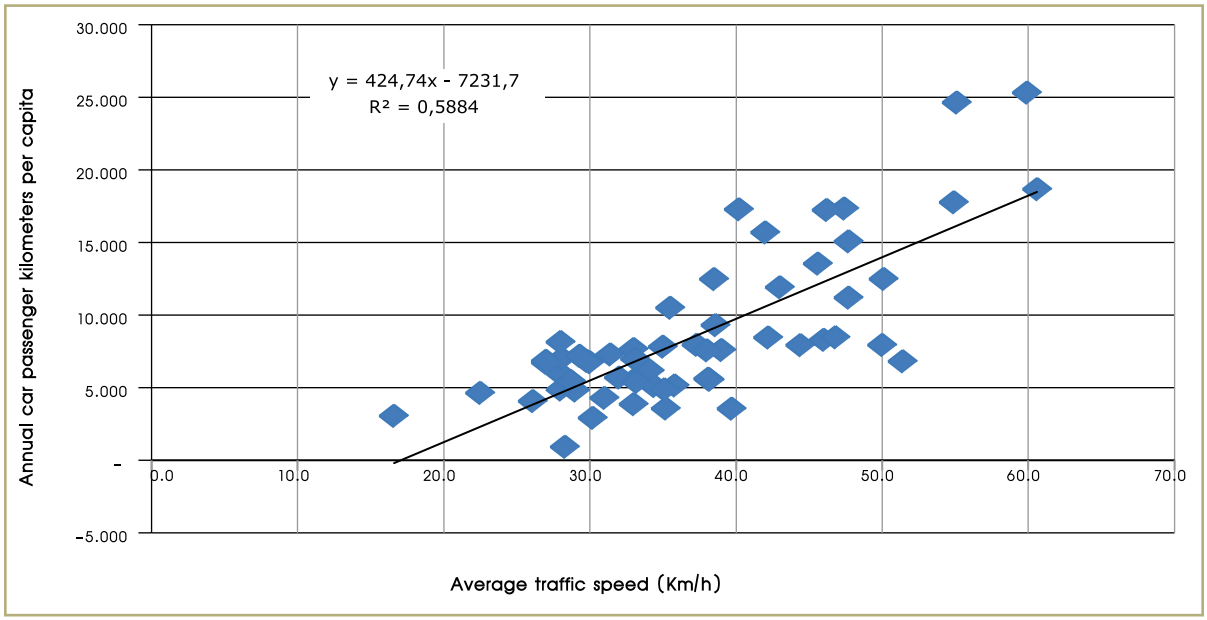
In contrast to the three reasons why there is a tendency to greatly overestimate the greenhouse gas reductions from the availability of more fuel efficient vehicles and more smooth flowing traffic (in fact there will often be increases rather than reductions), there is also a tendency to underestimate the greenhouse savings from mass transit use. The data from Tables 2.7 and 2.8 show that mass transit modes are generally in the order of 50 to 80% more efficient than cars. However, evidence shows that mass transit does even better at saving fuel – especially if it is a rail system. This is because 1 km of train travel has been shown to save between 5 and 7 kms of car travel.[21]

Figure 2.10: Two models of understanding how freeing congestion leads to fuel savings (Model 1) and to increases in fuel use (Model 2)



Source: P Newman & J Kenworthy, Cities and Automobile Dependence: An International Sourcebook, Gower, Aldershot, 1989.

Figure 2.11: Average road traffic speed versus per capita car use in 58 cities



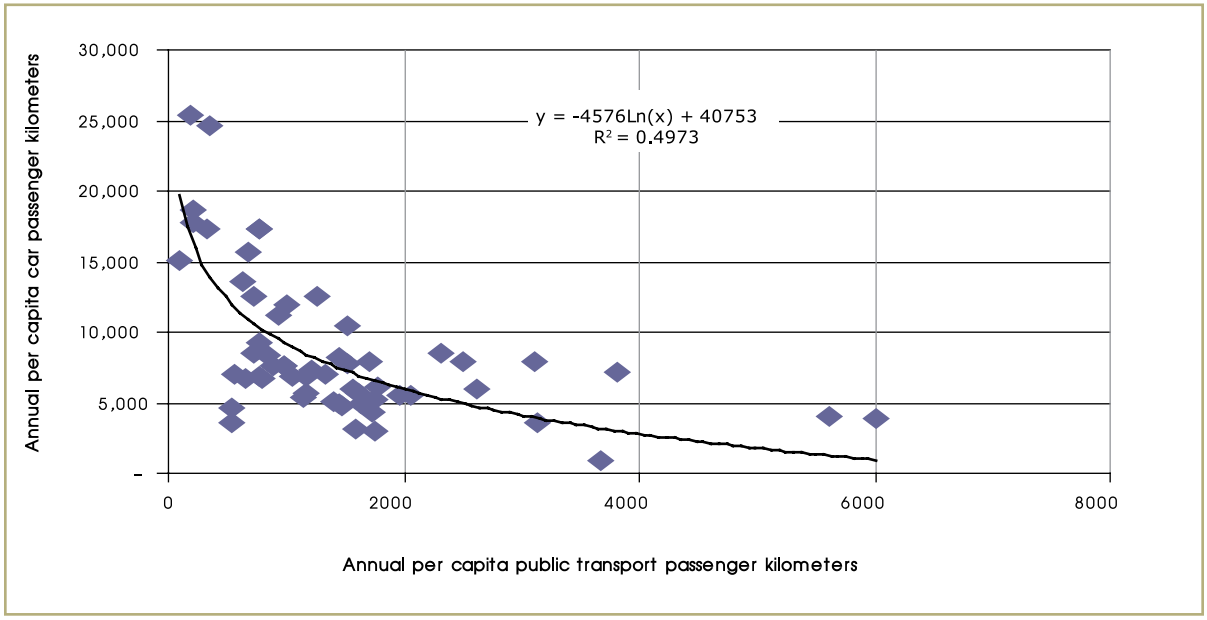
Box 2.2. A more sustainable way to reduce congestion

A much more effective way to reduce congestion and save fuel sustainably involves striking a balance between enabling personal vehicle travel and enabling greener modes. If congestion can be reduced by reductions in car use then a city has a more sustainable solution to congestion and fuel use. London put in a congestion tax to reduce congestion and pay for the motor vehicle's external costs. Singapore and Oslo had also done this but London was the first big city to attempt a city-wide approach. The London initiative ringed the city with sensors that enabled people to pay automatically or to fine those who did not pay when they crossed the cordon into the main part of London. Most importantly they put the money raised back into better transit. The result was a 15% reduction in traffic and much better bus services, both because they were able to meet their schedules more easily and because they had more buses. The 60,000 fewer vehicles per day was much preferred by those who chose to continue driving and 50-60% of those who stopped driving changed to transit. For the cities of the world, it showed that such intervention can be done, that you can tax the car to make greener urban transportation work. Other cities are now moving to a congestion tax; Stockholm found that there was a reduction in congestion of 25% at the morning rush and 40% in the evening, about half the people moved to transit with a 4.5% increase in transit patronage (from a very high base).

Figure 2.12 shows the relationship between car passenger kms and public transport passenger kms from the CUSP Global Cities Database. The most important thing about this relationship is that as the use of public transport increases linearly the car passenger kms decrease exponentially. This is due to a phenomenon called transit leverage whereby one pass km of transit use replaces between 5 and 7 pass kms in a car due to:

- more direct travel (especially in trains),
- trip chaining (doing various other things like shopping or service visits associated with a commute),

Figure 2.12: Car use decreases exponentially with increases in public transport use due to 'transit leverage'



Source: P Newman, J Kenworthy & G Glazebrook, How to create exponential decline in car use in Australian cities, AdeptNet Policy Forum, 08-06-E-Ad, 8 July 2008.

- giving up one car in a household (a common occurrence that reduces many solo trips) and
- living or working nearer to transit, often induced by transit oriented development.[22]

Transit leverage is not as pronounced in relation to buses as they don't have the same direct speed (unless BRTs are being used) and they don't facilitate land use change as easily. These calculations can mean a very significant change in greenhouse gas emissions is possible when mass transit policies are being considered. Good mass transit can bring about dramatic reductions in car use and a focus on transit oriented development, as can be seen in a number of places.[23] This is therefore a source of considerable hope that sustainable transport modes can dramatically save GHG whilst improving the liveability of a city.

Endnotes

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14. An exception to this has been ferries which are sometimes more greenhouse gas emitting.
15. The primary energy use for electric rail modes in each city will vary according to the overall efficiency of electrical generation in each country, including power station efficiencies and transmission losses. The use of primary energy in modal energy consumption for electrical modes would have necessitated a fuller accounting of the energy used in producing and delivering petrol, diesel and gaseous fuels, if a genuine comparison were to be made.
16. Data are from J Kenworthy & F Laube, The Millennium Cities Database for Sustainable Transport. UITP, Brussels, 2001, which was a study of 100 cities (16 were incomplete) and 27 parameters using highly controlled processes to ensure comparability of data. See also J Kenworthy, F Laube, P Newman, P Barter, T Raad, C Poboon & B Guia, An International Sourcebook of Automobile Dependence in Cities, 1960-1990. University Press of Colorado, Boulder, 1999.
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3. Description of Concrete Mitigation Technologies and Practices in the Transport Sector

This chapter is divided into fifteen sections — from A to O. Each section lays down strategies for improvement in transport services which can contribute towards mitigation. The fifteen sections are bundled together in terms of outcomes they can achieve. We therefore have:

Section A-D on **Increasing use of Low Carbon Modes**

a) The Walkable Locality
b) Supporting Cycling
c) Mass Transit
d) Influencing Travel Choices

Section E-F on **Reducing Overall Travel**

e) Transit Oriented Development
f) Reducing the Need to Travel

Section G-L on **Making Current Modes More Low Carbon**

g) Private Vehicle Demand Management
h) Improving Private Vehicle Operating Standards
i) Traffic Management
j) Electric Vehicles
k) Vehicle and Fuel Technologies
l) Motorised Three-Wheeler Taxis

Section M on **Low Carbon Freight**

m) Freight Transport

Section N-0 on **Low Carbon Air And Water Transport**

n) Air Transport
o) Water Transport

Increasing Use Of Low Carbon Modes

A. The Walkable Locality

Robert Salter*

1. Introduction

At 6:00 on a Friday evening in 1972...the renewal of Curitiba began. City workmen began jackhammering up the pavement of the central historic boulevard, the Rua Quinze de Novembro. Working round the clock, they laid cobblestones, installed streetlights and kiosks, and planted tens of thousands of flowers. Forty-eight hours later, their meticulously planned work was complete. Brazil's first pedestrian mall--one of the first in the world--was ready for business. By midday Monday, it was so thronged that the shopkeepers, who had threatened to sue because they feared lost traffic, were petitioning for its expansion. Some people started picking the flowers to take home, but city workers promptly replanted them, day after day, until the pillage stopped. The following weekend, when automobile-club members threatened to retake the street for cars, their caravan was repulsed by an army of children, painting watercolors on mall-length rolls of paper unfurled by city workers. The boulevard, now often called Rua das Flores (Figure 3.1), the Street of Flowers, quickly became the heart of a new kind of urban landscape. The children of those children now join in a commemorative paint-in every Saturday morning. The city is blessed with twenty downtown blocks of pedestrian streets that have regenerated its public realm and reenergized its commerce and its polity.[1]

Figure 3.1: Rua XV de Novembro, Curituba, also known as the Street of Flowers

Picture Credit: Mathieu Bertrand Struck, Wikimedia Commons, http://commons.wikimedia.org/wiki/File:Rua-XV.jpg viewed 22 March 2011.

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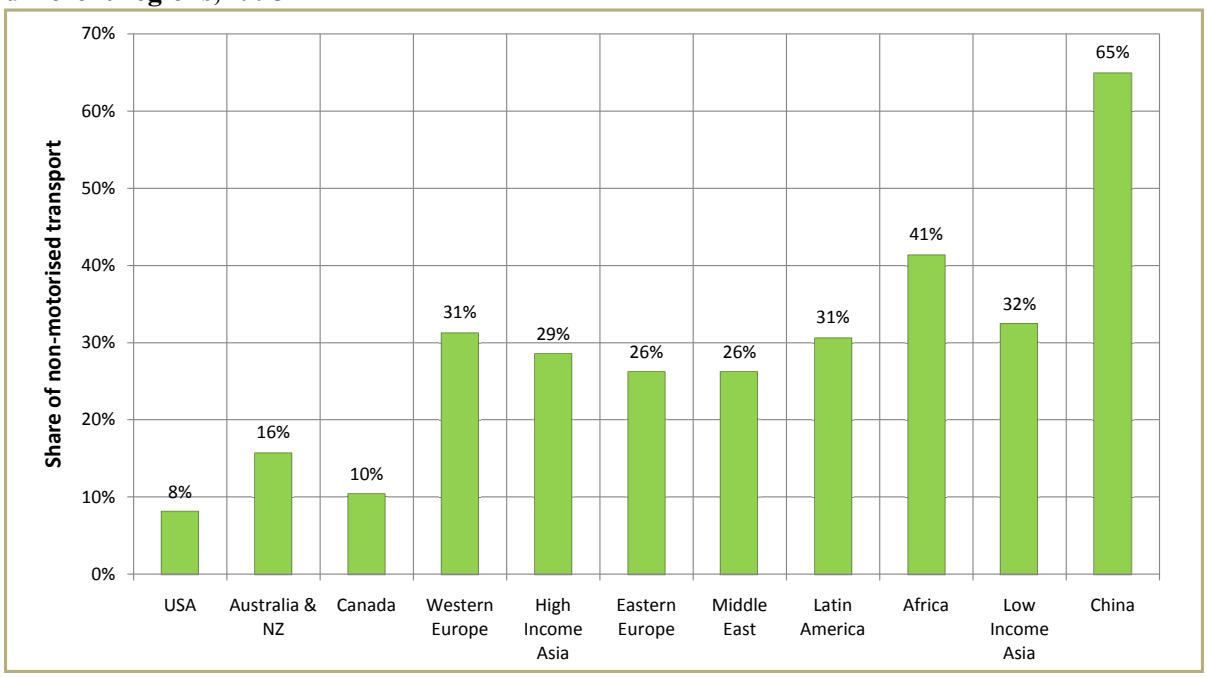
This is just one example of how pedestrian facilities can transform a locality. The Walkable locality is a package of practices and technologies that enable cities and towns the world over – in developing and developed countries – to become urban communities of the future: communities that are better functioning, safer, more sustainable, better connected, more inclusive, healthier and more attractive. Walkable localities have networks of well-designed, well-connected walkways that enable people to get to their destinations or to public transit safely, pleasantly and without delay. This section outlines the concept of a walkable locality, and explains how it can be achieved, with attention to:

- the provision of walkways that enable people to walk from one point to another as directly as possible
- town planning measures to maximise the proportion of journeys that are walkable
- the integration of walkway networks with mass transit routes and services
- control of motorised traffic and non-transport land uses, and separation of walkways from motorised traffic, to ensure that pedestrian travel is safe and pleasant
- the enactment and enforcement of laws and regulations to support these measures.

The section focuses on walking facilities in cities and towns, where problems of congestion, blocked pedestrian access, and danger from vehicles are most serious for pedestrians. Walking in villages is not such a problem as long as there is little vehicle traffic and as long as roads and paths are in reasonable condition. Walking long distances in rural areas is not a good transport solution. This is especially the case for women who spend many hours a day collecting water and firewood.

Levels of non-motorised transport (walking and cycling) vary greatly across the world and within both high and low income groups of countries. Figure 3.2 shows these levels for cities in different regions of the world.[2] Two things in particular are notable: the similarity of levels in cities of low income Asia and high income Asia, and the very different levels in cities of wealthier regions (USA, Australia/New Zealand, Canada, Western Europe and high income Asia). This demonstrates that levels of walking and cycling have little to do with national wealth, and a great deal to do with the direction a country or city chooses to move

Figure 3.2: Levels of non-motorised transport as a percentage of all transport in cities of different regions, 1995



Based on Data from: Jeffrey Kenworthy and Felix Laube, The Millennium Database, UITP, 2001.

in. If it has a commitment to promoting walking and cycling and designs its urban areas accordingly, then higher levels of these transport modes can be achieved.

2. Development contribution

Economic

Good walking facilities can save time and money. Most trips – even those in private vehicles – involve some walking. Given that walking is a slower mode of travel, indirect routes resulting from a lack of walkways and crossings, and very slow walking speeds caused by congested walkways, represent a major loss of time and therefore a significant economic cost to individuals and cities of developing countries. This can lead people to choose motorised vehicles instead, but for middle and lower income families, the cost of such vehicle travel can eat up a large proportion of family income or important trips may not be taken because they are too expensive.[3]

Moreover, the pollution, road accidents and lack of exercise resulting from car and motorbike use lead to sickness and injury and thereby add to a country's health costs and absences from work.[4]

On the other hand, good walking facilities are far cheaper to provide than other transport infrastructure. What's more, such facilities encourage and support mass transit use, and World Bank research shows that countries with higher levels of transit use spend much less on transport as a proportion of their total spending,[5] and help to reduce developing countries' dependence on increasingly expensive foreign oil.

And safe, attractive, pedestrian-and-transit-friendly cities can be more appealing to outside business and tourism.[6] Increasingly, people working in the new knowledge economy are attracted to walkable urban environments.

Social

Walking promotes physical and mental health. It reduces or prevents obesity, cardio-vascular disease, diabetes, depression and sleep disorders. As people switch from cars or motorbikes to walking, cycling and mass transit, asthma and other respiratory diseases aggravated by motor vehicle pollution are also reduced.[7]

Walking is a form of transport that everyone can afford and almost everyone can practise (and if users of wheelchairs and walking aids are accommodated in the walkway design, there are few indeed who cannot practise pedestrian travel). Adequate networks of functional walking routes mean that people on all levels of income have better access to employment, education, health care and other services vital to their wellbeing. Thus, good walking facilities promote equality and inclusion.[8]

It is also a very safe form of travel, as long as pedestrians are protected from motorised traffic (and to a lesser extent from the weather). As people move from cars and motor cycles to walking and transit there are fewer vehicles on the roads to pose a threat to others. Road deaths in Bogotá were reduced from 2-3 a day to 1-2 a day largely as a result of major improvements in walking and cycling facilities.[9]

As well, walking is a very practical mode of travel, especially in urban areas. Over 60% of trips in cities of developing countries are less than 3 kilometres in length and therefore very suitable for walking, and in the most sustainable German cities now, 80% of trips within this range are taken on foot or by bike.[10] With walking, there is no vehicle to be parked, damaged or stolen. And while the climate in developing countries may be cited as a factor that deters walking, average temperatures in these countries are about the same as summer temperatures in Europe, where walking is very popular as a means of transport.[11]

If walkways are shaded, heat and direct sunlight are much less of a problem. And the difference in travel speed between walking and motorised transport is not as great as might be thought, given the reduced speed of motorised vehicles in cities as a result of either congestion or traffic calming measures.[12]

As well, walking builds community. Studies show that in neighbourhoods where walking is common people know their neighbours much better than in neighbourhoods where most people drive.[13] Pedestrian environments are great places for people to congregate, and for children to play.[14]

Finally, when good walking facilities are combined with good mass transit a large range of destinations are within practical, safe and affordable reach.

Environmental

As stated earlier, walking produces no greenhouse gases and is completely non-polluting. Good walking facilities encourage and enable people to use mass transit, and every person who walks or uses transit instead of using a conventional car or other motorised vehicle reduces the production of pollutants, greenhouse gases and noise, and helps to conserve the world's non-renewable resources.

Cities with more pedestrians, and more public spaces suited to pedestrians, are also more attractive, safe and pleasant environments for people to live in.[15]

Furthermore, as a pedestrian occupies just one sixth of the space of a car, walkways occupy much less space than roads and thereby enable higher urban densities to be achieved, and these in turn have many other environmental advantages.

Narrow pedestrian streets can also save energy by shading buildings. The new zero-carbon city of Masdar in the United Arab Emirates has such streets, and they shade both the pedestrians and the buildings, thus creating pleasant walkable areas that reduce motorised travel, and require less energy to cool buildings.

3. Greenhouse gas emissions reduction potential

Once walkways are in place, walking as a mode of transport produces no greenhouse gas emissions at all. A walking trip of 2 kilometres (a very feasible distance) reduces greenhouse gas emissions by 419 grams of CO_2 (equivalent) if it replaces a car trip.[16]

4. How a more walkable locality can be achieved

The core of a walkable city is a well-functioning network of walkways. This should allow everyone in urban areas to walk wherever they want to go safely, pleasantly and fairly directly. The following considers in broad terms what this entails and how it can be achieved, but governments and city leaders wanting to improve walkways in particular localities may want to use a walkability auditing tool such as *Is my area walkable?* produced by Anne Matan as an appendix to this guidebook.[17]

Location of walkways

Ideally, walkways should be at least as extensive as roads, so that pedestrians can easily walk between any two points. But a locality improving its walkways should give priority to the most popular routes, and to routes most likely to encourage people to use mass transit. There should be safe crossings at reasonable

intervals on all major obstacles, such as main roads, railway lines and canals. Most walkways are located alongside roads (as footpaths or sidewalks) but there can also be separate walkways, which may or may not double as bicycle ways. Town planning changes that make urban locations more accessible on foot are also important, and these are described further on.

Width of walkways

Walkways should be at least two metres wide, and more if there is heavy usage, for example, 3.5 metres wide if 5,000 people pass per hour. Some sources recommend that they be much wider than this,[18] but in established high-density areas this may not be possible. Traffic route construction manuals give further details of width and other design requirements, and are listed in the references.[19]

Freedom from obstacles

Walkways need to be free of obstacles, which can force walkers onto dangerous roads, slow them down, or deter them from walking altogether. Such obstacles include parked vehicles, street traders, animals, piles of rubbish, shanty dwellings, poles, signs, and building or road-repair materials. Bollards can be placed along the edges of walkways to prevent cars parking on them. Some of the uses of walkway space just mentioned, such as the street trade and shanty dwellings, may be an important part of street life or meet vital human needs, so they might simply need to be restricted to certain areas that don't block pedestrians.

If other activities or objects are allowed on walkways, then the total width of the walkway may need to be increased so there is sufficient clear space for pedestrians. More space can be obtained for pedestrians and cyclists by narrowing roads, by creating streets free of motorised traffic, or by having streets that are shared by all modes, with vehicles travelling at pedestrian speeds.

It is also necessary to ensure that the walkway surfaces are even, in good repair and cleaned regularly, and it's best if there are no steps or steep curbs to obstruct pedestrians who have handcarts, wheelchairs or prams.

Ensuring that walkways are sheltered and attractive

Walkways should be sheltered from the sun and the wind by trees and buildings, and pathway materials should not absorb heat, which means they should be lighter colours. Walkways can be one part of a larger network of linked pedestrian areas that enhance a city's liveability, areas that can include parks, squares, car-free streets and children's playgrounds, and feature trees, lawns and other planting, ponds, seats and tables, and public artworks. The new local park network in New York has been linked to an expanding pedestrian system, including the closure to traffic of Times Square and much of Broadway.[20] And Indonesia's Kampong Improvement Program has reduced traffic in laneways linking public courtyards and main streets.[21] In general, cities and nations will have varying budgets for these sorts of improvements, but the more walkways can be sheltered from the elements and made safe and pleasant places to be, the more they will attract pedestrians.

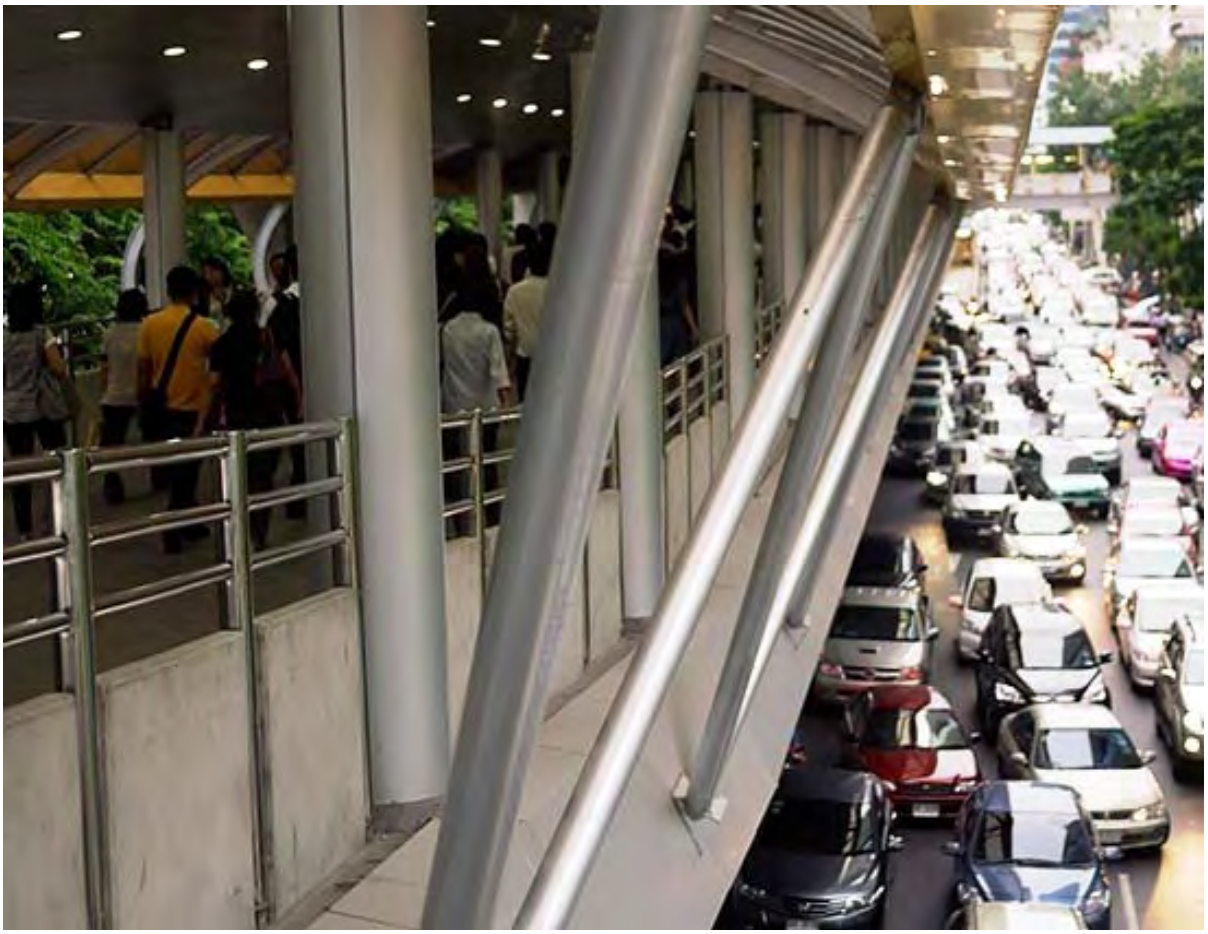
Protecting pedestrians from motorised traffic

A vital part of making walkways safe and pleasant is protecting them from traffic noise, pollution and danger. Means of crossing major roads and other barriers at reasonable intervals can include pedestrian crossings or traffic lights with pedestrian signals or phases. Signals should have tolerable cycle time (e.g. 90 seconds or less) and enough time for pedestrians to reach the other side at a moderate speed (e.g. 1

m/sec). Furthermore, if these signals show pedestrians how long they have to wait before crossing, and how long they have left to get across the road, unsafe crossing of roads can be reduced. However, it is vital that pedestrians can use these crossings safely. If drivers tend not to stop for pedestrians using them, stricter enforcement and heavier penalties are warranted. In some special cases, such as very wide roads and expressways, overpasses and underpasses could be provided to enhance pedestrian connectivity and avoid road safety hazards. However, many people do not use overpasses and underpasses if they are much higher or lower than the walkway level, so it is best to have crossings at the walkway level if this can be achieved safely. In some areas this is not possible, and pedestrian walkways may have to be built over busy traffic (Figure 3.3). To enhance accessibility overpasses or underpasses should have ramps, escalators or elevators.

Car- free areas, especially in city centres and major shopping precincts, are becoming very popular in cities around the world (e.g., Figure 3.4). Streets or localities can be car-free continuously, or for parts of the day or week. Bogotá, like Curitiba, the city cited at the beginning of this section, has made a strong commitment to pedestrianisation. It closes 120 kilometres of roads to motorised traffic each Sunday, allowing about two million people to cycle, rollerblade, jog and walk.[22] Making commercial areas car-free can also dramatically improve their profitability, as cities in China, Colombia, Brazil and Europe have seen.[23]

Figure 3.3 An elevated walkway in Bangkok, sometimes the only solution to help pedestrians avoid the traffic



Picture Credit: Karl Fjellstrom, itdp-china.org .

Figure 3.4 The Istiklal is a pedestrian-only street in the Beyoglu area of Istanbul, Turkey. The street has restaurants, coffee shops, clubs, shopping, movie theatres and embassies

Picture Credit: John Walker.

There are many 'traffic calming' devices that restrict the number and speed of motorised vehicles, and help to ensure that drivers respect pedestrians and cyclists. These devices include very low speed limits, speed humps, 'rumble strips' (which make a noise when vehicles go over them), one-way or dead-end streets, and streets that are narrowed and may have curves added to the lanes. Any space freed up by these measures can then be used for trees, gardens and seats. There can be frequent pedestrian crossings, and if they are at the walkway level rather than the slightly lower road level it emphasises that this is 'pedestrian space'. Different paving materials and the absence of road camber and curbing can suggest a driveway rather than a road and moderate driving behaviour accordingly. In these and other ways the appearance and configuration of streets can be changed to reduce speed and to signal that streets are used by other modes of transport with equal or even greater rights to the space.[24]

Further ways to encourage pedestrian travel

Many people avoid pedestrian travel because they have to carry luggage, shopping or other goods. But transporting such items is much easier with the use of some simple devices – things like trolleys, handcarts and cases with wheels. If these are not readily available, encouragement can be given to small businesses to manufacture or sell them. Encouraging the delivery of goods can also help.

Pedestrian travel can also be encouraged through public information and education campaigns, perhaps in conjunction with the promotion of mass transit use, because the two modes are so often used in the one trip. Maps of walkways can be sold or handed out in paper form, and they can also be available online and to mobile phone users.

A measure that encourages children to walk is the 'walking school bus'.[25] This is an arrangement whereby groups of children walk to and from school together under the supervision of one or more adults, and it is described in the *Influencing travel choices* section of this chapter.

Town planning to promote walking

High density urban areas encourage pedestrian travel, because destinations – such as shops, workplaces, homes and transit stations - are likely to be closer and therefore easier to walk to.[26]

'Transit oriented developments' – which have shops, businesses, services, schools, health and entertainment facilities, and higher density residential areas close to train and bus stations – encourage both mass transit use and pedestrian travel (Figure 3.5). These are described in the section of this chapter titled *Transit oriented developments*.

Particular building designs can also encourage walking. Pedestrians feel safer if buildings are located closer to the street, and if each street has many homes or businesses with street frontages. In such an environment there is more social contact, and building occupants can have 'eyes on the street' and look out for neighbour and stranger alike. Compare this with a street composed of the long blank walls of factories, businesses or residential enclaves, or one in which apartment blocks and other buildings are set back from the road and must be reached by isolated (and often unlit) paths. Unless people feel completely safe, especially at night, they will tend to use other forms of transport if these are available. Urban design to create safe, walking areas is a key element of 'crime prevention through environmental design'.[27]

Figure 3.5 Pedestrians feel at home in this Transit Oriented Development in Bogotá

Picture Credit: Karl Fjellstrom, itdp-china.org.

Integrated transport planning to prioritise pedestrian travel

In transport planning the needs of pedestrians are often ignored because there may be quite separate planning processes for different transport modes, and in most cases no one government agency has particular responsibility for pedestrian travel. There is thus a need for transport master plans that integrate all modes of transport, including walking, in planning processes. Bogotá's master plan, for example, stipulates that priority should be given to pedestrians.[28] Such planning should include an explicit commitment to the provision of walkways that allow safe and fairly direct walking between any two points in a city.

Many cities are also appointing a coordinator for non-motorised transport, as well as a taskforce representing the many stakeholders in this area of transport, including transport and public works departments, police, city planners, business, travellers' advocacy groups and other community organisations.[29] These taskforces should have the power to ensure that transport projects meet the needs of pedestrians and cyclists, and they also have an important role in public education, promotion and safety campaigns for non-motorised transport. In Auckland, a walking coordinator has initiated 150 'walking school buses' (described earlier).

In deciding where to start to improve pedestrian facilities, it is a good idea to select areas of high actual or potential pedestrian traffic as pilot projects. These are likely to be areas containing schools, universities, shopping centres, markets, factories or other large workplaces, mosques, temples or churches, or transit stations. Or they can be areas in which traffic accidents involving pedestrians are common.

Design standards for walkways may need to be changed. Many existing design standards are derived from developed countries and based on very car-dominated transport systems.

As well as changes to physical infrastructure, building better pedestrian facilities may require changes to laws and regulations, increased penalties and better enforcement. Such changes may concern speeds on adjacent roadways, giving way to pedestrians at crossings and intersections, car-free areas, and prevention of car-parking and other obstacles on walkways.

Compared with other transport developments, improvements to pedestrian facilities can be achieved quite quickly.

5. Costs and sources of finance

Improvements to pedestrian facilities can also be achieved at low cost, relative to other transport developments. Costs will vary greatly depending on the length and width of walkways, the extent of upgrading that is necessary, the kinds of road crossings put in place, the surfacing materials used, and a range of other factors. But in general, walkways cost only a small fraction of the cost of roads, and they can even be created with paint on pavement.

And while walking and cycling facilities have often failed to receive the attention they deserve, the tables are now turning. Many developed cities have recently accepted that they are not competing for global and local investment because they are not walkable enough in their major centres. Jan Gehl cites examples from London, New York and Melbourne as well as the most documented example of Copenhagen.[30] Similar trends in transport priority can be seen in Singapore and Hong Kong and now well-designed emerging cities like Curitiba, Guayaquil and Bogotá are gaining multilateral funds and international reputations as cities of the future, while their mayors have gained great popularity for the positive changes they have made to millions of lives. The likelihood that countries around the world will put a price on carbon means that this trend will become stronger, and localities with good non-motorised transport facilities and public transit will be the winners. Multilateral funding sources are described in Chapter 4.

6 Conclusion

Walking, then, is an inexpensive, efficient and healthy way to travel short distances, and to link up with mass transit in order to travel longer distances. In the right environment, walking can also be a very pleasant mode of transport, and cities that have good pedestrian facilities and high levels of walking are usually very pleasant places to live. In addition, walking produces no greenhouses gases and no local pollution, and it is not a danger to anyone else in the way that motorised transport can be. However, in order for walking to be a pleasant and practical transport option, and in order to encourage more people to walk, certain requirements have to be met. Well-designed, safe and well-connected walkways and pedestrian crossings need to be planned and provided. In particular, walkways should be connected to transit stations and to major residential areas and sites of human activity. And if urban areas are fairly dense and have mixed land uses, walking becomes a reasonable transport mode for many of the trips people make as they go about their daily lives.

Endnotes

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15. Gehl and Hook.
16. See Ch 3, Table 3.2.
17. See Appendix III, Anne Matan, *Is my area walkable?* [This Appendix has been prepared as a walkability auditing tool for this section.
18. Anne Matan, personal communication.
19. These design considerations and further reference manuals are discussed in Hook.
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B. Supporting Cycling

Athol Moore*

1. Introduction

There are more bicycles in the world than cars, and the manufacture of bicycles continues to outstrip car production. In 2009, 59 million cars were produced, down from 69 million in 2007, but in 2007 130 million bicycles were manufactured. Bicycles are a practical, zero-carbon transport solution the world over.[1]

Since the 1960s and 1970s many European countries and cities have decided to support more sustainable transport modes - public transport, walking and cycling - to address the multiple problems of car use. In the area of cycling, supportive policies and infrastructure that followed have now reversed the rapid decline in cycling in many localities. For example, Amsterdam and Copenhagen started supporting cycling in the 1960s and have seen continual growth in cycling ever since.[2]

In Germany, supportive planning and policy ensure that only 15% of trips between 1 and 3 km in length are made by car, bus, train or taxi[3]. The rest are made by walking (55%) or cycling (30%) despite high levels of car ownership and wealth. By comparison, in Surabaya, Indonesia, 60% of trips between 1 and 3 km are motorised, while walking (30%) and cycling (10%, including becak trips) play a smaller role due to unsupportive infrastructure and policies.[4]

A number of developed countries have realised that cycling is a very efficient and feasible form of transport for short to medium distances. Where supported by governments and non-government organisations, cycling's popularity and its contribution to the overall transport system have greatly increased. For example London has seen a 91% increase in cycling over nine years[5] and New York has doubled the number of people cycling to work in four years,[6] thanks to supportive policies, programs and infrastructure.

In Latin America too there have also been concerted efforts to increase the popularity of cycling, for example, in Bogota, Colombia, in Concepción, Chile, in Lima, Peru, and in Quito, Ecuador. In Bogota 4% of travel is now by bicycle, compared with 0.58% in 1998.[7]

In order to increase the level of cycling it is necessary to address the barriers to it, barriers like:

- a lack of safe and interconnected cycle routes
- the cost of bikes
- shortages of mechanics and spare parts
- concerns about bicycle security
- perceptions that cycling is unsafe, unsuitable in certain weather conditions or terrains, low status, culturally inappropriate or impractical.

And while some see a high level of bicycle use as a sign of low economic development, in fact many of the world's wealthiest cities have a relatively low mode share for private cars (motorised personal transport), whilst public transport, walking and cycling play a far greater role, as the Figure 3.6 shows. (Note: the City of Copenhagen lies on the 'most efficient pattern' although 'Greater Copenhagen is in the 'European pattern'.)

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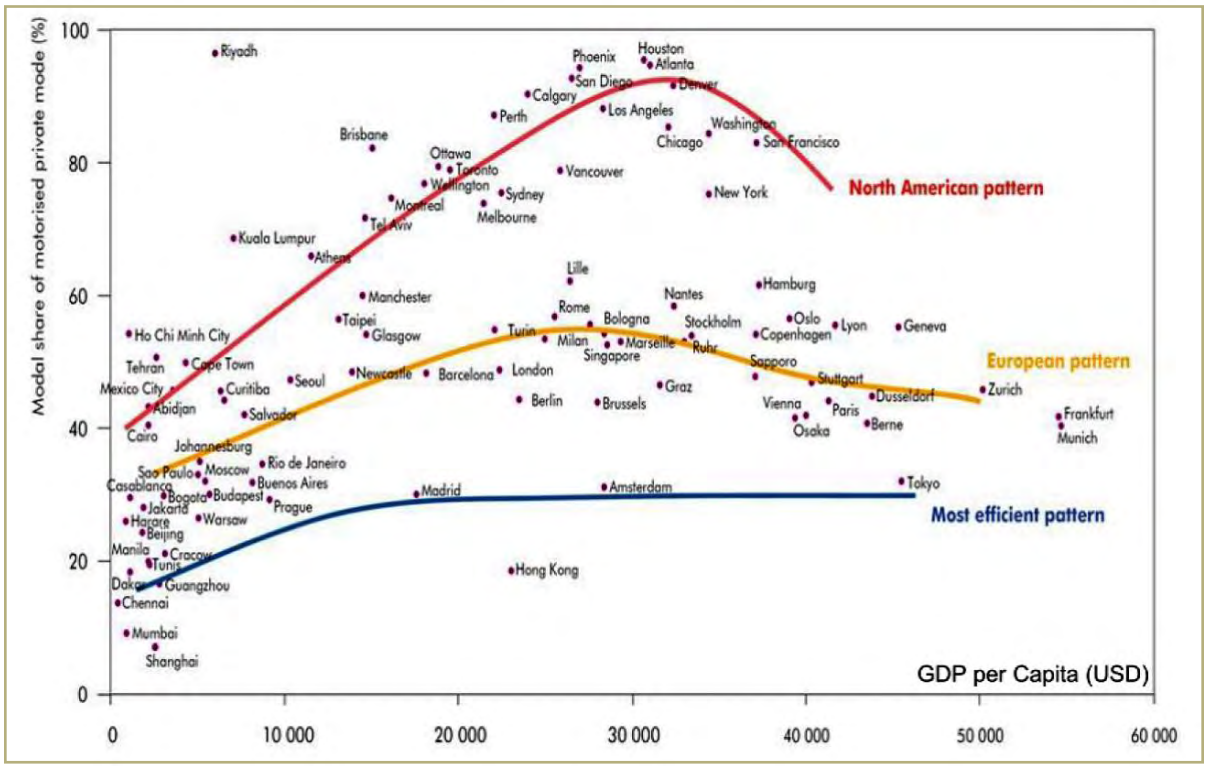
Figure 3.6 The relationship between GDP and motorised personal transport



Source: UITP 2006 (Courtesy of Systra) .

This section outlines how cycling can play a much more significant part in meeting transport needs in the developing world, as part of a mix of low or no carbon transport modes for the twenty-first century. This can be achieved through measures to:

- provide safe cycling routes
- address other urban planning issues
- make bicycles more affordable
- enable access to servicing and parts
- increase bicycle security
- educate the public and raise the status of cycling.

2. Benefits of increased cycling

Cycling can make an important contribution, not only to the transport system, but also to the environment, the economy and the social fabric of communities.

Economic benefits include:

- **Transport efficiency:** cycling and walking are the most space efficient transport modes for short trips. Bicycles need less than a third of the space cars need to transport the same number of people.[8]
- **High benefit to cost ratio from investment in facilities:** the cost of building facilities for cyclists is small, compared to those for cars, but the economic benefit can be significant. Benefits include

reduced road infrastructure, congestion and pollution; improved road safety for pedestrians and cyclists; and savings in private and public transport running costs. In Chile the cost of bicycle infrastructure is one tenth the cost of roads ($US 180,000 compared with $US 1.8 million per kilometre). Sao Paulo, with little cycling, loses 7% of its GDP as a result of traffic congestion.[9] Economic studies in four South American cities found that constructing cycleways had a benefit to cost ratio of 7.3:1 over a ten year period.[10]

- **Access to markets:** Bicycles can transport small freight loads over short distances at little or no cost, allowing small subsistence farmers and traders to access markets and customers affordably.
- **Reduced reliance on fossil fuel:** Increased use of bicycles reduces reliance on crude oil, which most countries must import.
- **Higher worker productivity:** It has been demonstrated that cycling to work leads to better attention levels, higher productivity and reduced absenteeism.[11]
- **Greater economic inclusion:** Because of its affordability, cycling gives more people access to jobs, education and services.[12]
- **Improved safety:** Increased cycling reduces traffic fatalities and serious injuries because it reduces the number of car trips (which cause fatalities) and because – as experience in Copenhagen demonstrates – significant increases in cycling, along with better cycling infrastructure, can sharply reduce the absolute number of serious injuries to cyclists. Between 1996 and 2006 bicycle paths there increased by 20% and the number of cyclists increased by 25%, while in the same period serious cycling injuries were reduced by 62%.[13] Thus increased cycling reduces a significant economic and social burden.[14]

Social benefits include:

- **Affordability:** A bicycle provides high levels of personal mobility at very low cost. In Chile, the cost of a bicycle is the same as the cost of transport tickets for two months.[15] As well, there are no fuel or parking costs and no taxes. This gives individuals more disposable income to spend on other things.
- **Equity across localities:** Cycling can provide high levels of personal mobility for negligible cost in dispersed settlements, including rural or peri-urban areas, where population densities make public transport economically less viable.
- **Health:** Physical inactivity results in increased health problems such as obesity, heart disease, diabetes, stress and high blood pressure. Cycling increases physical activity levels and reduces the economic cost of health problems. A study in Australia found that physical inactivity cost the healthcare system $1.5 billion per annum.[16] Traffic pollution also affects health. In Europe 310,000 people die annually from respiratory and circulatory disease caused by vehicle emissions.[17]
- **Education:** in many rural areas children walk long distances to school as public transport is either unavailable or too expensive. This can lead to frequent absences, reduced concentration and leaving school at any early age. A bicycle can significantly improve a child's access to education opportunities.

Environmental benefits include:

- **Emissions:** a bicycle emits no greenhouse gases or local air pollution when operated and far less than a car when manufactured.

- **Noise and congestion:** bicycles are far quieter than motor vehicles and take up less space. Electric bikes have similar advantages.
- **Sprawl:** By requiring less road space and by reducing the average length of trips, cycling contributes to urban consolidation.

3. Greenhouse gas emissions reduction potential

A two kilometre bicycle trip saves 419 grams of CO_2 (e) if it replaces a car trip, although there are some emissions generated in the production and distribution of bicycles.

4. Measures to promote cycling

These benefits can only be realised if cycling is supported through appropriate measures that are implemented by all spheres of government, in pursuit of the following goals:

Better and safer cycling routes

The biggest barrier to cycling in urban areas is the lack of safe cycling routes. Off-road cycle paths can provide a safer and less stressful environment for cyclists, but such paths are not without their problems. For example, they can become unusable if they attract too many pedestrians, and they can be dangerous where they cross streets or driveways and bring cyclists into contact with motorised traffic. One solution to the latter problem is to make these crossings more noticeable through on-road painting, as occurs in Copenhagen where the blue colour of cycleways crossing a road is very distinctive. However, in many places road use is the only option for cycling and, where this is the case, roads should provide cycling facilities that are safe, pleasant and appropriate.

Some key principles for the planning and design of cycle networks are as follows:

- **Coherence and directness:** Cycling routes should take people as directly as possible from their point of origin to their destination. However, constructing a network of cycling routes that allows this to occur takes time to achieve. It can be built incrementally by prioritising those routes or sections of routes that have the greatest potential for cycling, or involve the greatest risks to cyclists. Over time existing routes can be linked to create a continuous and interconnected network of routes that provides coherent connections between the places where people live, work, shop and play. And, as is the case with the road network, signage on the cycle network can increase coherence for users.
- **Safety:** Busy arterial roads are often the main impediment to cycling. Removing safety risks to cyclists within the road corridor, or providing high standard alternative routes can greatly increase levels of cycling. Cyclists need to be protected from other vehicles travelling on the same road, and from other vehicles at intersections.

In Bogotá, Columbia, bicycles were allowed on all urban streets. These streets were however hazardous for cyclists and in 1998 bicycle trips were less than 1% of total trips. By 2001, after 250 km of new bicycle facilities were constructed ridership had increased to 4% of total trips. In the same period, traffic fatalities in Bogota fell from 2-3 a day to 1-2 a day, largely as a result of dramatic improvements in cycling and walking facilities.[18] In Bangalore the new 88 km long BRT 'Janmarg' was opened with cycling and pedestrian facilities all the way along it. Although there are some issues with the number of cross streets the system seems to be working well and has given a big boost to cyclists, who are a vanishing group in most Indian cities.[19]

Cycle lanes should be clearly distinguishable, perhaps in a different colour and using a different road material. In some countries cycling lanes are placed between parked cars and the footpath. Whichever side of parked cars a bike lane is located on, there should be a space between these cars and the lane that is wide enough for a car door to open without colliding with cyclists or forcing them into traffic. Cyclists should be protected at major intersections, preferably with traffic lights, which may have 'bicycle-jumps' to allow cyclists to take off first. Two (or more) lane roundabouts are not safe for cyclists because changing lanes in the roundabout in order to turn can be dangerous.

Unsafe cycling infrastructure has been identified as a particular barrier for women, who tend to be more risk averse than men and have greater responsibility for transporting children. Women also tend to carry a higher load of domestic tasks than men and therefore planning safe cycling routes should include connections between residential areas and places for shopping and education.[20] In cities with good cycling facilities like Amsterdam and Copenhagen women of all ages are regular cyclists.

- Comfort and attractiveness: Cycle facilities, whether on-road or off-road, need to have a smooth riding surface, as few as possible steep inclines, and little or no need for cyclists to stop and dismount. This can be achieved through good engineering design, appropriate materials, quality construction and ongoing maintenance.

  To be attractive, cycle routes do not necessarily have to go through scenic areas, but it helps if unattractive routes are avoided. Cycle routes are unattractive where users' personal safety may be threatened, such as isolated and badly lit routes. Community safety through environmental design (CPTED) principles should be applied to planning and designing cycle facilities, and more information about this can be found at www.cpted.net.

  Busy pedestrian pathways are also unattractive for cyclists, and thus cycle and pedestrian routes should only be combined if there is light use by both modes, and clearly separated if there is potential for heavier use.

Appropriate land use, development planning and regulation

Integrated land use and transport planning are essential if sustainable transport is to be achieved. Planning and regulation can help to ensure that walking and cycling are supported by the following conditions recommended by the International Bicycle Fund (www.ibike.org).

- safe and convenient access to education, recreation, shopping, services and other facilities
- secure parking areas for bicycles, [including at public transport stations], and encouragement of workplaces to provide changing rooms, showers and lockers for cycling employees
- mixed-use, higher-density urban development well served by public transport
- integrated public transport and cycling networks and facilities so that cycling can be a feeder mode for public transport, [and bikes can be carried on public transport]
- avoidance of massive parking lots that separate urban areas and the provision of public access routes through major developments to increase their 'permeability'.

More affordable bicycles

In many countries, bicycles are classified as luxuries and subject to high taxes and import duties, resulting in bicycles and spare parts becoming unaffordable for many potential owners. In 2002 Kenya scrapped

import duties on bicycles and components to make them more affordable to those most vulnerable to rising fuel prices.[21]

Moreover, in many countries the cheapest bicycle is not always the most appropriate one. Mountain bikes with multiple gears and off-road tyres – often the cheapest bikes available – are meant for infrequent, recreational cyclists. Their over-complicated components are not of sufficient quality or toughness for more regular use, and cyclists may not know how to repair them. More sturdy and appropriate bicycles are often much more expensive and spare parts may not be readily available. Thus, durable bikes for everyday use are often not accessible or affordable, unless they are made locally, as they are in India and China.

In response to this, in 2003 the Institute for Transportation and Development Policy (ITDP) designed the California Bike, an affordable, rugged bicycle designed for African conditions. The bicycle uses good quality mountain bike components, thus reducing later maintenance costs. A rugged design that can carry heavy loads is produced in a six-speed and single-speed model, the latter specifically aimed at rural areas. The ITDP works with a network of small bicycle distributors, and has partnered with the South African Department of Transport to make these bicycles available to urban and rural communities most in need. South Africa's Shova Kalula (Ride Easy) program has distributed thousands of subsidised California Bikes in poor rural and outer-urban communities to address high levels of transport disadvantage in these communities.

Developing countries should also consider the setting up of local bicycle assembly and/or manufacturing businesses, perhaps initially with the help of government and/or cycling support organisations. In this way bikes can be designed to suit local conditions and the budgets of local people. Such an appropriate

Figure 3.7 California bikes used in South Africa's Shova Kalula (Ride Easy) program

Picture Credit: www.qhubeka.org .

technology could be a realistic CDM project (see funding mechanisms in Chapter 4). As of 2006, two-thirds of the world's bikes were being made in China.[22]

Many people cannot save to buy a bicycle because they have little or no income, or a significant portion of their income is spent on transport. This issue can be addressed through the provision of low-interest micro-loans or through income generating projects. For example, a South African NGO, Qhubeka, has established small agri-business ventures to create income generating opportunities for subsistence farmers.[23] A bicycle is one of the first purchases for most participants in the program.

In Bogotá, Fundación Ciudad Humana, a local organisation, arranges for people participating in cycling education programs and city bike tours to get discounts on bicycles purchases from local vendors.[24]

Load-carrying bicycles or bicycle trailers, as illustrated below, can make a bicycle into a freight vehicle, allowing small farmers or traders to cart their produce to market at a fraction of the cost of motorised transport. Bicycles that can comfortably carry small loads and/or children (Figure 3.8) can increase the viability of cycling for trips to take children to school and do shopping, which are predominantly made by women.[25] These bicycles may however not be affordable for many who might benefit from them, and so here too low-interest small loans and income generating projects can promote employment and assist micro-businesses in transport disadvantaged communities.

Figure 3.8 Cycles are a practical solution for small cargo loads in local areas as well as carrying people

Picture Credit: www.workcycles.com.

Good access to servicing and parts

A major impediment to cycling, especially in rural and outer-urban areas, is the difficulty of access to servicing and parts. Urban residents may be able to walk to a shop to get spare parts, whereas more isolated cyclists may need to make a long trip on foot or by public transport. Even in urban areas there may not be anyone to fix the bicycle, or to do so at an affordable price. If cycling is to be a viable mode of transport for both rural and urban communities it is vital that they have access to affordable bicycle parts and maintenance.

The South African Department of Transport's Shova Kalula (Ride Easy)[26] program establishes bicycle sales and servicing micro-businesses in transport disadvantaged areas, in partnership with the local community. The program establishes each micro-business in a recycled shipping container, trains a bicycle mechanic and shop manager/owner, provides start-up capital in the form of bicycles, and works with bicycle importers and distributors to ensure a sustainable supply chain. By creating a network of these micro-businesses throughout the country, cycling becomes far more accessible in small rural communities. The benefits to these communities include improved access to education, employment and markets.

Better security

Bicycle theft and vandalism are major disincentives for cycling, so there needs to be safe parking for bicycles. New commercial and residential developments can be required to provide secure bicycle parking for employees, customers, residents and visitors, and government should work with local businesses to improve the security and quality of bicycle parking.

Security in informal settlements is often difficult and a bicycle can be especially vulnerable to theft. One strategy to reduce the risk of bicycle theft is to reduce the value of the commodity by making cheap bicycles readily available. The Bicycle Empowerment Network (BEN) in South Africa has partnered with non-government organisations in developed countries to recycle donated and discarded bicycles, and it sells or donates these in impoverished urban communities in the Western Cape.[27]

Changing attitudes towards cycling[28]

Among the biggest barriers to increases in numbers of people cycling are public attitudes towards it. The following are some attitudes, and some strategies for addressing these:

Individuals or cultural groups may believe any of the following: that cycling is just for poor people who can't afford motorised vehicles, that it for children, for men only, or for sports or recreation purposes only. Ways to address this include:

- Promotional campaigns showing males and females of all ages and socio-economic groups cycling to work or for other practical purposes in ordinary clothes and on 'city cycles' (that is, not sports or mountain-bike types). As part of this, people can be made aware of cycling's popularity as a mode of transport for males and females of all ages and classes in Northern Europe and elsewhere.
- Having political and community leaders and other high-profile people cycle themselves.
- Guided city bike tours and ride-to-work days.
- Being persistent and recognising that cultural attitudes rarely change overnight. But each person won over to cycling becomes, by their very example, a cycling campaigner with the potential to win over others.

People may believe that cycling is impractical because of the weather (too hot, too cold, too rainy), the terrain (too hilly), the exertion (it makes the rider sweaty), or the time it takes. Strategies for addressing these beliefs include:

- Citing the experience of other countries in which people cycle in warm, cool or rainy weather, including those of northern Europe where it sometimes snows.
- Identifying the proportion of days when the weather is actually unsuitable for cycling, as people may tend to exaggerate this. Many parts of developing countries have temperatures quite suitable for cycling. Cyclists can also check weather forecasts and use alternative transport on unsuitable days.
- Promoting geared or electric bikes in hilly areas. This was an approach taken in Valparaiso, Chile, given its hilly terrain.
- Provision of showers in workplaces.
- Provision of information about the actual time required for trips by bicycle and alternative modes.
- Encouraging people to try cycling out, individually or in organised cycling events.

People may see cycling as unsafe. Strategies for addressing this concert include:

- All the measures already described to actually make it more safe.
- Provision of information about the safest bicycle routes.
- Education about its actual level of safety, and about benefits to health and well-being.

Measures like these to try and change attitudes to cycling should incorporate the following features:

- Blending different methods: the affective (portraying cyclists as happy, free, modern, stylish, etc); the rational (presenting evidence-based arguments about cost, health, safety, the environment, etc); the practical (taking people on bike tours or showing them how to do basic repairs) and the social (doing things in groups, which reinforces the normality of cycling and makes it more fun).
- Organising events that address the situation of particular groups of cyclists or promote cycling in particular ways. For women, recent studies have shown that group cycling and cycling events also provide an important socially supportive environment that can encourage more women to start and continue to ride bicycles for transport.[29] In Bogota, Lima and Quito, Sunday cycling events and festivals are organised. Bogota's event, known as Sunday Ciclovia, involves the closing of 120 kms of city streets to other traffic.
- Getting the media on-side, as well as other sectors of society, such as businesses, academics and community organisations. Cycling organisations can be encouraged to form and given support. Corporate sponsorship of cycling events can be arranged.
- Educating motorists to respect cyclists and watch out for them.
- Educating children. Positive attitudes to cycling can be instilled at an early age by by including cycling and road safety education in the school curriculum and ensuring the provision of safe cycling routes to schools.

Other ways of improving the accessibility of cycling

- **Improvements to bicycle taxis:** Bicycle taxis have tended to be old, uncomfortable and seen as old fashioned. In some cities they are being phased out, supposedly for humanitarian reasons. The Institute for Transport and Development Policy (ITDP) has been working in India and Indonesia to

improve the design, reputation and regulation of bicycle taxis, and to build their image as an efficient, environmentally friendly and equitable means of transport.[30]

- In cities such as Barcelona, Brisbane, New York, and hundreds more in Europe, America and elsewhere, bicycle taxis or pedi-cabs are a small but popular, environmentally friendly way of getting around. If well-regulated to ensure safety and order and avoid an over-supply of them, they can improve the image of cycling.
- **Bike share schemes:** Bicycle sharing or hire schemes are very popular in European cities and are gaining popularity worldwide, with Mexico City, Rio de Janeiro and Santiago implementing them.[31] Most modern schemes require expensive infrastructure and extensive support but the cost of this can be partly met by membership fees and advertising on the bikes. If supported by a network of safe cycling routes they can raise the image of cycling and act as an extension to the public transport system. They are not as expensive as most urban road expansion programs and do offer considerable reductions in car use as has happened with Paris's Velib scheme.[32]
- **Electric bicycles:** As well as being useful for hilly terrain (as just noted), these are useful when there are heavy loads to be carried or when riders are not very fit. These may be more expensive than regular bikes, but they are less expensive than cars, motorcycles and motor scooters and so on balance are relatively cheap. In China the cost of an electric bicycle is 2,000 Renminbi ($290 US), which is cheaper than the cost of a scooter and faster than a peddle bicycle, at 20kph.[33] They still provide exercise, and are relatively quiet and able to tap into renewable energy. Chinese cities have very large numbers of electric bicycles. In 2008, customers in China bought approximately 90% of the 23 million electric bicycles sold worldwide, and even though there are 25 million cars on their roads, they have four times as many electric bicycles.[34]

5. Costs and sources of funds

Bicycling is an inexpensive and efficient form of transport compared with most other modes, particularly car use. As already noted, the cost of constructing cycle paths or lanes is about one-tenth of the cost of constructing roads. If included as part of the design for a new or upgraded roadway the cost will be a small fraction of the total cost of the roadway. Providing cycling lanes on existing roads can be cheaply done when resealing or restriping roads as part of regular maintenance. Building and maintaining cycling paths are ideally suited for labour–intensive methods and can be part of a job creation program with tangible transport benefits to communities. As already described in this section, a number of foreign and local non-government organisations assist people to meet the costs of buying bicycles, through low-interests loans. The development of cycling infrastructure can be financed from a range of sources, and these are described in Chapter 4. Concepcion, Chile, for example, obtained finance from the Global Environment Fund and the Chilean Government.[35]

6. Conclusion

Cycling is a cheap, healthy, efficient form of transport that only produces greenhouse gases in the production and distribution of bicycles, and it is very well suited to short to medium travel distances. It is also very inexpensive for cities and other localities to develop cycling routes, relative to the cost of other transport infrastructure. If measures are taken to provide this infrastructure, and to address issues of urban density, bicycle affordability, access to servicing, security, and the status of cycling, it is likely to increase in popularity as an important part of low-carbon transport systems in developing countries.

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C. Mass Transit

Peter Newman* and Robert Salter**

1. Introduction

Mass transit is a key ingredient in a sustainable, low-carbon transport future, whether in urban or rural settings, in developing or developed countries. It covers three modes of public transport: trains, light rail (or trams) and buses. Train systems include long haul trains (running at either normal or high speed), Metro (subway or elevated urban trains) and conventional suburban trains. There is also rail freight, which is discussed in the Freight section of this guide. Buses include bus rapid transit (or BRT) with dedicated road lanes and other distinctive features, and conventional bus services that share lanes with other traffic.

Figure 3.9 Light-rail, trains and buses are all key parts of the global transport future

Picture Credit: Claire Pendrous.

A good mass transit system provides services that are frequent, fast, punctual, safe, comfortable, clean and affordable. It provides transport at the times and in the locations that people require. The system is accompanied by good walking and cycling access to and from transit stations. Town planning measures complement good transit by encouraging higher urban densities and mixed land use, particularly near stops and stations. In this way, homes, workplaces, shops, schools, health centres, services and recreation facilities are closer to transit, and more people can use it as they go about their daily lives.

Middle Eastern cities are building $80 billion of new high quality transit including the new Dubai Metro and a service to do the Haj. China and India are now prioritising mass transit as the solution to their traffic problems with 82 Metros being built in China and 14 in India. Most other cities and localities around the world recognise – or are quickly coming to recognise – the economic, social and environmental necessity of good transit systems in the twenty-first century. On the other hand, many localities in the developing world

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do not yet have a basic organised bus service, that is, a coordinated, quality service that systematically covers the locality.[1]

2. Benefits of mass transit

Economic benefits

Mass transit can move large numbers of people at less cost to the individual and society. It is much cheaper to transport a large number in one vehicle than to move one person in each of a large number of vehicles. (While cars can potentially transport four or five people, in fact they only transport 1.52 on average, based on the 84 city survey described in Chapter 2.) Thus, it is not surprising that cities and countries that have high rates of mass transit use spend much less on transport overall than do localities where larger proportions of the population use private vehicles.[2]

Mass transit also makes it easier for people who can't afford private vehicles, or can't drive them, to get to workplaces, shopping areas and educational institutions. This means that more people are able to be economically active as workers, buyers and sellers, and as well-educated workers of the future.

Public transit and denser cities reinforce one another through a 'virtuous circle'. Transit moves large numbers of people in a smaller space, thus saving space and allowing greater urban density. Vuchic first set out the passenger capacity in the different modes. He suggested that a train service could carry up to 50,000 people per hour in a space that could only convey 2,500 car travellers per hour. In the same time and space light rail and BRT could both convey 10-20,000, while conventional buses could convey 5,000.[3] Since then, there have been data claims of over 40,000 passengers per hour on the Bogota BRT and over 80,000 per hour on the Hong Kong Metro and Mumbai rail system (which carries 10 million passengers a day). Such huge numbers are related to the density of these cities as only mass transit can adequately service places where space is at such a premium. In car-based cities densities are much lower. It is argued that viable transit requires densities over thirty-five people or jobs per hectare.[4] Moreover, the provision of transit, given its benefits, can further increase densities in its corridor.[5] Finally, a denser city's infrastructure costs less per resident.[6]

Social benefits

Mass transit's greater affordability,[***] and its accessibility for people too young or unable to drive, makes it a form of transport that more people can use to meet their needs: to get to health and other services, to make vital social connections and, as just noted, to work, shop and learn. Thus it is a factor leading to greater equality and social inclusion.[7]

Clean, efficient mass transit makes for healthier communities, because it is responsible for less pollution and fewer traffic accidents, and it encourages walking and cycling.

And communities with fewer private vehicles, an effective mass transit system and good walking and cycling routes are pleasant places to live in, with less congestion and noise, and greater levels of social interaction – all factors that have been shown to boost health and happiness.

*** Public transit in fact is often expensive and unaffordable for people on low incomes, but it is cheaper than car ownership, and the challenge for governments – discussed later in this section – is to make it as affordable as possible.

Environmental benefits

As well as using less energy and emitting less greenhouse gas than private vehicles do, mass transit has many other environmental benefits. As just noted, much larger numbers of people can be transported within a given space and period of time than private vehicles can transport, and this contributes to higher densities.

In denser urban areas, less energy and other resources are required per urban resident for the provision not only of roads, but also of all the other services these residents need – footpaths, bicycle paths, electricity, gas, telecommunication lines, water, sewerage, stormwater drainage, and so on. And in denser urban areas people travel shorter distances for work, shopping, leisure and social purposes, and this leads to further energy savings.

And despite being denser, if cities have clean, efficient mass transit they will have less of the crowding, noise and pollution that cars, motor-bikes, motor-scooters and other private vehicles generate. Pollutants like particulates from diesel are major causes of asthma and other respiratory diseases. A well-designed mass transit city will also have good networks of safe walkways and cycleways to enable residents to walk or cycle for short trips, or to walk or cycle to transit stations for longer ones. These non-motorised means of travel are of course completely non-polluting and, to the extent that they replace trips using other transport modes, they help to reduce overall pollution and greenhouse gas emission levels.

3. Greenhouse gas emissions reduction potential

Details of the variations in mass transit CO_2 equivalent emissions are given in Chapter 2 to show how they vary across different cities. The summarised energy efficiency data by mode in 84 cities are provided in the table 2.8.

In some cities exceptionally low energy usage can be found, such as 0.05 MJ/pass-km in Chinese light-rail, due mainly to high loadings. When estimating greenhouse gas reduction potential from mass transit it is also necessary to consider the 'transit leverage' factor, the tendency for every kilometre travelled on transit to replace between 5 and 7 kilometres of total travel, which is described in Chapter 2.

4. Implementing a good transit system

Complementary and integrated modes

Good public transit is designed as a whole system. For example, trains or BRT will move larger numbers of people longer distances, and then bus services, with shorter trips and fewer passengers, will radiate out from transit stations. BRT and Light-rail may exist as an in-between mode in terms of its passenger capacity and route lengths, and local buses can complete an urban transit network, linking fast cross-city services to corridor services and local routes. As part of this integration of transit modes, timetables, ticketing and information provision will be integrated, so that a person can use two or three modes to travel from departure point to destination easily, without long delays, and on one ticket (see the section *Influencing travel choices*). New technologies also assist with network planning, organisational management and integrated ticketing.

The following are some salient features of the different transport modes:

- **Train systems:** These can carry 50,000 (perhaps even 80,000) passengers per hour in one direction on one line, and are suited to major arterial urban routes, as well as regional and long distance travel. Costs vary enormously depending on whether it is a Metro system (with a subway or overhead line), a fast rail system, or a conventional speed system at ground level (which is the least expensive). But even normal speed trains can be faster than alternative modes. Bangkok has a new train system travelling through and above its crowded streets at speeds reaching 60 kilometres per hour, averaging 25-45 kph compared with the Bangkok traffic speed of 14 kph and bus speed of 9 kph.[8] Rail lines can be built down the middle of freeways, as in Perth and Oregon.

Figure 3.10 Tainan High Speed Rail Station, Taiwan

Picture Credit: Kok Leng Yeo.

- **Light rail systems:** These can carry 10-20,000 people per hour down one corridor, and thus they are suited to routes that have fewer travellers than train systems can carry, but more than bus systems usually can. They normally take up the equivalent of one traffic lane, a lane which, as previously noted, can only carry 2,500 car travellers an hour. Light rail is attractive to cities wanting to regenerate corridors or to provide a higher capacity system where there is space in the roadway. The latest models no longer require overhead wires, as batteries can be recharged at stops.
- **Bus systems:** These include conventional buses, which must share lanes with other traffic, and normally only take a maximum of 5,000 passengers per hour on one route. Conventional buses are a critical part of any city's transport system as they offer flexibility and linkage to the faster, higher capacity mass transit systems. New technology buses can provide a safer and more comfortable service and with GPS installed can enable passengers at bus stops to know exactly when they are arriving.
- **BRT systems:** Bus Rapid Transit (BRT) has increasingly been used to provide a faster, higher capacity bus service.[9] BRTs require dedicated lanes, off-road stops, rapid boarding and alighting, level boarding, pre-board fair collection or checking, frequent service, large capacity, clear signage and real-time information displays, clean engine technologies, signal priority, intelligent control systems and excellent customer service. In one dedicated BRT lane 10-20,000 passengers can be carried – with some carrying over 40,000 – but at higher levels there is a risk of buses 'bunching' at stops. This problem can be reduced with multiple doors on the bus and well-designed stations, as occurs in Curitiba. Cities like Curitiba, Bogotá and Ottawa have examined moving to rail to solve this problem. There can also be problems with noise and emissions. BRTs can be cheaper if they take over a road lane, although this can be a difficult political issue in cities. Other cities with BRTs include

Bogotá, Mexico City, Jakarta, Beijing, Kunming, Chengdu, Guangzhou, Istanbul, Ahmedabad (India), Paris, Los Angeles, Pittsburgh, Miami, Boston and Brisbane.

Advantaging transit

To attract passengers, transit needs to be faster than cars on the same routes. This is why it helps if trains travel at high speeds and have grade-separated intersections with roads. BRT and light rail need dedicated lanes and priority traffic signals to achieve this required speed advantage (Figure 3.11). Moreover, there is little point in having fast travel speeds if passengers have to wait a long time for the transport to arrive. This means frequent services and integrated timetables for the different modes so that, for example, a person switching from a train to a bus has minimal waiting time. Mass transit will also have a speed advantage over private vehicles if city governments refrain from building more and faster roads. While this may increase traffic congestion in the short term, the intention is that such congestion will encourage private vehicle users to switch to the faster transit services. And making private vehicle travel more expensive – through, for example, petrol taxes, registration charges or congestion taxes – achieves two things: it recovers some of the environmental and social costs of private transport, and it is another measure to encourage people to switch from private vehicles to transit.

5. Town planning and transit oriented developments (TODs)

Transit oriented developments are areas of new development around BRT and train stations that feature higher density residential complexes and a mix of other land uses, for example, shops, workplaces, educational institutions, health facilities and other services, as well as good walking and cycling paths. TODs can reduce car use by around fifty percent, save money on infrastructure, and encourage community interaction.[10]

TODs can occur where there are 'greenfield' (new) sites 'brownfield' (old industrial) sites or 'greyfield' sites (redeveloped old housing areas). TODs should include a range of housing types, including affordable

Figure 3.11 Luas Light Rail Train in Dublin

Picture Credit: C. G. P. Grey, Wikimedia Commons, http://commons.wikimedia.org/wiki/File:Ireland_-_Dublin_-_Tram.jpg viewed 22 March 2011.

Figure 3.12 Bus Rapid Transit can, as this Bangkok street scene demonstrates, move passengers to their destination much faster than ordinary buses – and private vehicles

Picture Credit: Karl Fjellstrom, itdp-china.org.

housing for those on low-incomes. The increased value of TOD properties can be used to help fund the mass transit system, a process known as 'value capture' that is discussed below (and TODs are described in more detail in another section of this chapter).

Not every area can be a TOD, however. In other parts of cities the challenge is to make changes within an already established infrastructure of buildings, roads and other features. Over time, with new developments and altered building uses, higher densities and more mixed land use can be permitted and encouraged. Existing thoroughfares can be used for walking and cycling paths and dedicated transit lanes. Traffic can be restricted and calmed through a variety of measures. And available land and buildings can be used for parks and other community facilities. All of these measures complement good transit systems and make them more viable.

Raising the status of mass transit

Mass transit sometimes has an image problem. It can be seen as a second-rate form of transport, used only by those who can't afford their own vehicles. However, this image is changing rapidly, as modern mass transit is attractive, clean, comfortable, safe, fast and frequent. The stations as well as the transit vehicles need to be of a high standard (Figure 3.13 & 3.14). Climate control can make a big difference, as can proximity of stations to shops and other attractions. Sophisticated marketing can also lift patronage. Such measures will counteract the growth in many developing world cities of very car-dependent greenfield housing estates and gated communities.

Modern transit services in all parts of the world amply demonstrate that people at all levels of society will choose mass transit if the quality is good. In fact, rail-based cities in the 84 global cities sample are 40% wealthier than non-rail-based cities.[11] There has been a big growth of new transit systems in developed countries, including the United States and Australia, with railways being built, for example, in over 100 US cities. Many parts of developing world have an advantage in that cities are already dense enough to make transit very viable, and transit does have to compete with such a high level of private vehicle use.

Figure 3.13 Modern Metro station in Shanghai

Picture Credit: Karl Fjellstrom, itdp-china.org.

Good quality bus systems also raise the status of mass transit, providing high quality services and infrastructure. The newer systems include well segregated bus lanes, accessible and enclosed stations with prepayment and level boarding, lower emission buses, integrated information systems for centralised control and user information, and a distinctive image.

6. Intercity, regional and rural transit services

Modern mass transit is just as important for towns, villages and rural areas as it is for cities, and it is also vital for intercity transport. The absence of sufficient transit services outside and between cities has two major adverse effects.

Firstly, it means continued high levels of use of less sustainable modes of transport, including trucks, cars, motor-bikes and air travel. Although air pollution, such as particulates from diesel, may not have as severe

Figure 3.14 Modern BRT station in Guadalajara, México

Picture Credit: CTS Mexico.

an effect in the countryside as it does in the city, greenhouses gases are just as bad wherever they are emitted. And petroleum, a limited resource, is still being depleted. Moreover, traffic accidents in rural parts of the developing world are a significant cause of death and injury.

Secondly, it puts a real brake on national development, and on the ability of ordinary people, especially for the poor, to carry out normal daily activities. Most people cannot afford their own vehicle. Therefore they must rely on walking, on the existing less than adequate public transit services, on animal transport, or on various kinds of three- and four-wheeled vehicles adapted to carry passengers, vehicles that may not be available and affordable when they are needed. This means that it's much harder and takes much longer for children to get to school, for the sick to get to health services, and for people to get to jobs. An estimated 75% of maternal deaths could be prevented through quicker access to childbirth services, facilitated by transport, and girls' enrolment in school can more than triple with the completion of a rural road (which is, of course, a precondition for a bus service).[12] Hours and even days can be wasted walking or waiting for infrequent transport services.

Thus there is a need for good train services between cities or towns, and for more bus services to radiate out from train stations and population centres into outer urban localities, villages and rural areas. If developing countries can afford rapid trains these will be more competitive with cars and air transport, but the cost, of course, is more.

7. Selecting and implementing the right transit modes

In choosing the most appropriate transit modes for particular localities, planners and communities need to consider a range of factors. These include cost, population density, and whether there is space to build railway lines or dedicated lanes for BRT or light rail. These factors should be considered very carefully from the outset, because experience indicates that once cities or localities select a particular transit mode they tend to stick with that and not adopt other modes later.[13]

Mass transit systems represent a large public investment. If you are making this investment for your locality, you need to ensure that the public – who will ultimately be paying the cost – are aware of the full range of benefits mass transit provides, because greenhouse gas reduction may not be high on their list of priorities. There are many other benefits to tell them about: faster, safer, more comfortable travel; less traffic pollution, congestion and noise; fewer people killed or injured in traffic accidents; cheaper transport for the nation and for individuals, especially people on low incomes; a more pleasant city in which to live and move around; healthier and more connected residents; and a more efficient transport system to service a twenty-first century economy.

Given the systemic and technological complexity of modern integrated transit systems, developing the necessary capacity to plan, construct and operate such systems can be a major challenge. One solution is to form a partnership with a locality that already has such technologies and systems in place. For example, the city of Kunming in China is twinned with the Swiss city of Zurich and, as one part of this, the Swiss partners have helped to build the capacity of their Kunming counterparts in the transport area. This has seen the development of a transport master plan, and the design and implementation of a BRT system.[14]

8. Costs of transit systems and sources of finance

Comparing the costs of various modes of mass transit is fraught with difficulty as so many local factors can make costs vary hugely for each mode. The costs of going above ground or underground are always

higher than on-ground though this may just not be possible in some dense cities. The main consideration is the capacity of the system to attract patronage and the mode that is best able to do that needs to then be assessed against the costs of the cars that will be cramming the city if the system is not built. High capacity systems like fast rail (regional, Metro and suburban) are most expensive to build, but will take the highest proportion of car travel out of the urban system, and this can be demonstrated to provide higher benefits than costs.[15] And transport that is more costly to build may also be cheaper to run.[16] When assessing the benefits and costs of mass transit, many factors need to be taken into account, including predicted travel time savings, reductions in fuel, pollution and accidents, and space saved when the city builds up around the transit infrastructure (known as 'agglomeration economies').[17]

A rapid train system costs about the same per kilometre as a freeway, whether the train or freeway are at ground level, underground or above ground. Perth's new southern train system costs much less than a normal freeway to build ($A17 million per km) and frequently carries the equivalent of eight lanes of traffic.[18]

Transit systems can be financed and managed through public-private-partnerships, with private partners building the system, operating it, or both. When the transit system in Buenos Aires switched to private operators, patronage doubled over a five year period and the budget burden of the system was reduced by nearly US$1 billion per year.

Systems can also be financed through land development, as mentioned in the TOD section. Real estate above and around transit stations can be sold by government or private developers to help finance the transit system. Such property will sell for a higher price because of its closeness both to good transit and to the many facilities clustered around transit stations. It will tend to keep its value in bad times and appreciate faster in good times. Hong Kong and Tokyo financed their rail systems in this way, and many US cities are using Tax Increment Financing based on land development to fund new rail projects. In relation to Hong Kong, see *Rail and Property Development in Hong Kong: Experiences and Extensions.*[19]

Public funds may also be available through the World Bank, regional development banks or bilateral development cooperation arrangements. In addition, climate change funding mechanisms may fund transit projects, specifically, the Clean Development Mechanism (CDM) and the Global Environment Facility (GEF). These are described in more detail in Chapter 4.

Transit operating costs can of course be at least partially covered by passenger fares. Almost all modern public transit systems are subsidised by government, and each city or locality must decide the amount of subsidy it can afford to provide. Making transit affordable for all socio-economic groups should be a high priority, and one option is to offer concessional fares for specific groups, such as older people, children and those out of work or unable to work. In this way public support is being targeted at those who might not otherwise be able to afford the transit.

9. Conclusion

Mass transit is critical to the proper functioning of any city, town or rural area. A range of transit modes offer different capacity opportunities, and therefore the potential for high or low impact on car use. Higher capacity systems cost more to put in, but offer much more potential reduction in total transport costs and greenhouse gas emissions. The social, economic and environmental costs of *not* having an efficient mass transit system never go away, so it is really a case of stemming these costs earlier or later.

Endnotes

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16. See, for example Agence Française de Développement (AFD) and the French Ministry of Ecology, Energy, Sustainable Development and the Sea (MEEDDM), *Who pays what for good transport? Handbook of good practices, CODAU,* 2009, http://www.codatu.org/english/studies/handbook_good_practices.pdf, viewed 23 Feb 2011. Figure (p 13) and Figure 3 (p 14) show how trains, though more expensive to build, are cheaper to run, especially if they have high carrying capacities. It should also be noted that there are much cheaper rail options than MRT if countries cannot afford this.
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D) Influencing Travel Choices

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1. Introduction

Travel is complex in the modern world, especially in cities. There are a large number of ways of getting around: cars and taxis and auto-rickshaws; bicycles, motor scooters and motorcycles; buses, trains, light-rail and ferries; and of course on foot. These are just the more common modes of transport; many others are variants of or additional to these.

Travellers tend to pick one or a few modes of transport and stick with them. They get to know the ins and outs of these modes: the routes they can travel, how long trips take, how much they cost, how frequently they operate, and so on. They will routinely take the same modes of transport each time they go to work, or to school, or to the shops.

The trouble is, as this guidebook outlines, the transport modes people habitually take may not be the best ones for the environment (especially in the face of the global warming threat), for society, the economy or even to meet their own needs for cheap and fast travel. Governments and national leaders therefore need to ask how travellers can be assisted and persuaded to switch to the most appropriate mode for each trip. Of particular interest in the context of this guidebook is the question of how to encourage people to use sustainable, low carbon transport modes, in particular, mass transit, cycling and walking. This section, 'Influencing travel choices', seeks to address this question, specifically by focusing on:

- information provision, especially about the routes, timetables and costs of mass transit services, and about cycling routes
- behaviour change programs, which employ a range of methods to encourage and assist people to use more sustainable low carbon transport
- integrated ticketing for different modes of mass transit, which make multi-modal travel easier.

Modern information provision systems, behaviour change programs and integrated ticketing have, to date, been applied more in developed countries that in the developing ones. This is in part because the problem of car dependence is much worse in developed countries, leading to far greater greenhouse gas emissions per traveller, and concerted efforts are required to encourage the switch to other modes. But with rapid economic growth in many developing countries, the increase in car and other private vehicle use is dramatic. For example, vehicle sales in China rose from 5.1 million in 2004 to 13.6 million in 2009, with an estimated 18.6 million sales in 2010.[1] India's *Nano*, retailing for $US 2500, is expected to usher in mass car use in that country. Other developing countries will see accelerating economic growth in the future. Of course, citizens in these countries have as much right to use cars as in developed countries, but the world as a whole needs to travel more sustainably and cities need to avoid the costs of congestion, pollution and traffic accidents that are associated with high levels of car use. Among other measures, this involves dramatically reducing car use (predominantly in developed countries) or avoiding car dependence in the first place (predominantly in developing countries).

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There is, therefore, a clear need for measures to encourage and facilitate sustainable travel choices in both developed and developing countries. And all the measures described in this section have proven to be feasible and effective in locations in which they have been applied. Behaviour change programs in developed countries have been shown to reduce car trips by 10% or more across neighbourhoods targeted by such programs, as well as increasing walking, cycling and public transit use, and these programs have also saved around $30 (in socio-economic costs of pollution, congestion, health and fuel) for every dollar they cost.[2] It is harder to assess the difference that good information provision and integrated ticketing systems have made because these features tend to be applied across whole transport systems alongside other improvements to those systems. But modern transit systems in most developed world cities have instituted these measures over the past five years and dramatic increases in public transport use are now being seen in US and Australian cities and in most European cities while car use per capita is declining for the first time. This transformation is due to a number of factors but these include the provision of smart cards, integrated ticketing and modern information systems.[3] In the US, vehicles sales declined every year between 2004 and 2009, from 16.9 million sales in 2004 to 10.4 million in 2009.[4]

There are many other ways of encouraging or enabling people to travel more sustainably, for example, through better urban design, more extensive walking and cycling paths, other improvements to transit services, the development of electric vehicles, pricing and parking policies to discourage private vehicle use, and traffic management that prioritises the most sustainable modes. These all complement the measures in this section, and are described in other sections of this chapter.

2. Benefits to be gained from these measures

Economic benefits

Greater use of mass transit, walking and cycling, and reductions in unnecessary travel, mean less money spent on transport by both individuals and whole societies. As well, those who cannot afford private transport can participate more fully in work and education if they have the opportunity and capacity to use other transport modes.

Social benefits

Measures to facilitate lower car dependence can lead to better health, from increased walking and cycling, from fewer accidents and from reduced pollution. Neighbourhoods in which there is less car use also tend to have higher levels of social interaction.

Environmental Benefits

The measures described in this section can lead to reduced local pollution, greenhouse gas emissions, noise, congestion and use of finite resources.

3. Potential reductions in greenhouse gas emissions

If people travel less because they eliminate unnecessary trips or they walk or cycle, then they save 130-170 grams of CO_2 e for each kilometre not travelled by car. If they switch to transit they cut greenhouse gas emissions to a half or a third of what it would have been in a car, as described in Chapter 2. In fact the reduction may be much more due to ‘transit leverage’.

4. Implementing measures to influence travel choices

Information provision

To use trains, buses, light-rail and ferries people need to know where they run, when they run and how much they cost. It is also very useful to know the actual time of departure from the stop or station – which may vary from the scheduled time - and this can be supplied through real time information processes. Information can be provided by paper timetables, phone enquiry services, static signage and staff at stations or in vehicles, as well as through digital signage, on-line sites and mobile phone applications. Different kinds of information can be available in different places and through different media as appropriate. For example, digital displays and audio messages on transit can tell passengers the name of the next station, while the actual time of departure can be viewed on a digital display at the station (Figure 3.15), or via a mobile phone application as the traveller approaches the station or stop.

Travellers may need to use multiple modes of transit, as well as walking or cycling, to get where they want to go, and so they need to know how they can make their trip as quickly and directly as possible. This requires information about the routes, times and costs of the different transit services. Transport authorities can set up a service themselves that collates and provides such information, or they can do so in conjunction with a third party such as Google Transit, as is discussed below.

Providing good information systems for the public is critical. It not only increases existing users' confidence in the service; it also encourages those not using transit to consider it as a viable option. Passengers' experience of public transport is influenced by the ease with which they are able to navigate themselves

Figure 3.15 In Antwerp, Belgium, a digital display advertises when the next buses will arrive in real time

Picture Credit: Karl Fjellstrom, itdp-china.org.

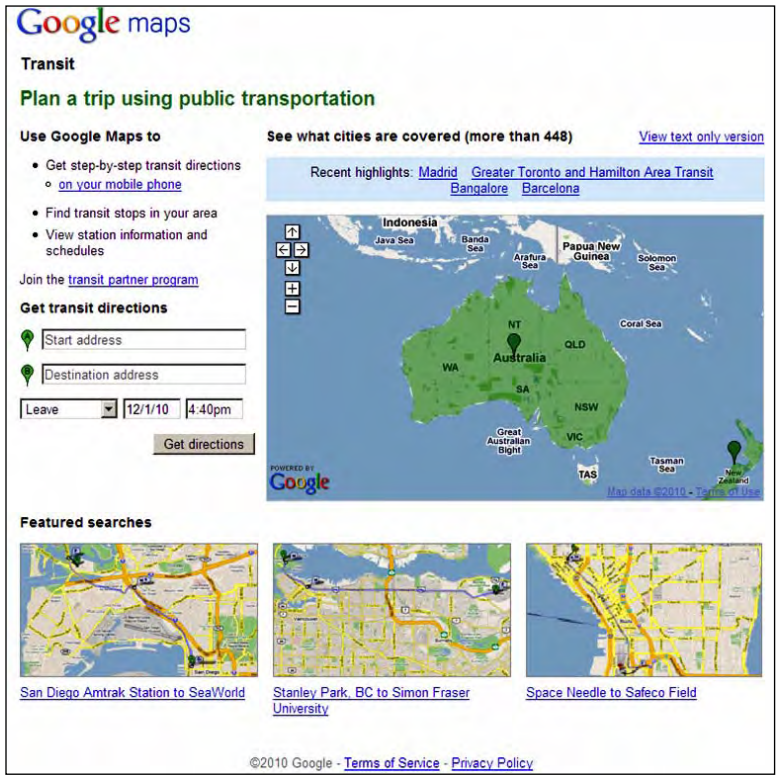
through the system, and this is best achieved through the provision of different information systems catering to the different needs and preferences of users at the various stages of the journey (pre-trip, at stops or stations, in transit vehicles, at any points where the traveller must switch to other transit modes, and at the destination).

Public information systems are only as good as the quality of the data fed into them. The end result of poor data will always be a lack of confidence in the information system. And when data is managed in multi-modal systems, perhaps with different private companies and government agencies involved, there is always the risk of incorrect information being supplied to the public. The answer is to have, where possible, a single data management system that all the various information systems are a part of. This will minimize the chance of incorrect information being given to the end user.

Good data management is critical to success when implementing and integrating advanced information systems, as well as other systems requiring access to this information. These systems can include integrated smart ticketing systems, real-time passenger information systems, and intelligent transport systems (ITS's). ITS's, which are becoming more common, attempt to improve public transit services by reducing congestion, improving passenger and driver safety, and increasing the amount and quality of information available to the public so that they, in turn, can make more informed decisions when using transit.

One consideration often overlooked in transit information systems is the provision of information in a way that is accessible to people with disabilities. Depending on the types of disability passengers have, they may require information to be provided in visual, audio or tactile forms, and of course consistency of information across these different forms is also important. Travellers who are not functionally literate will also need information to be conveyed verbally or via visual symbols.

Figure 3.16 Google Transit can plan a multi-modal journey from departure point to destination



Source: www.google.com/transit.

Increasingly, transport agencies are recognising the benefits of allowing the public to access information via third party products and services. For example, Google Transit (Figure 3.16) is a free and relatively simple way in which people can access transport information, at very little cost to the public transit provider. Google Transit can provide information on transit routes, times and costs. It is now fully integrated into Google Maps and currently has at least some information about transit services

in, among other countries, Mexico, Colombia, Brazil, Chile, South Africa, Egypt, India, Thailand and China. This system, which can be included on transport agency websites, can enable users to type in a point of origin and a destination and be given several options for making the trip, by multiple modes if necessary, with the routes, distances and times of the different modes, as well as distances and routes for any walking required.

If cycling is to be encouraged, information about safe cycling routes also needs to be publicly available, in paper and electronic forms as well as via street signage. And if there are walking routes that are additional to the normal footpaths beside roads, these will need to be publicised as well.

In the past, when urban populations were static or grew slowly, and there was much less growth and innovation in transport services, these populations learned fairly naturally and easily how they could get around, in the context of growing up and living in their urban communities. But today, as tens of millions of people migrate to cities every year, and as new transport systems are created, partly to cope with this influx, more deliberate methods of disseminating information are required. It is vital that new migrants to cities are able to access information about the more sustainable forms of transport as soon as they arrive – rather than the less sustainable ones – so that these can quickly become their habitual ways of moving around.

Behaviour change programs

In cities in both developed and developing countries the car provides a strong visual demonstration of social status and the potential benefits of travel comfort. However, using the car brings higher costs, traffic delays and stress to the driver. Community Based Social Marketing[5] programs help consumers to explore the barriers and benefits of transport choices and to really understand the gap between the aspirations (as portrayed in car advertising) and realities of car use. Rates of car use are much higher in developed countries, but there is a serious risk that these rates will substantially increase in developing countries as a result of rapid economic growth and urbanisation, and so pre-emptive action is necessary. Let us, therefore, look at how successful behaviour change programs operate in developed countries, and then briefly consider how these might be adapted to developing world circumstances.

In car dependent cities up to 80% of trips are made by car and around 60% of the population will have not used alternatives to the car at all on any given day.[6] Providing information alone is insufficient to influence the majority of car users who are not seeking to change modes. The impact of information and services relating to alternative modes is limited by the barriers to changing modes, including a lack of awareness, acceptance and experience of the alternatives. It is in addressing these barriers that travel behaviour change programs have a strong role to play. The research[7] and practice[8] of travel behaviour change programs reveals that voluntary behaviour change requires:

- positioning of travel alternatives as ‘normal’ activities that are being adopted by many others in the community
- coaching conversations to enable individuals to identify their own motivations for change (these may be to contribute to reducing climate change, improve personal health, save money, reduce stress, reduce travel time or many other personal benefits)
- providing information in the context of the new conversation around changing modes
- prompting behaviour change at the point of decision, such as messaging on a key chain for the car keys
- interrupting the current driving behaviour through special events or at life changing moments such as a new job or moving house

- engaging people in making commitments to themselves and sharing them with the behaviour change coach, a partner, friend or colleague, and
- enabling the intrinsic rewards (more time, better health etc) of the new behaviour to be embedded through reflection and conversation.

The same approach can be taken in developing world communities that have a level of car dependence, but where it has not reached this stage there will of course be significant differences, although focusing on the barriers and benefits of different transport modes, and on the gap between aspirations and realities of car travel will be common to both. In China there is a new awareness of the need to control the growth in numbers of vehicles on the road as the rapid growth in cars threatens to undo many of the advantages in their recent economic growth. They have implemented an odd-even number plate day to reduce cars allowed onto the road and a number of programs are beginning on behaviour change. The National Energy Saving Handbook in 2007 was implemented, first in Shanghai and other big Chinese cities. Part of this was aimed at enabling people to reduce their car use.[9]

The important thing is for the planners of behaviour change programs to start with local circumstances, and to explore (through surveys and interviews) the realistic transport choices that are available to the community for different trip purposes, destinations and times of day. Where there is choice, and the alternatives to the car (or other motorised vehicle) offer benefits to the individual, there is potential for travel behaviour change.

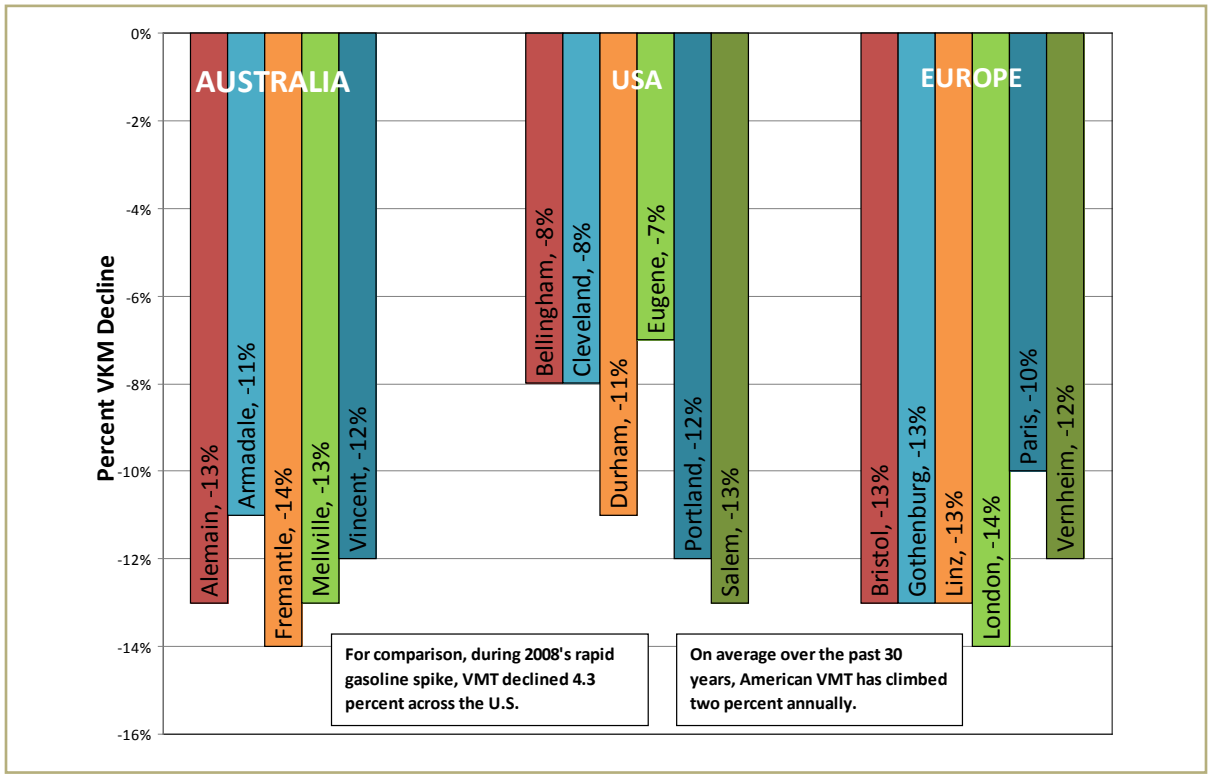
Behaviour change programs in places like schools and work places provide an opportunity to apply many of these points about successful behaviour change. People in these settings already know one another and have things in common, so group norms influence the individual's behaviour. When it comes to changing their travel behaviour, they can get practical information about alternative forms of transport and try these out together, giving each other help and support.

TravelSmart is a behaviour change program that has worked mainly with individuals and households, because it is in the home setting that all car trips (those for work, education, leisure, shopping etc.) can be discussed to identify the ones most easily changed to an alternative to the car. This program, designed to reduce private car use, is now being applied across the world. It encourages people to use other modes of transport, to make shorter trips, to use the one trip for a number of purposes, and to travel at times when roads are less busy. It can be used in conjunction with pricing policies, regulation, and investments in mass transit and facilities for walking and cycling.[10]

In Western Australia, *TravelSmart's* work with households involves assisting them to identify what motivation and information they need in order to reduce their car use – for example, information about the times, routes and costs of bus or train services, or the locations of bicycle routes – and then it supplies this information to those households. *TravelSmart* follows them up to see how they are going and to encourage further change. Support is provided verbally, as well as in printed form and on-line at http://www.travelsmart.gov.au/.

TravelSmart programs have consistently delivered reductions in car trips of 10% or more, as well as increases in walking, cycling and public transport use[11]. In Perth, Western Australia's capital city, it has worked with more than 450,000 residents, at a cost to the state of under A$36 per resident. Worldwide, individualised approaches to travel demand management have been delivered to approximately five million people.[12] If you take into account the reductions in the public and private costs of car use that it has achieved, the program saves $30 for every dollar it costs.[13] The increased public transport fare revenue

Figure 3.17 TravelSmart programs have delivered real reductions in car use across the developed world



Source: Department of Planning and Infrastructure, Government of Western Australia.

alone can recover the costs of *TravelSmart* in less than five years. When delivered in association with new or improved public transport services *TravelSmart* adds 40% more patronage than occurs with new services alone.[14] And on average, each program participant produces 225 kg less carbon dioxide from their travel each year.

TravelSmart contributes to the establishment of new social norms and helps to build communities that are more able to use alternatives to the car. It works best when there are opportunities for people in a locality to use other modes of transport. In preparing for a behaviour change program of this kind it is important to research the barriers and benefits of the different transport modes available, to work out how best to communicate with the target audience, and to collect data on transport usage before and after involvement in the program to see how effective it has been. A guide to implementing *TravelSmart* type projects has been produced in the UK.[15]

The *TravelSmart* model has led to the development of a broader behaviour change program called Living Smart,[16] which deals with a broader range of changes which people can make in order to live more sustainably, including – as well as travel – home energy and water use, the products we buy, recycling, food gardening and community building.

It's good if more sustainable travel habits can be established from an early age, and the 'walking school bus' program does just this. A 'walking school bus (Figure 3.18)' is a group of children walking to or from school with one or more adults supervising them. It can be informal – two or more families taking turns to walk their children to school – or more formal, with a planned route, a timetable and a roster of volunteers.

Figure 3.18 Walking School Buses provide safe, healthy travel to and from school and thus provide a grounding for the young in sustainable transport

Picture Credit: Missouri Bicycle & Pedestrian Federation/mobikefed.org.

Children can be 'picked up' or 'dropped off' along the route just as a regular school bus does. A variation is the 'bicycle train' in which adults supervise children riding their bikes to school. Walking or riding to and from school provides valuable exercise for children. It enables them to learn early that walking and cycling are very practical, pleasant and healthy forms of local travel. At the same time, the adult supervision that walking school bus schemes provide ensures that children – especially very young ones – are safe, thus overcoming a barrier that causes parents to prevent their children from walking or cycling. The experience of walking or cycling teaches children about their neighbourhood and environment, as well as gaining road safety skills and equipping them for independent mobility as they get older. Finally, these programs, if they are supervised by parents or volunteers, involve virtually no costs.[17]

In Santiago, Chile, a behaviour change program initiated by the Ministry of Planning has been trialled in a range of settings: a school, a factory, the city government, and a government department. It has sought to reduce car use because of the serious air pollution this is causing. The program used a method called 'travel blending', which involved diary keeping and discussion. In the school, students discussed their personal travel in class and then with their parents at home. Alternatives to car travel for the children and their parents were considered and tried – initially for perhaps one day a week. In these pilot programs between 60% and 90% of employees and students who were able to participate did so, and the program has since been extended to other organisations in Santiago.[18]

These are just some of many community based social marketing approaches that can change people's travel behaviour. Through such approaches, people can be encouraged and assisted not only to change their *personal* travel habits, but also to become active in supporting and promoting change at business, community and government levels, so that the quality and availability of low carbon transport can be increased.

Integrated ticketing

It is much easier for travellers to use a multi-modal transport system if they can buy one ticket that entitles them to travel on different modes to get to their destination, and this is now happening in many cities and localities. Such a system does not have to employ the latest smartcard technology, though this is ideal. Even if it uses a lower technology ticketing solution, the key is to allow passengers a seamless journey on a well-planned and integrated system with, for example, bus routes radiating out from train stations.

Hong Kong's Octopus Card is used by 95% of adults there between the ages of 16 and 65, generating over 11 million daily transactions.[19] As well as its use for all forms of public transport, it can be used in stores and restaurants and for a range of other transactions.[20]

Transperth in Western Australia provides another example of an integrated ticketing system. It is run by the Public Transport Authority of Western Australia and covers bus, train and ferry services for the state's capital city, Perth. At the core of the system is *SmartRider,* a fully integrated smartcard ticketing solution providing travel and transfers across modes. Users can top up the credit on their *SmartRider* cards at transit stations, on buses, at selected stores and through on-line transfers from their bank accounts, including, if they like, automatic transfers when the credit dips below a certain level.

Figure 3.19 Adding value to the Octopus Card in Hong Kong. The card can be used on any form of public transport (e.g., bus, metro, train, mini-bus, tram and ferry)

Picture Credit: Karl Fjellstrom, itdp-china.org.

The Public Transport Authority provides the central control and future planning for all *Transperth* services, while the bulk of those services are delivered by commercial contractors on five to ten year contracts tendered on a staggered basis. This regular testing of the commercial service delivery market ensures good value for money in the context of a finite budget, and also promotes a strong focus on high-quality customer service. The key to the model is having the transport authority maintaining control of the system's management. Services within the system may be contracted out, but the transport authority sets specifications and standards that must be met, manages the awarding of contracts, assesses contractor performance, and undertakes planning to ensure that the system is an integrated one with complementary transport modes and devices such as integrated ticketing to ensure ease of use by travellers.

5. Costs and sources of finance for these measures

As already mentioned, *TravelSmart* in Perth has been delivered at a cost of less than $36 per participant, and the program saves $30 for every dollar it costs. *TravelSmart* in Western Australia has been funded by the various agencies that benefit from the outcomes, including the state Departments of Transport and Environment, federal departments of Environment and Health, local governments and private bus operators. The major costs of delivering *TravelSmart* are the labour costs of telephone coaching and information delivery teams, and as such the costs and benefits of delivery in developing countries may be estimated based upon the relative difference in wages and public transport fares between the developing country and Australia.

Costs for information systems and integrated ticketing are difficult to separate from overall costs of building modern transit systems, and are frequently not disclosed for commercial reasons. However, if particular transit services are contracted out by government, then these are not costs that the government has to bear because they are part of the user fares.

6. Conclusion

Information systems, behaviour change programs and integrated ticketing all, in different ways, help travellers to switch to more sustainable travel options. Between them, they raise awareness about these options, encourage and support travellers as they try them out and, on an ongoing basis, enable them to use often complex systems with relative ease in order to meet their transport needs. Of the information based options, travel behaviour change (community based social marketing) provides the strongest return on investment. Although rare in the developing world the first signs of behaviour change programs are appearing.

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Reducing Overall Travel

e) Transit Oriented Development

Mark Bachels* and Peter Newman**

1. Introduction

Transit Oriented Development (TOD) is a policy process that links land use to transit in order to make the most of the transit system. It is a major policy to reduce car dependence. Transit oriented developments (TODs) are the result of this policy; they generally have higher densities for residential and commercial activity, provide very pedestrian friendly environments and are closely connected to a quality public transport station. Parking is less available and is managed to reduce its negative impacts, and walking, cycling and transit use are encouraged. TODs are intended not only to bring about high quality community development, but also to be part of overall growth strategies along corridors or for entire metropolitan areas, strategies to decrease urban sprawl as well as car dependence.

This linking of land use planning to make use of the benefits of transit corridors and transit centres, is now a major policy in the developed world. Many cities in the developing world are already transit oriented, with major corridors carrying immense numbers of people, surrounded by much denser mixed-use localities, less car dependence and less restrictive planning codes than cities in the developed world. And developing world cities the world over are increasingly following the lead of cities such as Bogotá and Curitiba and accentuating these trends in their recent planning, with higher density development along transit routes, and a range of other measures to favour low carbon transport planning.

This section will outline some case studies of TOD. It will also outline a new approach that takes advantage of the land value increases that accompany good quality transit. If these increases can be captured and used as a means of financing and assisting the building of the transit system, then this can be called Development Assisted Transit (DAT) – see Box 3.1. There are emerging examples of this across the world, though Hong Kong and Tokyo have been practising it for many years.

Box 3.1 TOD language?

There are many words to describe what is going on around stations. The term 'Transit Adjacent Development' (TAD) merely associates transit with land use, and is not worthy of further consideration. The new term 'Development Assisted Transit' (DAT) describes the process whereby land developers fund all or part of the cost of the transit service integrated into the TOD, in return for which they earn extra income from the enhanced value of the properties there, given their closeness to transit. The term provides a better understanding of how land development can actually help build transit, rather than transit simply enhancing the land development (which is all that is implied in the TOD concept). Others have called DAT 'Joint Development' (see note 1) but this is not specific enough. The idea of value capture lies behind the concept of DAT but is also used for any infrastructure or amenity improvement. TOD and DAT both result in TODs being built next to transit.

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Cities across the developing world are emerging with their own models of this kind of DAT as they address the need to provide expensive transit systems while accommodating powerful forces of development. While relatively new in most cities, DAT is a strategy that can be adopted the world over, which is why it is described here. It provides a way in which finance can be obtained not only for the transit services, but also for walking and cycling facilities, for parks and even low income housing close to stations, as transit providers and housing providers have a mutual interest. It therefore lends itself to Public Private Partnerships. In cities with limited public budgets to fund transit services, improvements to footpaths and public spaces and the like, such a method of financing has big advantages. In fact, schemes for DATs may be easier to implement in many developing world cities, because they will not be challenging accepted financing, planning and transport procedures and regulations to the extent that they do in the developed world.

The case studies of TOD are taken from Delhi and several cities in the USA, whilst the case studies of DAT are taken from Hong Kong, Christchurch (NZ), Portland and Bangalore.

TODs can generate both negative and positive 'externalities' for those living and working in the broader locality. They invariably raise the value of property in the area generally which is positive for land owners but hard on renters who may be pushed out due to the inability to pay higher rents that flow from higher property values. So it is important that governments take measures to ensure that some of the housing associated with the development is low income, and that a proportion of housing in the broader locality remains affordable for those on low incomes. On the positive side, local residents and workers can take advantage of the transit services, walking and cycling facilities, parks, employment opportunities, reduced pollution and noise, and more attractive environments that the TODs have generated and financed (wholly or partly).

Thus, in short, Transit Oriented Developments are well-designed, higher density, mixed-use precincts or areas of development which include public transport stations.[1] They feature jobs and residential buildings within five to ten minutes walk distance of a transit station or stop, and the best examples generate a sense of place for the community that lives, works and plays there. Development Assisted Transit achieves the same result as TOD but uses the potential leverage of the transit to raise finance from the building of the area around the planned transit. Thus, high-quality TOD communities deliver increases in walking, cycling and public transport, and reduce private vehicle use.[2] They also mean less drain on limited government and city budgets.

2. Benefits of Transit Oriented Development

Economic benefits

TODs reduce the cost of living. By clustering a mix of uses within walking distance of stations, development can lessen reliance on cars and other private vehicles. This can significantly reduce living costs for those individuals and families who might otherwise outlay a large proportion of their income on buying and running a vehicle, and can allow this money to be freed up to meet other household needs. One assessment of the household economics of TODs found that TOD residents use cars about 50% less and save around 20% on household income as they need one less car per household.[3] In denser and less car-dependent developing world localities, the need for TOD residents to have a private vehicle is likely to be even less.

TODs can be, in part, self-funding via value capture mechanisms. Governments, businesses and home buyers all recognise that an address near a transit station is a good one, and the value of such

property rises accordingly. If the land is zoned for higher-density residential use or mixed use the value can be even higher. The process by which government helps to generate these rising property values and then reaps financial rewards is commonly known as 'value capture.' And this can be used to help finance not only the development of mass transit through DATs but also special community services or social housing due to the extra value in the land provided by the transit.

Redevelopment of land around stations is economically beneficial over new fringe development. The evidence that urban sprawl is economically costly in terms of infrastructure, transport, greenhouse and health has been reviewed globally and applied to the Australian situation comparing TOD type redevelopment to urban fringe development.[4] Productivity gains in the economy of 6% were estimated simply due to the extra walking done by those in the TOD compared to urban fringe development. As a result of this kind of evidence TODs are happening in highly car-dependent cities like those of Australia and the US,[5] and they can also help to prevent car-dependence becoming a problem in developing countries as they grow economically.[6] Planners have been concerned to reduce car-dependence in 'greenfield' (new) developments (as discussed in 'new urbanism' literature) but the evidence of success is not good.[7] However, the evidence that TODs reduce car-dependence and improve alternative transport use is much better.[8]

The economic evidence that DATs can assist the building of transit systems is found in the growing number of cities that are using land development to help finance their quality transit systems.[9]

Social benefits

TODs deliver travel choice and convenience. The proximity of transit infrastructure and services to homes, jobs, shops, schools, universities, other daily activities and special events makes everyday travel easier and faster. A variety of transport forms are available, and because more people and activities are clustered around stations, people are more likely to use transit services. It thus becomes economical to provide such services more frequently, and this in turn makes them even more convenient for users.

TODs promote healthy lifestyles. TOD planning gives special emphasis to walking and biking. Active travel is a key factor in achieving a sustainable and healthy community. In some TODs, approximately one-third of trips are made on foot, which has significant positive impacts toward improving community health and reducing obesity.

TODs save on unnecessary travel. As TODs are high-density, mixed-use developments, more destinations are within easy walking distance, whether they involve going to work, shopping, accessing services or recreational facilities, or mixing with family and friends. As Sam Adams, Mayor of Portland, Oregon, put it, success is 'the trip not taken'.[10]

TODs benefit those who cannot or choose not to drive. By creating a network of connected centres, more travel options and destinations are accessible to a broader cross-section of the population. Recent research shows that TOD residents in the United States are half as likely to own a car as the general population is.

TODs create more vibrant neighbourhoods. TOD neighbourhoods accommodate a broader mix of uses and lifestyles, and a variety of family forms and sizes, including single people, couples without children, nuclear families and extended families. TODs can thus create a diverse and vibrant urban village community.

Environmental benefits

TODs make more efficient use of land. Their denser and more mixed-use development pattern results in a broader range of land uses within convenient walking distance, making it quicker to reach destinations by non-mechanised transport and thereby reducing a person's overall transport. This reduces the need for cars and frees up land currently dedicated to moving and parking cars. In fact, TODs often limit car-parking spaces, which frees up funds and land for other purposes. [11]

TODs create a green dividend. By using space more efficiently and reducing car dependence, TODs also reduce fuel consumption, air pollution and transport-related greenhouse gas emissions.[12]

TODs and associated urban infill development relieve pressure on the urban fringes. The use of infill, mixed use of land and increased densities contribute to urban renewal and significantly relieve pressures to build on the urban fringes. Thus more land on the fringes can be retained for purposes such as food-growing.

3. Greenhouse gas emissions reduction potential

TODs have been shown to reduce travel by at least half compared to average urban development. An Australian study found that residents of TODs each generated on average 4 tonnes of greenhouse gas from their daily travel, or 2.5 tonnes in well-located TODs, compared with 8.4 tonnes in standard fringe development.[13]

4. TODS and their implementation in more detail

The defining features of a Transit Oriented Development are:[14]

- a mix of uses, horizontally or vertically
- a high level of activity for around eighteen hours of the day
- compact, pedestrian-oriented design
- moderate to higher density development, especially near transit
- limited parking
- a range of other green features

As well as this, they often demonstrate:

- a sense of vitality
- a commitment to innovation, flexibility, and the removal of barriers to development
- evidence of leadership and community vision
- responsiveness to market supply and demand

These defining features of Transit Oriented Development can be described in more detail as follows:[15]

A mix of uses

Creating a mix of land uses provides diversity and variety, helps to define the centre and creates an active eighteen-hour-a-day environment.

The diversity in land uses enables people to take care of the majority of their needs within a short walking distance. The mix of uses can be either vertical, on different floors of the same building, or horizontal, located next to each other in the same or separate buildings.

The key is to locate the various uses close together, make them easily accessible and supportive of each other.

For example, in Dallas, Texas, the Mockingbird Station is a 4-hectare, mixed-use TOD that features a movie theatre, 211 loft apartments, retail, a planned new hotel, offices and restaurants.[16]

Fruitvale Transit Village is another example of this mix of uses. It includes a childcare facility, health care facility, senior centre, library and community resource centre, as well as affordable family and senior housing, retail and office space, and a pedestrian plaza. It is also an example of a centre designed by and for the neighbourhood surrounding the station. Located in a low income neighbourhood, the residents, along with the Unity Council (a non-profit community development organisation), began developing the Transit Village Plan to link the local economy to transit, thereby increasing pedestrian and bicycle traffic and revitalising the neighbourhood. Connected directly to the BART Transit Station, this mixed-use TOD provides a sense of arrival and was a catalyst for the economic and social transformation of the community. The village covers about 10 hectares and has over 400 employees and 200 housing units. The village station was designed to serve 15,500 passenger trips daily.

Figure 3.20 Fruitvale Transit Village, Oakland, California

Picture Credit : Parsons Brinckerhoff.

An active, eighteen-hour place

A mix of employment, residential and recreational land uses within the TOD or easily accessible from it means that the numbers of people using the transit system are much more even throughout the day, evening and weekends, and involve a more even number of passengers in both directions. This is a much more efficient use of transit than a pattern of high usage in one direction at weekday peak commuting times, and much less use at other times.[17]

Pedestrian-oriented design

Within a TOD, non-car trips increase when a mix of uses is easily accessible and arranged in a way that enables safe and pleasant travel on foot rather than by car. In Portland, Oregon, research found that residents of TODs were twice as likely to choose to walk for non-work trips as residents of the general region.[18]

Creating a good pedestrian environment requires attention to the scale and attractiveness of spaces. As one design study on TODs put it, 'most people do not feel comfortable walking in a wide-open area with busy traffic passing close by. Pedestrians are drawn to streets and paths with a feeling of intimacy and enclosure'.[19]

'This feeling can be created by locating buildings close to the sidewalk, by lining the street with trees, and by buffering the sidewalk with planting strips or parked cars. People on foot enjoy small details, such as displays in shop windows, street level lighting and signs, and public art and displays.'

Figure 3.21 Pioneer Place in Portland, Oregon, incorporates the transit station directly into the design of this 10,000 square metre mixed use TOD in the heart of downtown Portland

Picture Credit: Parsons Brinckerhoff.

Moderate to higher density development near transit

Residences or workplaces near transit stations provide a ready demand for transit trips, and higher densities further strengthen this demand.

TODs should have higher densities than surrounding areas, and, within TODs, densities should be highest nearest transit. Experience indicates that 15 to 17 dwelling units per hectare will support a bus line and 20 to 60 dwelling units per hectare will support a rail line. When the density increases to over 123 dwelling units per hectare, the number of car and non-car trips are equal. From US based research, the general rule is that a 10 percent increase in density equates to a five percent increase in transit trips. Although the figures may be different for developing world cities, the trend will be the same: in higher density areas transit will have more passengers and will be more affordable, both to run and to ride on.

Limited parking

Parking is one of the most challenging aspects of any TOD. In developed cities, typical suburban commercial or shopping development, with 50 to 75 percent of the site devoted to surface parking, results in land use densities that are too low to support transit services. But by limiting the parking supply (and moving parking from surface parking lots to on-street parking or parking structures) not only can this low density land use be improved, but also residents, shoppers and employees will be encouraged to walk within the TOD and to use transit to get to the TOD.

Figure 3.22 The Embarcadero line in San Francisco is part of a TOD design that has moderate to high densities, a mix of uses, development at a pedestrian scale, and the creation of a defined centre and civic spaces.

Picture Credit: Parsons Brinckerhoff.

There needs to be sufficient parking to meet car needs that cannot be satisfied by transit. Shared parking between people using the TOD for different purposes can reduce the need for parking by up to 25 percent when compared with conventional ratios, depending on the mix of uses.

Parking facilities should be located so that buildings, not parked cars, are the dominant visual feature. The design of the parking needs to relate to the streetscape, circulation routes and pedestrians, and to be integrated into the development. The City of Reston, Virginia, when adjusting its codes and design guidelines to support mix-use development, changed its parking standards and ratios, to discourage personal vehicle use, and to require carparks to be well-designed and concealed.[20]

Other green features

As we have seen, TODs contribute to increased urban density, and encouraging people to travel less or use forms of transport that produce low (or no) greenhouse gas emissions. But they can reduce emissions further and generate other environmental benefits through a range of other features. These include energy-efficient building designs and appliances, smart grids and smart metering, on-site renewable power generation, water-saving appliances and gardens, water recycling, and the use of planting – including on walls and roofs – to 'air-condition' buildings.[21]

Some points about implementation of TODS

To ensure success in the delivery of TODs, the following need to be attended to:[22]

Town planning schemes need to be supportive and to be adapted to reduce car-dependence. In the developed world, TODs are often 'illegal', in the sense of not being consistent with planning legislation, with town planning scheme codes and with traffic engineering standards. These codes have been devised to build suburbs and shopping areas on the assumption of car dependence — with each dwelling or building serviced by car use alone – and the codes often also specify low densities and single use zoning. The picture can be mixed in developing world cities, but in general they tend to allow higher density building development and more mixed land uses, and they tend not to require so much car parking, if any at all. (This is discussed more fully below.)

Contracting arrangements need to ensure proper integration between all aspects of the TOD and cooperation between government and private parties involved. The power of TODs lies in the fact that government and the private sector can work closely together to build both the TOD and the transit system, and revenue raised within TODs can help to pay for the transit system. This close synergy is being demonstrated today in many cities around the world. It requires equity arrangements to enable private funding to occur, and contractual arrangements to ensure necessary cooperation between transit operators, land developers, financiers and different levels and departments of government.

Communities need to be engaged. The community may not be happy about car dependence and may like the idea of TODs, but at the same time they may not support a TOD nearby, a phenomenon sometimes referred to as the NIMBY ('Not In My Back Yard') syndrome. They may fear that the increased density and urban activity will lead to traffic congestion, loss of amenity, increased crime and noise, and reduced real estate values, rather than seeing the opportunity to be part of a village and an exciting, visually appealing city-building process. Engaging the community early in the planning process enables key concerns to be resolved, and improvements suggested by the community can then be incorporated in the TOD project.

Land assembly in station precincts needs to be made easier, and facilitated. A major challenge, when seeking to ensure the commercial viability of private sector involvement in a TOD, particularly in existing urban areas, is that of ensuring that the private developer can assemble disparate parcels of land to achieve a development close to transit that is of sufficient size. There need to be incentives, either in planning codes or financial development incentives, to encourage land amalgamation around station precincts. This can also be facilitated by government working in collaboration with the private sector.[23]

It is critical that there is governance across agencies in delivering TODS. Councils, government agencies and funding authorities need to work closely together to ensure accountable and responsive governance of TODs. On the government side, these cooperative arrangements normally involve public transit agencies, planning agencies and transport or traffic agencies.

The specifics of TOD implementation in developing countries

The major difference between developed and developing country cities when it comes to TODs is that in the latter most land use is already dense and mixed. The main task is therefore to build the transit system and to ensure it is adequately linked into the land use through good pedestrian connections and good networks of buses and auto-rickshaws. When this happens the dense, mixed areas will often regenerate and create further development options.

One of the significant advantages of the new Metro in Delhi is that it has been used to regenerate old parts of the city and also helped to focus and build new centres more effectively. The Metro consists of 6 lines with 161 km of service and 135 stations and significant regeneration and development are observable at each station. The first line opened in 2002 but recent lines have linked the central area of Old Delhi into the network as well as linking it to the new city of Gurgaon near the airport. Both were failing as transport access to them was poor. Old Delhi had been emptying out as the cramped streets became less accessible. Cars and auto-rickshaws just did not fit in, so shopkeepers were moving to more accessible places. The City was dying. With the coming of the Metro the area's fortunes have reversed. The underground station now sees shoppers pouring out of the station at all hours and shopkeepers and residents have returned to their closed and once-forgotten buildings.

At the other end of the Delhi Metro the new centre of Gurgaon had been struggling as traffic had rapidly filled the new streets and the buses were not competing adequately. Once the Metro went through to Gurgaon the residents and workers had a quality option linking them rapidly to the whole city. The result has been a dramatic interest in further development around the Metro station.

Delhi Metro shows that when quality transit is built into a developing city it can help focus and regenerate urban areas in the same way that TODs have been seen to operate in the developed world. As passenger numbers for the Delhi Metro are considerably more than numbers for most developed city rail systems, the resulting income from fares helps justify the investment in a short period of time.

Town planning regulations in the developing world vary greatly when it comes to issues like maximum densities, mixed use zoning, and required parking provision for new developments. For example, in Bangkok regulations are quite loose, thus allowing high density developments near transit stations. In India, on the other hand, they are stricter, and often prescribe unnecessarily low densities (although still higher than most developed country densities); this has been amended in areas close to Delhi Metro stations. In many parts of the developing world, following the trend in car-dependent developed cities, there are now minimum parking provisions in new developments which will encourage higher car use and undermine

Figure 3.23 Chawri Bazar Metro Station amidst very dense urban development

Picture Credit: Saurabh Gupta.

successful future TODs, for example, in Malaysia, Philippines, Indonesia, Thailand, and increasingly across South Asia. Such requirements are more modest in China and Vietnam.

If developed world style regulations that reduce densities, forbid mixed land use and encourage more car traffic are already in place in developing world cities, a first step may be to have special provisions for TODs. If done well, this will serve to demonstrate the potential benefits of such provisions over a wider area. But it is important to get it right. In Curitiba, for example, most of the high-rise residences near Bus Rapid Transit stations are occupied by wealthy people who drive cars. Increasing restrictions on parking spaces and requiring the provision of some low-income housing would reduce this problem. This issue of the effect of town planning regulations on car use and urban densities is also dealt with in other sections of this chapter.

Some examples of Development Assisted Transit

DATs are appearing in many cities: the new Copenhagen Metro was built entirely out of land development funds; the Aguas Claras development in Brasilia financed the Brasilia-Samambaia underground Metro; the redevelopment of central Tokyo station is being funded out of land development around the station; and in Istanbul land development has funded a number of transit system improvements.[24]

The Hong Kong Mass Transit system was built using DAT principles. The Mass Transit Railway (MTR) Corporation in Hong Kong used the experience of the rail builders in Tokyo to acquire land around each station that was to be part of their planned MTR system. Then they became the developer and were able

Figure 3.24 Kowloon Station, Hong Kong

Picture Credit: Parsons Brinckerhoff.

to leverage considerable financial benefit from the land development venture, and these funds were then ploughed back into the MTR. The train system now makes more money from land than from fares. In 2009 they made a net profit of HK$7.3b and out of this the MTR made HK$3.55b from property and HK$2.12b from rail operations.

Kowloon Station is considered the flagship of mixed land use development for the Mass Transit Railway (MTR) Corporation in Hong Kong. The station is owned and operated by the MTR and involved four joint ventures to develop 16 residential towers, a commercial building and a hotel over and around a multimodal transit hub. In all, the development provides housing for over 58,000 families, over 230,000 square metres of office space and a 330-room hotel. The development is built on a massive podium with its roof designed as a park. The podium box houses a shopping complex and the transit hub of the MTR, as well as buses, mini buses and taxis.

The station serves local residents, employees and visitors to Kowloon, as well as providing access to Hong Kong International Airport, via the MTR. It provides in-town check-in service for flights and free shuttle bus services to most major hotels in the urban centres.[25]

Pearl District DAT

In Portland, Oregon, the Pearl District is a 90-block area that was largely abandoned industrial, warehouse and railway land adjacent to the CBD. The City of Portland wished to make it a model regeneration development with a quality transit system at its base. However it did not wish to pay for the transit system. The not-for-profit business Portland Streetcar Incorporated was set up to manage the building and operation of the system within the Portland TriMet system. Funds were raised from businesses that wanted to be in the Pearl District and that could see the advantages of the light-rail system that was to be built

there. The system has been extremely successful, both at facilitating development and as a transit system. Since the Pearl District regeneration began in 1997 the area has experienced an increase in density directly linked to the presence of the streetcar line. As of 2007, the area had over 2,700 residential units and has seen US$879 million worth of development since 1997. The Portland area was the first city in the US to demonstrate a reduction in vehicle miles travelled in the past decade while increasing its economic growth. The Pearl District was a major part of that success.[26]

Christchurch Bus Xchange, Christchurch, New Zealand

It is possible to use DAT principles to assist in the development of part of a transit system, rather than building an entirely new line or system. An example of this is the Christchurch bus exchange which was built as part of a redevelopment of the whole system, in partnership with a developer whose building was able to benefit from the increased numbers of people using the facility he helped build with the City of Christchurch.

In the late 1990s the Canterbury Regional Council and Christchurch City Council established a Public Transport (PT) Advisory Group, made up of approximately 20 members representing key agencies, interest groups, users and non-users. The PT Advisory Group met for a year to establish an overall public transport strategy for Christchurch. Measures identified by the Advisory Group to improve public transport included better integration of land uses, increasing frequency of services, improved transit priority, better ticketing, and new bus interchanges.[27]

The Christchurch Bus Xchange involved successful public engagement, and governance by multiple agencies and the developer, to produce a modern bus station. The bus Xchange is integrated with two floors of retail, a new primary school, an over-street bridge built to provide better access between a major department store and the main street, and short-term car parking built to support the increased retail activity. The entire development and Bus Xchange was encased behind and within a heritage building. The project also required significant investment in smart-card ticketing and real-time information systems, which galvanised system-wide major investments. Since completion of the Bus Xchange development (and a number of other projects) patronage has more than doubled throughout the system.

The Bus Xchange set new standards for the quality of public transport passenger facilities, particularly the off-street waiting lounges, which have carpeting and air-conditioning, are separated from buses by sliding glass doors, and are supported by real-time passenger information. The Xchange also has numerous direct connections to surrounding retail areas. As a result of these qualities, the Bus Xchange has since its opening been the subject of international interest. The developer was also able to gain considerably from the extra numbers using the rest of his building.

A similar experience has occurred In Bangalore where the new Metro is being built. The involvement of private developers at some stations has been used to assist with the building of some quality stations in exchange for the right to direct pedestrian traffic from the Metro through their developments. Based on this idea a proposal to regenerate the Bangalore commuter rail system through land development around stations has been proposed.[28]

5. Costs and sources of funds

TODs and DATs do not cost more; they just need an appropriate planning framework to enable them to occur. Trubka and colleagues found that in Australia TODs saved A$85,000 per dwelling in infrastructure costs compared to new greensfields development, and over 50 years will save A$250,000 in transport

Figure 3.25 Christchurch Bus Xchange

Picture Credit: Parsons Brinckerhoff.

costs per household, as well health savings and a productivity gain of 6% due to increased walking.[29] DATs can enable transit systems to be built that otherwise would just be dreams.

6. Conclusion

Transit Oriented Developments are a model for contemporary urban planning, with their higher densities, mixed land use, closeness to transit, walkable streets and restricted parking. In the developed world, they have demonstrated a very different way of living in cities, a way that is attractive, convenient and low-carbon. Developing cities tend to already have higher densities, mixed use and low levels of car use, but there will be other features of TODs described in this section that can be applied in order to improve urban life.

Development Assisted Transit is a step forward in developing TODs through new partnerships between land developers and transit operators – partnerships that provide hitherto difficult-to-source finance for these projects. By helping to meet the costs of transit through the sale of property, cities with limited budgets can develop transit services and achieve a more sustainable built environment at the same time. Examples of DATS are appearing in the developed and developing world.

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F) Reducing the Need to Travel

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1. Introduction

An important way to reduce the greenhouse gas emissions that transport produces is to encourage and enable people to travel less. People travel less overall when they switch from private vehicles to mass transit, walking or cycling, for reasons that will be explained. They travel less if their work is closer; if shops, health services and education are closer; and if family, friends and leisure activities are as well. They travel less if several purposes of travel can be covered in one trip, which is more likely if the places they need to visit are closer. They travel less if they can use technology to communicate with people and to perform tasks at least some of the time, instead of travelling somewhere to do this. And they may travel less if they live in a pleasant environment, and therefore have less need to go elsewhere to find satisfying places to be.

This section, therefore, considers a range of planning and other measures that can enable people to travel less. It deals mostly with reducing travel in urban areas, but the principles it applies can in many respects also be applied to rural communities. There are broadly five ways to enable people to reduce travel:

- by encouraging and enabling people to use mass transit and to walk and cycle, because people using these transport modes rather than private vehicles travel less in total
- by having denser communities, so that people are closer together
- by having more mixed land use, so that people's trip destinations – shops, schools, workplaces and friends' houses, for example – are also closer together
- by having greater community self-reliance, so that people can meet more of their needs and pursue more of their interests within their own communities
- by encouraging and enabling people to use information and communications technology to connect with others, to obtain information, and to perform tasks.

These factors influence each other in a complex range of ways. For example, when people switch to transit, there is a good chance that they will eventually move house or change jobs to live or work closer to a transit station, because they appreciate the convenience of this, and when many people do this it increases the demand for high density housing and work near transit. A transit oriented city requires much less land in which to move the same number of people, and therefore contributes to urban density, and a denser city makes transit more financially viable, because there are more potential customers to attract, and their homes and workplaces are closer to transit stations.

Also, in dense, more self-sufficient communities with mixed land use, trips become shorter, and it is more feasible to walk or cycle them. People doing this have much less need for private vehicles – for cars, motorbikes or motor scooters – and they are thus less likely to own them. In turn, if they don't own them, when they need to make a longer trip they are much more likely to use public transit to do so. Alternatively, a family in such a community may switch from owning two motorised vehicles to owning one (or refrain from buying a second one) and therefore share trips in the one vehicle more, or use transit more. And in denser communities, affordable parking will be less available, and roads will have less capacity to take large volumes of traffic, so people will take more trips on transit and fewer in cars.

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Cities around the world, from Vancouver to Vienna, from Singapore to Seoul and from Curitiba to Copenhagen, demonstrate the economic, social and environmental benefits that accrue when people can live a good life without having to travel far. This section outlines how other cities and localities can achieve the same outcomes.

2. Benefits of measures to reduce travel

Economic benefits

By reducing travel through the measures described, people spend less on transport. Governments also save on total transport costs (services and infrastructure), as well as spending less on infrastructure for water, power, sewerage, drainage and telecommunications. Time saved due to reduced travel and reduced congestion raises productivity, as documented in a study done by the transport unit of the Economic Commission for Latin America and the Caribbean on the costs of GDP loss in Latin America due to congestion.[1] As health improves as a result of reduced pollution, accidents and travel stress and more exercise, there will be lower health costs. With better alternatives to private vehicles, those without such vehicles are more able to participate in work, education and economic life.

Social benefits

These measures are likely to generate a stronger sense of community. As a result of reduced pollution and traffic accidents, better social connection and a more pleasant and less noisy locality health is likely to improve.

Environmental benefits

These measures will lead to lower levels of local pollutants and greenhouse gases, as well as reduced noise, congestion and depletion of finite resources.

3. Greenhouse gas emissions reduction potential

There are a number of measures to reduce travel described in this section, and they can be applied in different ways and combinations, over different geographical areas, and to differing extents. Given these variations, therefore, it is not possible to give a meaningful figure or range for the greenhouse gas reduction potential of these measures. However, Figures 2.2, 2.3, 2.4 and 2.5 in Chapter 2 show graphically the huge differences in 84 cities around the world on matters of urban density, public transport use, private vehicle use and greenhouse emissions. They show clearly that greater urban density, less private vehicle use and increased mass transit use will greatly reduce greenhouse gas reductions. Each of these is either an example or a cause of reduced travel, as this section explains. In each of these areas, the difference between cities like Atlanta and Houston at one end and Dakar and Mumbai at the other is enormous.

4. Details of these means of reducing travel and how they can be implemented

The means of reducing overall travel introduced above are detailed below. They are considered individually, and then the effects they have when they are combined is described, with the examples of Vancouver, Curitiba and Surabaya to illustrate this.

Increasing mass transit use, walking and cycling

As shown in Chapter 2, every kilometre of transit use replaces from three to seven kilometres of car use. This phenomenon, known as 'transit leverage', means that people switching to transit substantially reduce their absolute level of travel, and it results from a number of factors. For example:

- Trips may be more direct, especially in trains.
- 'Trip chaining' is more likely to occur, that is, doing other things while on a commuter trip, like shopping or accessing services.
- Transit users are more likely to own one vehicle instead of two, or none at all.
- Eventually, many of them, when changing jobs or moving house, will select a home or workplace closer to a transit station, because it is more convenient, thus contributing to greater urban densities close to transit.

Evidence also shows that people who walk or cycle, to get to their destination or to a transit station, build better connections in their own communities than do people who drive.[2] This means that they will appreciate their locality more and be inclined to spend more time there. And for practical reasons, they are also more likely to use local shops and services. Moreover, localities with lower rates of private vehicle use can devote less road and parking space to such vehicles, and be more compact as a result, and in turn greater urban density means that people don't need to travel so far.

Figure 3.26 Reducing the space devoted to parking here would lead to greater urban density and more human-scale community spaces

Picture Credit: Zachary Korb.

Thus, the use of mass transit, walking and cycling as transport modes reduces greenhouse gas emissions twice over, because these modes generate fewer (or no) emissions per passenger kilometre, and they cause people to travel fewer kilometres. There are many ways through which governments and leaders can encourage and enable people to use these modes more, and they are explained in detail in a number of sections of this chapter, specifically in *Mass transit, The walkable locality, Supporting cycling, Influencing travel choices, Transit Oriented Developments, Private vehicle demand management, and Traffic management.*

In general, though, it involves provision of public transit (trains, buses and light-rail) that is clean, comfortable, frequent, punctual, affordable, at least as fast as private vehicle travel, and available when and where people need it. It involves the building of safe and direct walking and cycling routes. It involves designing multimodal transport systems in an integrated way, so they connect with one another and easy transitions can be made between them. It involves regulating private vehicle use so that it does not adversely affect users of other modes, so that private vehicles users pay the costs that this use imposes on society, and so that many of them are persuaded to switch to other modes. It also involves the shaping of cities in particular ways, and this we will now examine.

Higher urban densities

If there are more people living in a given area then, when those people want or need to interact, they don't have to travel as far to do so. On average, urban densities are already higher in the developing than in developed countries, although these averages hide great variations. For example, European, Japanese and other high-income East Asian cities are much denser than North American, Australian and New Zealand cities.

Greater urban density can be achieved through a range of means:

- having more medium and high rise, as opposed to low rise, buildings
- having smaller residences on average
- having less land devoted to private gardens attached to residences, and instead – because gardens are important – having more land under public gardens
- having less land overall as travel space (either in absolute terms or per resident as population density rises) and having a smaller proportion of this travel space allocated as space for private vehicles to travel or park, and a larger proportion devoted to mass transit, walking and cycling
- having more travel space converted for multiple uses, for example, a pedestrian street that has elements of a park, a locality for street vendors and repairers, an outdoor community gathering place, a playground, and – in effect – local residents' front gardens.

Property taxes or council rates calculated progressively, that is, at a higher rate for larger, more valuable properties, can be an incentive for people to keep their houses and gardens smaller.

Higher urban densities are not without their problems, however. In developed world cities in the 1950s and 1960s, there was a widespread movement to tear down inner urban low- to medium-rise dwellings that were considered 'slums', and to replace them with residential tower blocks, usually surrounded by large areas of open lawn that were intended to be used by residents. However, as people like Jane Jacobs soon pointed out, in tearing down the buildings, the planners also destroyed the relationships, routines and features of life that are the very essence of communities, and often rendered the residents of the new tower

Figure 3.27 Residents can still reap the benefits of attractive gardens when living in high density communities.

Picture Credit : La-Citta-Vita at Flickr.

blocks isolated and alienated from each other.[3] The open spaces between the blocks were rarely used, because they were seen as featureless, soulless, and – all too often – the domain of gangs and criminals. There were fewer 'eyes on the street', people going about their daily business of shopping, working, travelling to school or sweeping their front steps, who could, at the same time, look out for one another.

Thus, if major steps are to be taken to achieve greater urban densities, it is vitally important that planners – as much as possible – start from the fabric of existing communities, consult local residents on the changes they would like to see, and thereby help these communities not only to stay together, but to be strengthened by new developments. Through such consultation processes, various ways of achieving urban consolidation can be explored, for example, blending old and new, and high, medium, and low rise building, while retaining much of the layout, form and character of local streets where people come together.

It is important to build on a human scale. For example, if buildings close to streets are not taller than four or five storeys, then people in the streets won't feel dwarfed by them. And it is also a good idea to have many doors and windows facing onto the streets (rather than long, blank walls) so that people in the streets and those in the homes, shops and other buildings have more interactions, and there is a feeling of collective security and conviviality.

Higher densities and more attractive developments may push up the price of rents in both existing and new dwellings in the area, and make them less affordable for those on low incomes. Governments need to anticipate this and ensure that, at the very least, there continues to be affordable housing for all tenants already living in a redevelopment area.

Mixed land use

People will travel less if the destinations they need to travel to are mixed together in one locality rather than being widely segregated in planning zones (for example, residential, industrial and commercial zones some kilometres apart). Such zoning became widespread in the developed world, especially in English-speaking countries, with the growth in popularity of the car last century. It was considered desirable to separate where people lived from noisy, dirty, unsightly factories, and to a lesser extent from commercial areas, and cars enabled the longer trips that were then required to be made quite easily. However, once these patterns of land use were established, they were very hard to undo, and car driving became essential in such localities if people wanted to conduct normal lives.

In addition to the extra travel that localities with segregated land use generate, there is another major disadvantage. In 'dormitory' suburbs where almost every household has one or more cars and residents usually drive out of the suburb for work, shopping, recreation and other purposes, there is often relatively little social interaction within the suburb.[4] People have fewer reasons to interact with their neighbours, and in any case they can't do so if they just pass each other in cars. So it is harder for them to act together as a community if this becomes necessary, and those who don't have a car and are not well connected can lead very isolated and vulnerable lives.

The original reasons for segregated land uses have also diminished in importance. For example, with cleaner technology, pollution control and noise abatement measures, the adverse affects of industrial production can be reduced or eliminated – for the sake of employees as well as local residents. Nowadays in many developed world cities, the old inner suburbs with more mixed land use are highly desirable localities to live in, because they have more character and everything is closer.

Thus, developing world cities should seek to retain their mixed land use, and even increase it. They should be aware of the implications of allowing developments like gated communities, dormitory suburbs, shopping malls and large industrial zones to emerge, one of which is that such developments are likely to lead to significantly more private vehicle travel.

Local self-sufficiency

Associated with mixed land use is the notion of local self-sufficiency, that is, the ability of communities – both urban and rural – to meet a large proportion of their own economic needs. Trade across countries and across the world is clearly justified in many instances, but it is also important to recognise its costs. One important cost of global and other long-distance trade is that it greatly increases freight and (to a lesser extent) passenger transport. It is also argued that a less self-reliant local economy makes communities less diverse, less interesting, and more vulnerable to economic, political and natural forces in the wider world, such as rising or falling commodity prices (including rising prices of oil). It is possible to have a robust local economy while maintaining significant economic connections with the wider world, and such a state affairs will contribute to reductions in the need to travel.

National and local leaders can help to promote local economic development through small business loan schemes, advice and information services, and training programs. They can also make sure that the different parts of a locality are well-connected with each other via roads, paths and transit services, and that there are areas for markets and other local trade. As well, requiring people to pay the full economic, social and environmental costs of their transport (what economists call internalising the externalities) will tend to reduce private passenger and freight travel and encourage more localised economies.

The combined effect of all these measures

If you have all of these measures – higher urban densities, mixed land use, local self-sufficiency and increased mass transit use, walking and cycling – then they will not only reduce levels of travel individually, they will also do this by reinforcing each other. Thus, they can become far more low carbon localities.

The creation of Transit Oriented Developments developed world cities represents attempts to achieve this blend of features on a somewhat smaller scale. But there is no reason why the principles underpinning TODs (described in another section of this chapter) cannot be applied to a whole locality. In fact, many developing world cities already have the main elements of this – relatively high densities, mixed land use, local self-sufficiency and low levels of car use. Making such cities better places to live in, possibly increasing their populations, and thereby maintaining low per capita greenhouse gas emission levels or reducing them further involves a range of other tasks, such as:

- providing good quality public transit, as described elsewhere
- improving roads, paths and drainage, including ensuring that there are adequate walking and cycling paths and that these are clear of obstructions
- improving traffic management, particularly to allow pedestrians and cyclists to travel safely and to have their fair share of travel space
- providing sewerage, clear water, power and telecommunications infrastructure
- improving the building stock and general amenity to attract people to live and work there
- initiating new building development, including some that is higher rise, in consultation with the local community, blending in with the area's existing character, and including some low-income housing
- providing parks and other pleasant spaces, including the conversion of many inner city streets to pedestrian-only thoroughfares.

If these measures are taken, then the city will have avoided two pitfalls: it will not have become a high carbon, car-dominated city, and it will not have destroyed the physical and social fabric of existing communities in order to erect somewhat soulless tower blocks. In seeking to achieve something like a Transit Oriented Development on a larger scale, compromises will need to be made, because a living community is very different from an unoccupied site – the starting point of most TODs. However, over time, as buildings change hands and are pulled down and erected, and as changes are made to thoroughfares, infrastructure and services, the key elements of higher densities, mix land use, attractive pedestrian spaces and good transit can be realised more fully.

There are many urban areas, in both the developed and developing worlds, that are moving towards this model, sometimes in quite different ways. Downtown Vancouver, for example, was an area in decline in the 1970s and 1980s, but since then its population has grown by 135,000. This 'return to the city' has seen strong leadership from the City Council and the creation of quality urban spaces, good cycling and walking facilities, reliable transit (mostly electric rail and electric trolley buses) and most of all high density residential opportunities with at least 15% social housing (public and co-operative). So successful has this been that beween 1991 and 1994 car trips per day declined by 31,000 vehicles (from 50% to 46% of trips, and from 35% to 31% in the central area) whilst cycling and walking trips per day went up by 107,000 (from 15 % to 22%). Families are moving back in large numbers with the result that schools, child care centres and community centres have become crowded, while the number of cars owned in the city is less than five years earlier– probably a world first, especially in a city undergoing an economic boom.[5]

In the early 1970s Curitiba, Brazil, under the leadership of Mayor Jaime Lerner, started to reinvent itself as a pedestrian and transit city. Over one weekend it created a pedestrian precinct in the heart of town, initially in the face of strong opposition from shopkeepers and car drivers, but this opposition melted away when the change proved to be highly popular with the public. Lerner then implemented a bus rapid transit system that involved dedicated bus lanes with priority traffic signals and very rapid entry and exit for passengers. Garbage trucks could not get down the narrow lanes in the *favelas* or shanty towns and so, to avert the risk of rats and disease, residents were paid in bags of food and then bus tokens to carry their garbage up to a main road. The city government also established garden plots in the *favelas*, so that older men could teach young people how to plant and grow, and as a result residents grew their own food and supplied the city with trees and flowers for parks.[6]

A new shopping plaza was built downtown to draw middle-class residents back into the city, and a series of linear parks were created along the banks of restored natural streams that had previously been re-routed into underground concrete pipes. These parks also had paths, bike rental services, outdoor cafes, skateboard parks and other attractions. Thus, Curitiba drew people back to the city for work, leisure, shopping and other purposes, it boosted urban agriculture (thus increasing self-sufficiency and mixed land use) and it created a highly efficient, low-carbon transport system of Bus Rapid Transit and walking – all of which contribute to reductions in overall travel.

The Kampong Improvement Program in Surabaya, Indonesia, took another approach to the improvement of a locality. Though in 1993 Surabaya's kampongs occupied only 7% of the city's area, they housed 63% of the population, and so, while buildings were low rise, settlement was already dense. There were many features of kampong life that worked well. For example, the streets had multiple purposes: thoroughfares for the thousands of residents in each kampong, meeting places, marketplaces, playgrounds and the front yards of residences. On the other hand, there were also problems to be addressed to enable life to function better.

Figure 3.28 A pedestrian only shopping district in Curitiba

Picture Credit: Karl Fjellstrom, itdp-china.org.

However, instead of authorities imposing solutions, they empowered residents to identify the improvements they wanted, and to be actively involved in achieving these, through the formation of a large number of foundations, cooperatives and self-help action groups. Local government provided funding and technical and other support. Improvements made included upgrading of paths and roads, laying drains and culverts, laying water pipes, building washing and toilet facilities, improving rubbish collection, and constructing schools and health centres.[7] Streets within kampongs were closed to cars (which had been rare anyway), thus helping to preserve the traditional social life on the narrow streets. The only modes used within the kampong are walking, cycling and becaks, the traditional Indonesian trishaw.[8] Residents felt a strong sense of ownership of the changes that had been made.

Through this process, the Kampong Improvement Program in Surabaya managed to make life a lot better in already low travel, low carbon communities, by involving residents and retaining the best aspects of the existing community life. This example illustrates well the interconnectedness of appropriate transport, urban density, mixed land use and a degree of self-sufficiency, and the relevance of all these factors to reductions in travel and a low carbon transport future.

Using ICT in place of travel

Another, somewhat different, measure to reduce travel is the promotion of information and communications technology as a substitute for some travel. People can have conversations, locate and send information, conduct meetings and conferences, buy or sell things, do banking, manage finances, do stocktaking and perform a host of other personal and business functions via mobile or landline phones, computers, emails,

Figure 3.29 Teleconferencing means businesses generate fewer emissions from road and air travel

Picture Credit: Polycom.

the internet or social networking sites. Costs of the technology required are decreasing over time, and there are now many free video conferencing services such as Skype, MSN Messenger, Yahoo Messenger, NetMeeting and SightSpeed. While prices for telecommunications infrastructure vary enormously, a lot can be achieved with mobile phones and mobile internet connections. Bangladesh's Grameen Bank supplied local women selected as the coordinators of its savings groups with mobile phones, which enabled them to conduct the business of the group much more easily.

Such technology should not entirely replace face-to-face contact for business and personal interactions, because face-to-face contact is important practically and psychologically, but even if ICT is only used sometimes it can still bring about substantial greenhouse gas reductions.

5. Costs and sources of finance

For the costs of mass transit, see the *Mass transit* section. With regard to the costs of higher density, mixed-use urban localities, the buildings and infrastructure involved would, over time, be constructed anyway, and this form of development enables it to be done at much less cost, as explained in the *Transit oriented development* section. In any case, most of this expenditure is not undertaken by government. With regard to costs for information and communications technology, the hardware, software and services are private costs, with sufficient variation to allow even low-income earners to participate to some degree, and infrastructure costs also vary greatly such that different levels of technology can be implemented to suit government budgets.

6. Conclusion

The measures described in this section – switching transport modes, moving to higher density, more mixed-use and more self-sufficient communities, and greater use of ICT – lead to reduced travel and greenhouse gas emissions while at least maintaining, and probably improving, quality of life. The three examples cited demonstrate the diverse ways in which this can be undertaken, and the diverse outcomes that can be generated, while the underlying principles remain the same.

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Making Current Modes Low Carbon

G) Private Vehicle Demand Management

Mark Bachels* and Robert Salter**

1. Introduction

While the use of private vehicles – cars, trucks, motorcycles and motor scooters – is much lower in the developing than the developed world, this is changing with existing rapid economic growth in some developing countries, and the likelihood of such growth in others. Given the much higher levels of greenhouse gas emitted from private vehicles than from mass transit and non-motorised transport, it is imperative that rates of private vehicle usage be dramatically reduced in developed countries, and prevented from reaching high levels in the developing world. This can be done in ways that enable developing cities to be better places to live and work as traffic congestion is a chronic issue for health and the economy. The switch from private vehicles to mass transit can significantly reduce overall travel levels, as explained in Chapter 2. This section deals with measures that can be taken to reduce private vehicle use, or to curtail its increase, whilst enabling transport development goals to be achieved. The measures are:

- behaviour change programs
- parking policy
- other price incentives and disincentives
- restricting areas within which private vehicles can travel
- street design and traffic calming measures
- car-pooling
- car-sharing schemes.

With the exception of car-pooling and car-sharing, these measures will only be effective in reducing private vehicle use if other means of transport – namely, public transit and walking and cycling facilities – are available when and where people need them, or if information and communication technology (ICT) can be used in place of travel.

All of these measures have been implemented in many parts of the world, and examples of their use are described in this section. In general, they have so far been applied much more in the developed than the developing world, because car dependence and its adverse consequences are much worse there. But efforts are now being made to introduce demand management measures in developing countries, and some examples are included here.

Private vehicles transport both people and goods. This section focuses on reducing the demand for passenger vehicles; freight vehicles are covered in the *Freight* section of this chapter.

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2. Benefits

Economic benefits

Cities with a lower share of private transport spend less on transport overall than do comparable cities with a higher share[1]. Moreover, as there are many citizens who cannot afford to own private vehicles, nations and localities with a higher share of public transit can provide transport for more of their citizens. As a result, these citizens have better access to employment, education, shopping and services, all of which contribute to economic development. Reduced levels of pollution and reduced traffic accidents mean that a nation's health costs are lower, and there are fewer working days lost from illness and accidents.

Social benefits

Reduced private vehicle use is linked to more compact and less sprawling cities, better integrated communities, lower accident rates, more equal transport opportunities, and fewer harmful effects of pollution on health. People are also healthier because they are walking and cycling more.[2]

Environmental benefits

Decreased private vehicle use reduces local and global pollution of the air, land and water, including emissions of greenhouse gases. Noise and congestion are also reduced and fewer finite resources are consumed.

3. Greenhouse gas emissions reduction potential

Greenhouse gas reductions from private vehicle demand management are not easy to estimate but potentially large.[3] Elasticities of demand for car use have been calculated for fuel price changes and parking charges, so these can be used to estimate reductions in car use, but invariably these calculations use developed country data. Elasticities for fuel price suggest that a 10% increase in price will lead to a 3% decline in fuel use in a year or so, and 5% in 5 to 10 years; about half of this is due to reduced vehicle use[4]. It is probable that changes due to price will be very inelastic in developing cities where the alternatives to car use are dramatically more difficult (highly crowded buses, dangerous cycle roads and very busy footpaths). Thus it is even more reason to ensure that these demand management policies are introduced only if better transit, cycling or walking options are being provided at the same time. It is not possible to estimate the greenhouse gas reduction potential of the other measures considered in this section.

4. The implementation of particular demand management measures

Behaviour change programs

Reductions in private vehicle use can be achieved through behaviour change programs, as described in the *Influencing Travel Choices* section of this chapter Such programs – which can be run by government, businesses or community groups – seek to inform people about transport alternatives like walking, cycling and mass transit, and the many personal and environmental benefits these offer. Participants are then encouraged to try these alternatives out, starting with trips where the transition is easiest, for example, taking a bus to work if the bus-stop is close by, or walking the short distance to the shops or school.

Behaviour change programs can be delivered to groups of people meeting in community centres, workplaces, schools, homes or other places where people can congregate, or that can involve working

with individuals and households through home visits or phone communication. Information about transport alternatives can also be available in print and online, as well as being publicised through street signage. One very successful behaviour change program, TravelSmart, has consistently achieved reductions in car trips of 10% or more.[5] TravelSmart and other behaviour change programs are described in more detail in the *Influencing travel choices* section of this chapter, with information on levels of reduction of private vehicle use in different regions of the globe.

Parking policy

Private vehicle use can be reduced by reducing the supply of parking or by raising its price.[6] If it is difficult or expensive to park a car, particularly for regular trips such as commuting to work, people will be more willing to consider alternatives. Whether it is for on- or off-street, public or private parking, drivers should pay at least its full market cost– because this acts as a disincentive, because there is no valid reason for governments or businesses to subsidise it, and because governments can use the funds for other transport improvements. Moreover, when governments go in the other direction and impose price controls on private parking, as they have in Beijing, Guangzhou, Hanoi and Jakarta, this inevitably suppresses supply, while inflating – rather than reducing – demand for it. Many cities in the developing and developed world charge for parking, but too often it is provided free.

In the allocation of parking space in urban localities, priority should be given to public transport, emergency vehicles, parking for the disabled, taxis, delivery vehicles and short stay parking. And at certain times of the day or week, it may be necessary to convert on-street parking into dedicated lanes for buses or bicycles. A broad plan that cities can adopt is to have a traffic-free centre, surrounded by on-street parking for the special groups just mentioned, and general parking only permitted further out. Urban planning regulations should impose maximum rather than minimum parking ratios, to restrict the number of parking spaces in a locality, and thus encourage the use of other transport modes. Very limited parking provision is a feature of Transit Oriented Developments, which are described in another section of this chapter. Large expanses of ground level parking should be avoided, as these are unattractive, use up much land, and act as a barrier between neighbourhoods. Park-and-ride facilities at transit stations are better than inner city parking, but it is better still to provide feeder bus services and good cycling routes and facilities. Park-and-ride should be avoided in high-density localities.[7]

Governments have the ability – through their urban planning powers, local parking regulations and their own parking provision – to determine urban parking policies, and these are an important tool in reducing private vehicle use. They need not be concerned about vocal groups demanding additional parking, or about an apparent 'lack' of parking spaces, as the restricting of parking will in time reduce demand for it as people switch to other transport. Kampala, Uganda, reduced its heavy congestion in the city centre with stricter parking regulations, including one hour maximum parking tickets, and also reduced road accident levels and increased city revenue, while Shenzhen, China, increased parking fees to a level that sometimes equalled half the cost of keeping a car, and saw demand for parking drop by 30%.[8]

Other price incentives and disincentives

The cost of parking is just one example of the ways in which prices can be used to encourage the switch from private vehicles to more sustainable transport modes. Others include:

- **tollways** for freeways, major roads and bridges
- **vehicle registration charges**, which are universal, but can be increased to manage demand as they have been in Singapore, where registration charges are now 150% of the car's cost

Figure 3.30 London's Congestion Charging Zones clearly marked on the roads

Picture Credit: Duffman , Wikimedia Commons, http://upload.wikimedia.org/wikipedia/commons/0/07/London_Congestion_Charge%2C_Old_Street%2C_England.jpg viewed 22 March 2011.

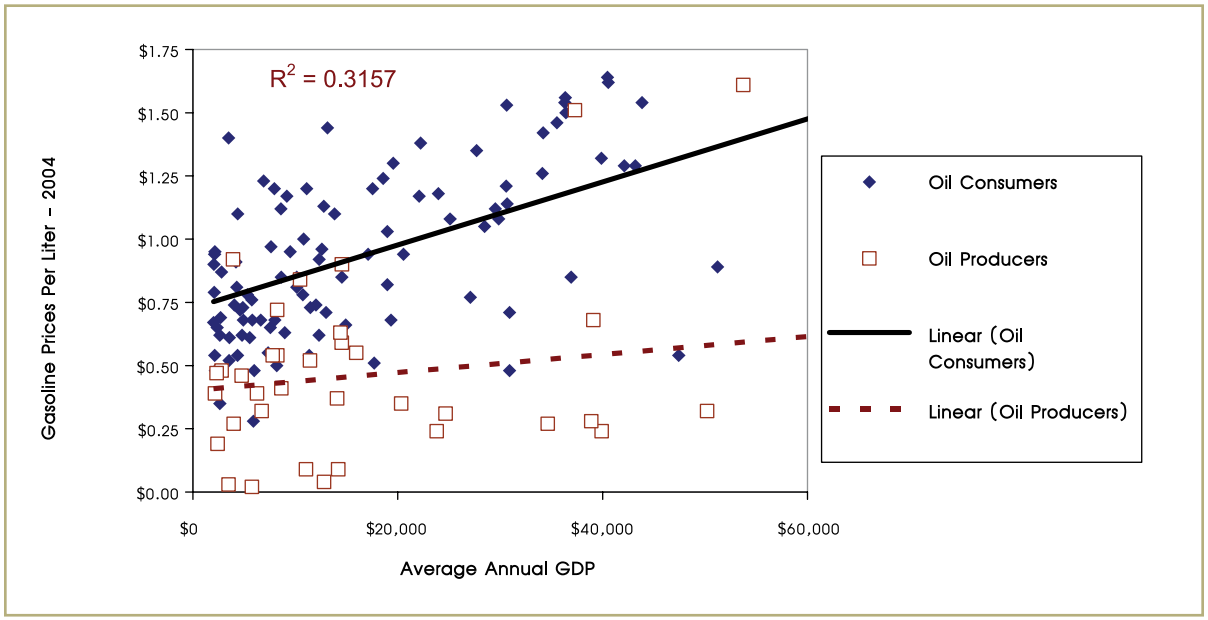
- **congestion taxes** to reduce traffic in central city areas, for example, in London, Stockholm and over a dozen other developed world cities.
- **fuel taxes**, which favour the most fuel efficient vehicles.

Congestion taxes and even tolls can vary in amount (from zero upwards) at different times of the day or week, to manage demand when it tends to be higher, and the toll or tax can be collected manually or electronically (so that, in the latter case, vehicles do not have to stop). London's congestion tax has seen a 21% decrease in traffic, and local residents and businesses have supported it.[9] A similar traffic reduction followed a trial of a congestion tax in Stockholm. London exempts hybrid vehicles from the tax, while Milan exempts fuel efficient and lower emission cars, and schemes in Norway offer discounts to lighter vehicles. In Singapore the tax varies according to the time of day and the level of congestion on particular roads.[10] Removal of fuel subsidies in Indonesia has seen the price of petrol and diesel rise by 126%, and instead the government is offering monthly allowances to around 19 million poor families to help them with living costs.[11]

Increases in fuel prices do not adversely affect prosperity, as shown in the figure 3.31. Economic productivity tends to increase with higher fuel prices, indicating that substantial increases in vehicle fees can be achieved without reducing overall economic productivity.

Other taxation policies can be changed to discourage, or refrain from encouraging, private vehicle use. For example, laws that allow car travel to and from work as a tax free expense should be avoided, or if there are to be tax free travel expenses the same tax free amount should apply to all transport modes or even favour the more sustainable modes. Similarly, companies should either refrain from subsidising their employees' travel to or from work or in their free time, subsidise all modes, or favour the more sustainable

Figure 3.31 Per capita GDP versus gasoline prices in different countries



Source: Todd Litman, Are Vehicle Travel Reduction Targets Justified? Evaluating Mobility Management Policy Objectives Such As Targets To Reduce VMT And Increase Use Of Alternative Modes, Victoria Transport Policy Institute, 12 Nov 2010.

ones. For example, they can provide transit passes or discounted tickets, and if done in collaboration with a transit agency the agency may supply these at a lower price. Policies that make car transport tax free, and company allowances covering employees' commuting and personal car travel, also fuel inequality, because they are usually only available to the higher paid employees. The Astra Zeneca Drug Company located in Britain has 4,200 employees but only 3,277 parking spaces. They encourage the use of public transport by subsidising buses and providing an inter-site shuttle bus free to all employees. They also provide reserved parking spaces for car sharing and offer flexible working practices (ie, tele-working), as well as improved on-site facilities for cyclists. These changes have led to 17% fewer solo drivers between 1997 and 2001.[12]

Restricting areas within which private vehicles can travel[13]

Another way to reduce car use is to restrict the areas within which private vehicles can travel. Some cities have defined an area, usually in the city's core, that is restricted to pedestrians and perhaps other special vehicles (such as bicycles, delivery vans, taxis and public transport). These restrictions may apply at all times or at just some parts of the day or week. Cities that have successfully implemented these measures generally have excellent transit (with public transit every five minutes or so) and high density living. The section on *The walkable locality* in this chapter describes how Curitiba pedestrianised its town centre. When Bogotá restricted car access during peak hours, there was a 28% decrease in road accidents. Bogotá's citizens have now voted to ban private vehicles from the streets for six peak hours a day from 2015.[14] Calle Florida Street, Buenos Aires' (Figure 3.32) famous shopping district, was pedestrianised in 1913, making it one of the oldest car-free zones in the world.[15] As well as adopting such measures in the centre of cities, they can be adopted in any urban development. The section of this chapter dealing with *Transit oriented developments* describes such areas in more detail. The Vauban neighbourhood in Freiburg, Germany, is completely car-free. A car-space can be purchased in a multi-story car park on the edge of town, but 70% of the residents have chosen not to have a car.[16]

Figure 3.32 Calle Florida Street, Buenos Aires, like pedestrian streets the world over, is an attractive, multi-purpose living space, and not just a walking route

Picture Credit: Luis Argerich.

An alternative to keeping cars off the roads altogether in certain localities, is to simply restrict the road space available to them. For example, a road carrying two or three lanes of motorised traffic in both directions might be redesigned to provide one lane each way for private vehicles, with the rest of the space being taken up by transit lanes, cycle ways, expanded pedestrian areas or roadside planting. All cities introducing Bus Rapid Transit systems with dedicated lanes have done this. Another option is to turn the whole road into a shared transport zone, that is, an area with very low speed limits and less demarcation between pedestrian, cycle and vehicle space.

Street design and traffic calming measures[17]

Related to these ways of reducing private vehicle traffic within urban areas are overall street design techniques and the 'calming' of traffic. A range of measures can be introduced to make transport safer, to ensure that different travel modes (such as walking and cycling) have fair access to transport space, and to ensure that different kinds of motorised vehicles use the right roads for the distances they are travelling. Bogotá removed kerbside parking to widen footpaths, and erected barriers to stop cars driving onto them.[18] A part of this process involves traffic calming: making changes to roads which – through a range of physical and psychological devices – cause vehicles to travel more slowly, more safely, and with greater consideration for local residents, pedestrians, cyclists and public transit users. The St George Street Revitalization project in Toronto, Canada, aimed to calm traffic on a busy thoroughfare. It implemented a 'road diet' (reducing the number of car lanes from four to two), improved pedestrian and cycling safety and amenities, and made the area more attractive as well. As a result, speed and road accidents decreased.[19] Traffic calming and other road design measures are described more fully in the *Traffic management* section of this chapter. Although they are not designed primarily to reduce car and other private vehicle use,

they do have this effect, and they therefore deserve to be included as a part of the range of demand management measures that should be considered.

Car-pooling

People who regularly travel along a similar route to the same workplace, school, university or other destination can car-pool, that is, travel together in the same car and thus save money and reduce fuel use and car emissions. They can either take turns travelling in each other's car, or travel in one person's car with the others paying petrol money. Parents driving their children to school can take turns driving other children as well. Car-pooling works best when people already know each other or have something in common such as their school or workplace. They will need to ensure that they can agree on matters like times of travel, punctuality, and smoking and music in the car. Workplaces and schools can encourage employees or students to consider this arrangement. Car-pooling appears to be mainly practised in developed countries,[20] but there is no reason why it should not also be practised in the developing world.

Car-sharing schemes

Car-sharing schemes are cooperative or commercial arrangements enabling people who sign up as members to use cars within the scheme. These cars are parked at various publicly accessible points in a locality, and members – who may be individuals or businesses – pay for the time they use the vehicle and the distance travelled, as well as joining and annual fees. Car-share provides additional mobility for those who mostly rely on walking, cycling and public transport and don't need frequent car access.

In fact, the average privately-owned car spends 95-97% of its life parked and only 3-5% on the road travelling.[21] If a car's use is shared across a number of users, then many of its costs are also shared. In addition, car users and local communities need to allocate less space for parking and, with more frequent use of vehicles, they are changed over more often and members get to use the most recent, efficient, environmentally sustainable models. Moreover, members of these schemes don't need to drive more than necessary in order to 'justify' a large investment – as private owners may feel they have to do – and members are also less likely to drive simply out of habit, instead of taking other transport modes.

Car use is booked and members have a special key, card or code number to access the vehicle. Car-sharing schemes work best if they make use of computer facilities, the internet and smart cards. This enables them to have online booking, on-board computers, car access through smartcards, wireless reporting and monitored, automated billing. While this may seem like a big investment in technology, it is not nearly as big as the investment in multiple cars and parking spaces that those members would be making if they were private car owners. Local councils usually provide the schemes with guaranteed parking, often free or at lower rates, because the councils benefit from the reduced pressure to provide parking spaces, and because they want to support more sustainable transport.

There are now many successful care sharing schemes around the world, in Europe, the US, Canada, Australia and Asia. One scheme in Singapore is linked to a residential development, with a ratio of one vehicle for every forty residents.[22] Zurich has 10,000 members of car-sharing schemes – about 2.3% of its population.[23] Further information on such schemes and on similar arrangements can be obtained online.[24]

5. Costs and sources of finance

Each of the above policies require some expenditure to implement but nothing like the large infrastructure projects that characterise the other measures discussed in transport policy. Furthermore they can be

Figure 3.33 Many local councils provide car share schemes with dedicated parking spots

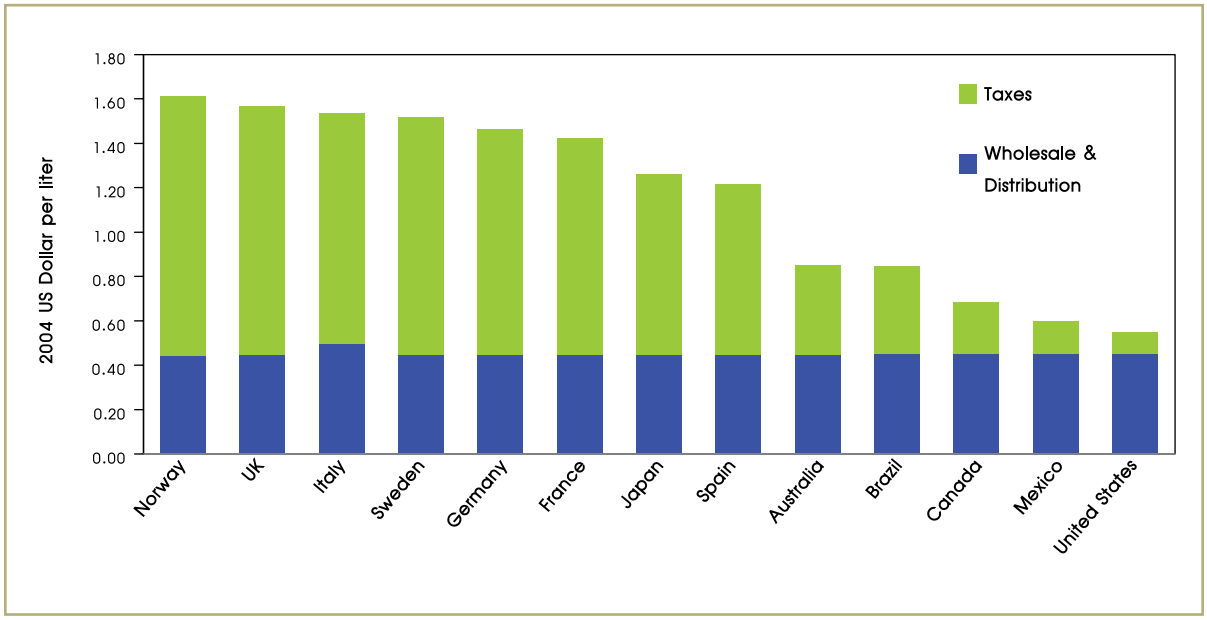
Picture Credit: Sarah G.

made either to raise revenue or to at least cover costs. Fuel taxes remain one of the major sources of government income to enable wealth to be created and distributed for long term projects. As shown in the Figure 3.34 the amount of fuel tax charged varies enormously and in the high taxing nations like Norway is set aside for long term infrastructure projects.

6. Conclusion

Reducing private vehicle use, or curtailing its growth, is vitally important if our world is to reduce levels of greenhouse gas in the atmosphere. Examples from around the world demonstrate that it *can* be achieved. It is generally only achieved when other transport options are good, and when travellers are helped to realise that they don't have to be dependent on cars or other private vehicles to get around. As this section has described, this can come about through information and education, through price mechanisms, through the way streets are designed and used, through parking policies, and through measures to encourage the sharing of cars. Localities that have taken these measures come to realise that reducing greenhouse gas output is just one of many benefits that can follow.

Figure 3.34 Transport fuel prices across countries



Source: Based on data from Todd Litman, Appropriate Response to Rising Fuel Prices: Citizens Should Demand, "Raise My Prices Now!", Victoria Transport Policy Institute, 15 March 2010, http://www.vtpi.org/fuelprice.pdf, viewed 23 Feb 2011.

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H) Improving Private Vehicle Operating Standards

Robert Salter*

1. Introduction

This guidebook describes a range of measures to develop transport services in ways that reduce greenhouse gas emissions, including shifting to mass transit, walking and cycling, reducing the need for travel, and introducing new fuels and electric and other vehicle technologies that reduce and even eliminate emissions from vehicles. All this can require money and time, but there are simple things that can be done immediately to the present vehicle fleet. This chapter shows how fuel use, local air pollution and noise can be reduced through a range of measures: regular maintenance, use of the right type and quality of fuel, appropriate retrofitting, restriction of vehicles allowed on the roads, and the timely retirement of vehicles.

More particularly, it discusses programs and policies that governments and national leaders can implement to advance these objectives.

Although the level of private vehicle use in developing countries is low compared with the level in developed countries, such vehicles are still a major source of emissions, particularly in megacities. This is because standards of maintenance tend to be poorer, the average age of vehicles is substantially higher, and fuel quality is often low, with, for example, a high sulphur content in diesel.[1] Fortunately, almost all countries have removed lead from their petrol, and this demonstrates what can be achieved through cooperative global action.[2] Numbers of private vehicles in many parts of the developed world are rapidly increasing with economic growth, so it is critically important to have in place policies that can help to ensure that conventional vehicles on the roads are operating as efficiently as they can be, thus minimising greenhouse gases emissions.

Accordingly, this section considers the following policy areas, through which to pursue these objectives:

- standards for vehicle fuel economy
- standards for vehicle emissions
- vehicle inspections
- adoption of particular technologies
- taxation and pricing measures for vehicle performance
- inclusion of emissions standards in warranties
- getting older vehicles off the roads
- standards for fuel quality
- driver or owner education.
- Benefits of improved operating performance

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2. Economic benefits

More efficient and better maintained vehicles save fuel, run well for longer and have fewer breakdowns that can cause business disruption. Fewer accidents and less pollution and noise mean low health care costs and less time away from work as a result of illness or accidents.

Social benefits

Reduced pollution and noise mean that people's health is better and their lives are more pleasant, and if vehicle inspections also include safety checks, as they often do, then there will be fewer accidents as well. If people rely on private transport, having more efficient, better maintained vehicles means their transport is more reliable, whether they are travelling to work, education, the shops or any other activities of daily life.

Environmental benefits

More efficient, better maintained vehicles lead to reductions of greenhouse gases, local pollutants and noise, and they reduce consumption of non-renewable fuels that are in diminishing supply.

3. Greenhouse gas emissions reduction potential

A well-maintained vehicle uses between 3 and 7% less fuel, and hence leads to a similar CO_2 reduction.[3] However, the 'Jevons effect' (also called the rebound effect) needs to be considered. This is when cost savings from more fuel efficient vehicles encourage people to drive more, thus cancelling out savings in greenhouse gas emissions. This does not mean that efficiencies should not be pursued; rather it means that other policies are needed as well to reduce vehicle travel before the full benefits of vehicle efficiencies can be seen.

4. Details of the policy measures and their implementation

Standards for fuel economy for new vehicles

Most countries have vehicle fuel economy standards. Those in the European Union and Japan are the most stringent, and China's standards are now more stringent than those in the United States, Canada and Australia.[4] The standards can be mandatory or voluntary, with mandatory ones achieving the best results. When it comes to standards setting, fuel economy/efficiency standards are the most direct way of reducing greenhouse gas emissions, because reductions in fuel use mean the same level of reductions in greenhouse gas emissions, and fewer local pollutants are emitted as well.

However, there are several problems with mandating vehicle fuel economy standards as a way of reducing greenhouse gas emissions. Firstly, improved fuel economy means cheaper travel, and this can encourage people to drive more (the Jevons effect). Thus, demand management measures should accompany it, or even replace it. One study found that carbon taxes are much more effective at reducing greenhouse gas emissions than are fuel economy standards.[5] This makes sense. While greater fuel economy makes travel cheaper, carbon taxes make it more expensive, with travel in less fuel efficient vehicles the most expensive.

A second issue with fuel economy standards is that they only apply to new vehicles, and a third problem is that, except for countries like China, India and Brazil that manufacture their own vehicles, developing

countries can only control vehicle fuel economy standards by banning imports of vehicles not meeting those standards. Many have received cheaper second hand vehicles phased out in wealthier countries, usually vehicles with much worse fuel economy, so a more consistent global approach to fuel efficiency standards would contribute to greenhouse gas reductions.

Standards for vehicle emissions

Vehicle emission standards are worthwhile for reducing emissions that cause local pollution, such as suspended particulate matter (SPM), oxides of nitrogen (NO_x), carbon monoxide (CO) and volatile organic compounds (VOCs), but they do not necessarily lead to fewer greenhouse gas emissions because these local air pollutants can be curtailed without reducing fuel consumption, by the fitting of emission control devices in vehicles. However, it may be argued that tighter emissions standards can be part of a basket of measures that, over time, will bring about a newer, more efficient and better maintained fleet of vehicles on a nation's roads.

Vehicle emission standards have been widely implemented in Latin America and Asia,[6] and this is having an impact on pollution levels. For example, in Mexico City, CO levels in 2000 were 48 percent lower than two years earlier, while NO_x levels were 26 percent lower. China adopted Euro 1 standards in 2000, and aims to meet current European standards with a 4-6 year time lag.[7]

Vehicle inspections

Full inspections usually assess (and sometimes adjust) vehicle performance, emissions and safety, so it can enable vehicle owners to reduce their emissions of greenhouse gases, as well as reducing local pollutants.

There is much debate about the cost-effectiveness of vehicle inspections as a device for reducing emissions. Some analysts see them as critical measures for achieving this,[8] while others maintain that they have only generated small environmental benefits and are not highly cost-effective.[9] However, the testing of vehicle emissions is necessary for many of the other measures discussed in this section, specifically, those that require emissions readings in order to charge fees, put vehicles off the road, order retrofitting, ban imports of low quality vehicles, or reach decisions on warranty matters. The effectiveness of emission inspections is likely to depend on a range of factors, including:

- their prevalence – the higher the proportion of vehicles checked the more polluting vehicles are put off the roads and the stronger incentive there is for owners to have low emitting vehicles, because they have more chance of getting caught
- whether inspections are planned or random – the latter will have a greater deterrent effect
- the degree to which inspection processes are properly carried out, with effective and well-maintained equipment, adequately trained staff, and strong safeguards against corruption
- the extent to which failing an inspection test has real consequences
- the overall level of emissions in a nation's vehicle fleet, which will in turn be influenced by the range of other measures adopted to reduce emissions – the rarer it is to find vehicles with over-the-limit emissions, the less cost-effective it is to have an extensive inspections system.

From this perspective, inspections may be especially valuable in countries and cities with very bad air pollution, provided the process is efficient and uncorrupted. Programs in China and Mexico are particularly cited as being successful.[10] Across the developing and developed world, a small proportion of vehicles

are responsible for a large proportion of pollution. One study found that 10% of vehicles were responsible for half of the emissions.[11] Inspections are likely to lead to faster adoption of emission control devices and a faster turnover of vehicles. But if a program is ineffectively implemented, the benefits will not follow. For example all vehicles in India are supposed to be inspected every three months for a 'Pollution Under Control' certificate, but proportions of vehicles in any one year in the 1990s with a valid PUC certificate ranged from 9% to 23%. Furthermore, only 1% of owners of vehicles found to be non-compliant were fined in 1997 (partly because of the paperwork required), and the practice of cancelling the PUCs of non-complying vehicles was discontinued in that year following public pressure. Moreover, an alarming 44% of new vehicles tested did not meet standards, and there is also a high level of adulteration of fuels in India.

It is best to separate the processes of inspecting and repairing vehicles, with the inspections conducted by centralised systems, and repairs and maintenance carried out by decentralised operators. This removes conflicts of interest and reduces corruption, and a centralised inspection system ensures greater consistency, cost-effectiveness, professionalism, and credibility in the eyes of the public. Inspection systems can be contracted out by public tender. There should also be random roadside vehicle inspections, but it is suggested that these be carried out by different bodies from those conducting the fuller inspections, to avoid a conflict of interest, and that roadside inspections be in the hands of a government organisation to enable the government to assess the effectiveness of the overall inspection system.[12] There is now low-cost technology to check the emissions of moving vehicles.[13] Inspections should target the kinds of vehicles generating the worst emissions. Ways of covering the costs of inspections are discussed later in this section.

Mandatory adoption of particular vehicle technologies or design standards

One way for emissions to be reduced is for governments to mandate particular technology design standards for new cars, or the retrofitting of technologies for vehicles already on the road. For example, catalytic converters are now compulsory in many countries, both for new and existing vehicles, because they prevent emissions of many local pollutants, and any countries that do not already require them for all vehicles should do so.

Many countries have adopted particular standards for vehicles permitted on their roads. For example, a large number of Latin American and Asian nations have adopted such standards, normally expressed in terms of their conformity to European or American standards (for example, Euro 1,2,3 and 4, and USETA).[14]

India's Supreme Court, following a long and complex court case about the rights of New Delhi's residents to breathe unpolluted air, directed the phasing out of the city's commercial vehicles that were more than 15 years old, the replacement of the city's pre-1990 autos and taxis with new vehicles using cleaner fuel, and the conversion of the city's auto-rickshaw and bus fleet to the use of compressed natural gas (CNG). The local government in New Delhi was required to enact this change, and this law eventually led to the Government of India mandating emissions standards aimed to achieve the goal set by the Supreme Court. The conversion of vehicles, especially the auto-rickshaws and buses in Delhi, has now been followed by Mumbai, Kolkata and other Indian cities with immediate improvements to air quality. The same approach is now being enacted in Indonesia to control the worst vehicles, especially their Bajajs (auto-rickshaws).

Thus, government can decide on a case-by-case basis whether to require the adoption of particular technologies or design standards, or to mandate specific emissions or fuel quality standards, in order to reduce levels of emission of local pollutants or greenhouse gases.

Taxation and other pricing measures for vehicle performance

A range of financial incentives and disincentives can be used to encourage appropriate practices related to the buying, operating and maintaining of private vehicles. For example, taxes on fuels can help to induce people to buy the most fuel efficient vehicles, maintain them better and drive them less. Evidence from the North shows a strong correlation between fuel prices (including taxes) and the average fuel efficiency of cars. Differential taxes on fuels can also alter relative prices of different fuels in order to encourage use of the cleaner ones. Grants or tax credits can be given for the adoption of particular technologies. For example, in Kolkata, India, auto-rickshaw owners are being given grants of Rs 12,000 to switch from petrol two-stroke to LPG four-stroke engines.[15]

Figure 3.35 The Toyota Prius allows you to monitor your emissions output

Picture Credit : It's Our City.

It has also been suggested that an emissions fee might be levied, following an inspection, as an alternative to a simple pass/fail ruling. The fee would increase with the emissions level. This would have the advantage that emissions levels not serious enough to have the vehicle banned could still be subject to a fee that would act as an incentive to lower emissions, while those vehicles with more serious emissions that would have seen them banned receiving heavy to prohibitive fees depending on the exact level.[16] If the fee was also related to distance travelled then there would also be an incentive to drive less, but such a policy really requires tamper-proof odometers.

Yet another alternative is to have an emissions fee that is simply determined by the model and year of the vehicle, rather than actual emission levels, on the grounds that this is administratively easier and cheaper and based on the assumption that there will not be large differences between vehicles in the same category. This would encourage people to buy newer, cleaner vehicles, and there could also be a provision whereby they could claim a rebate for getting certain repairs or maintenance done.[17]

Fees and taxes can be especially hard on those on low-incomes, but if the poor are compensated in other ways then they can be, on average, no worse off as a result of these measures.

Inclusion of emissions standards in warranties

Requiring manufacturers and sellers of new cars to include emissions levels in their warranties creates an incentive for them to do what they can to lower emissions.[18] Drivers and owners would also have more incentive to have their vehicle checked if they knew that the cost of any repairs or maintenance work would be covered by a warranty. Of course, the warranty could require certified regular maintenance by the owner, as most warranties already do. Vehicles under such a warranty could be exempt from any emissions fee.

Nations that only import vehicles and do not manufacture them are unlikely to have the power to require vehicle manufacturers to include emissions in their warranty cover, but they can more easily require local car retailers to provide this coverage.

Getting older vehicles off the roads

Emissions of pollutants and greenhouse gases tend to be much worse in older vehicles, and this is partly because emissions control equipment deteriorates in performance over time. Also, newer cars tend to be much more fuel efficient and have better emissions reduction technology. Furthermore, a British study of the total life cycle of a car found that only 9% of emissions occur during its manufacture,[19] which means that a new, efficient car can start to generate lower net emissions in a relatively short time. So it makes environmental sense to have newer cars on the road.

This can be encouraged through lower taxes of all kinds on newer and more efficient vehicles. It is also worth considering that taxes on new vehicles (such as import tariffs) or on vehicle sales may have the effect of encouraging people to hold on to older vehicles longer. Singapore, which has a registration fee for new vehicles of 150% of the vehicle's cost, has gone some way to addressing this problem by providing a rebate on this fee if an old car is scrapped in the process. In Brazil, if an old car is scrapped in the process of buying a new car with a catalytic converter, the buyer is exempted from the initial lump sum tax and road tax for five years.[20]

Another option is a simple payment to vehicle owners to scrap a vehicle, but this is a drain on government funds – as opposed to taxes on older vehicles which are a source of funds. The scrapping price needs to be higher than the used car price in the marketplace, although this scrapping price is likely to raise the price of the used vehicles – because the government, as a buyer of the vehicles, is creating extra 'demand' for them while the supply diminishes.[21]

Some nations, including a number in Latin America, have banned imports of used cars as a way of preventing an accumulation of older vehicles in their national fleets.[22] Other options are to impose a heavy import tax on used vehicles or engines as a disincentive, or to require them to pass a stringent emissions test as a condition of registration.[23]

Standards for fuel quality

As of May, 2010 there were only 11 countries in the world that still had leaded petrol. This demonstrates how change can occur through concerted international action. Sulphur in diesel fuel remains a serious

Figure 3.36 In Cairo and elsewhere in the world older vehicles need to be replaced to reduce greenhouse gas emissions and local pollutants

Picture Credit : Karl Fjellstrom, itdp-china.org.

problem in many countries, but there is no reason why governments cannot simply mandate substantial sulphur reductions as occurred with lead. This has already happened in developed countries and parts of Asia and Latin America.

Cleaner fuels have an immediate impact on the emissions of both new and existing vehicles. They can reduce the level of local pollutants, but they do not reduce fuel use and greenhouse gas emissions if they are just purer versions of the same hydrocarbons. This requires a switch to more efficient vehicles, reduced use of vehicles, or a lower carbon fuel such as compressed natural gas or ethanol. Some countries mandate the blending of fuels, requiring that they contain certain proportions of ethanol or biodiesel, for example. This is mainly done for energy security reasons, but it will also lower CO_2 levels in most cases. Care should be taken to ensure that the production of biofuels is a net carbon reduction process, and does not involve deforestation or the use of land required for food production. Alternative fuels are discussed in more detail in another section of Chapter 3, *Vehicle and fuel technologies*.

Even though measures to improve fuel quality do not always reduce greenhouse emissions, building a culture of responsibility for the emissions that vehicles emit – among drivers and among vehicle and fuel related businesses – must encompass responsibility for reducing or eliminating both local pollutants and

greenhouse gases. Developing a sense of responsibility about each of these issues will make it easier to develop a sense of responsibility about the other.

One problem is that countries without their own refineries have little or no power over the composition of fuels coming out of refineries. However, they can decide whether to impose import bans on particular fuels, or rely on technology within vehicles to remove pollutants. They can also inspect fuel at the retail level or in vehicles, because in some countries, such as India, there is a high level of adulteration of fuels.

Driver or owner education

If people are to drive or ride motorised vehicles, they need to learn the physical skills and judgement required to manage this, and they need to learn the road laws. If they are to own a vehicle, they should also learn about buying or selling a vehicle wisely, and about keeping that vehicle well-maintained. This will benefit them practically and financially, as well as making their vehicle safer and better for the environment. These skills and knowledge can be learnt voluntarily, but the learning will happen on a much larger scale if it must be learnt and is tested as part of the process of obtaining a driver's licence. (This in turn presumes that the licence is only given to those who genuinely pass a test of driving skills and knowledge.)

To help prospective drivers gain this information about buying and selling vehicles and keeping them properly maintained, governments or private organisations can run courses on it, or include it in broader driver education courses. Thus, prospective drivers or riders can learn about:

- the cleanest, most fuel efficient vehicles
- what regular servicing needs to be done (and what can happen if this is not done)
- the small things owners or drivers can do themselves, such as keeping tyres properly inflated
- the fact that their vehicle may be inspected, and the consequences of failing this inspection
- the right time to sell their vehicle.

Figure 3.37 New drivers need to learn how to take care of their car as well as how to drive it

Picture Credit: Ildar Sagdejev.

These are the sorts of subjects covered by a campaign called Auto$mart, which was started by Natural Resources Canada's Office of Energy Efficiency. Auto$mart encourages the public to make sound decisions about vehicle purchases (such as how to choose the most fuel-efficient vehicle), about vehicle maintenance and driving habits. This is also covered in driver education programs that Auto$mart runs for novice drivers, and more than 270,000 people have participated in these. They learn how to drive efficiently, when to drive (when you cannot walk or use transit), how to buy and maintain a vehicle with fuel efficiency in mind, and how what's good for your car is also good for your wallet and the environment. Most of the fuel-efficient driving techniques taught through the Auto$mart program also contribute to safer driving.[24]

5. Costs and sources of funds

Compared with the costs of developing transport infrastructure, the costs to government of administering the measures described in this section are relatively small, or in some cases government actually earns income from them. The income raising measures include all the taxes and fees designed to deter certain practices, such as driving inefficient vehicles. Many measures are inexpensive for government because they are just matters of regulation of fuel economy and fuel quality standards, the inclusion of minimum vehicle emission standards in warranties, and bans on imports of low quality used vehicles and engines. Policing emissions standards, while also a matter of regulation, is more expensive because it involves the checking of large numbers of individual vehicles. But this checking is done by vehicle inspection services, and there is a range of ways to pay for such inspections. Vehicle owners can pay a fee for the inspections and another for the certificate they receive. Governments can provide land to contractors for test facilities, reducing the costs of tests for the owners. A calculation, in a 2005 publication, of the costs of an overall check of a passenger car in Indonesia (emission and safety checks, plus tuning and simple repairs not involving spare parts) found it to be around US$22, but a simple emissions test would be much cheaper.[25] The cost of driving lessons and tests can also be charged to those taking them. There can also be cross-subsidisation of measures that cost the government money by those measures that earn it money.

For vehicle owners and for vehicle and fuel related businesses there may be significant up-front costs, but once made the greater efficiencies involved lead to reduced transport operating costs and in some cases reduced government charges.

If the costs these measures impose on vehicle drivers or owners seem unduly harsh, two things need to be remembered. Firstly, they represent an effort to require private vehicle drivers to pay the full costs of their trips, including environmental and social costs, thus lessening the practice of allowing such costs to be borne by society as a whole. Motor vehicle accidents are now a huge cost to society and these costs are larger on a per vehicle basis in developing nations. The costs of climate change are beginning to be understood and could also be very substantial. Secondly, they can also act as demand management measures, encouraging drivers to switch to safer, more efficient, low-carbon transport modes.

6. Conclusion

The measures outlined in this section are part of a bigger picture. Reduced greenhouse gas emissions will result from shifts to other transport modes, from reduced levels of travel, and from the adoption of new vehicle technologies and fuels. But at least in the short to medium future, these measures cannot, either individually or together, entirely reduce greenhouse gas emissions to the extent that is necessary. It is also essential that conventional private vehicles on the roads now and in the future are as fuel efficient and non-polluting as possible. The policy options just described are some avenues to achieve this.

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I) Traffic Management

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1. Introduction

Roads, streets and paths are part of the fabric of our communities, facilities for all to use. They enable us to move around in order to do what we want or need to do in our lives. But to ensure that this can happen effectively, and that traffic on these routes is not detrimental to our communities, the whole system of travellers, vehicles and travel routes needs to be carefully managed. This section addresses the process of doing so. Proper traffic management can ensure that:

- traffic flows smoothly and efficiently
- there is fair access for different transport modes, and the more sustainable modes are encouraged
- roads and streets are safe for all users, including pedestrians and cyclists
- roads full of motorised traffic do not constitute barriers blocking movement between areas
- congestion, local pollution and noise are minimised
- neighbourhoods, pedestrian areas and the overall character of localities are protected from the negative impact of high traffic levels
- greenhouse gas is reduced.

These goals, in turn, can be achieved through a range of measures, which can be divided into the following categories:

- the creation of a rational hierarchy of roads and streets that ensures particular street use, and so vehicles tend to be restricted to the most suitable thoroughfares to minimise traffic impacts
- roadways designed to maximise connectivity, with minimal dead-ends, especially for pedestrians and cyclists
- the use of design features and road laws to 'calm' or slow down traffic
- the allocation of road lanes and space to favour more efficient modes
- proper traffic control at intersections, in the interests of safety, fair access for all traffic modes, and smooth flow of traffic
- demand management measures, including pricing mechanisms and restrictions on road space and parking, to ensure that more smoothly flowing traffic does not have the adverse effect of encouraging large numbers of extra motorised vehicles onto the roads
- driver education and the proper enforcement of road laws.

2. Benefits of effective traffic management

Economic

If traffic is well-managed, vehicles travel more smoothly and there are fewer delays. This means time is saved and there is less wear and tear on vehicles. There are fewer costs to health from pollution and

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accidents. And as public transit, walking and cycling gain a bigger share of all travel undertaken, the total cost of transport to society as a whole goes down.[1]

Social

When traffic is well-managed, urban areas are safer, healthier and more pleasant to live in. There is less traffic intrusion into neighbourhoods and other social spaces. Those on low incomes have better transport services because public transit, cycling and walking gain better and safer access to travel space and thus become more viable alternatives to private vehicle use.[2]

Environmental

More smoothly flowing traffic, as long as it is associated with greater use of transit, walking and cycling, will reduce pollution and greenhouse gas production. If it is accomplished by building substantially more road capacity it can just increase the use of private vehicles and hence increase transport carbon. Also, when traffic congestion is reduced by increasing other modes and calming motorised traffic there is less noise and more balanced and sociable use of public spaces (see chapter 3).

3. Greenhouse gas emissions reduction potential

The potential for greenhouse gas savings from traffic management measures is a complex and controversial subject – see chapter 2. Reducing traffic congestion by increasing road capacity will lead to greenhouse gas reductions for individual vehicles, as they can travel more efficiently, but it does not lead to reductions overall as it attracts more vehicles onto the roads.[3] A car travelling smoothly at a moderate speed may be more efficient that one engaged in stop-start travel, but if this smoother traffic leads to an increase in the number of vehicles on the road the outcome is a net increase in greenhouse gas emissions. However if traffic congestion can be eased while at the same time reducing private vehicle use – through traffic calming, reduced road space for these vehicles, and a range of demand management measures – then greenhouse gas reductions can be achieved.

4. Measures to achieve better traffic management

A hierarchy of roads and streets

Users of roads and streets do so for different purposes and have different impacts on those around them and on the environment. Compare, for example, a semi-trailer hauling freight between cities, a car or motor scooter carrying a teacher to and from her school each day, and some children playing on a neighbourhood street. The vehicles mentioned impose certain costs and risks on other road users (such as the children playing), as well as on tax payers and the environment. It would be better if this freight movement and commuting were accomplished on public transit, but if private vehicles are to be used then risks and costs need to be minimised and the trips made as smooth and efficient as possible. Having different kinds of roads for different vehicles, purposes and lengths of trips can help this to occur.[4]

Freeways, highways and arterial roads can take longer distance traffic and almost all freight. Vehicles travelling on lesser roads can carry those travelling shorter distances, for example, to shops, local workplaces and schools. Inner city areas and neighbourhood streets can be mainly reserved for public and non-motorised transport, for pedestrian or non-transport uses of public space, and for vehicles leaving or returning to residences. Physical barriers and calming devices, pricing policies such as congestion taxes, regulations barring particular kinds of vehicles from particular roads, and restrictions on parking are all measures that can be used to prevent or discourage the use of roads and streets by the wrong vehicles for the wrong purposes or trip lengths. And freight depots can be kept away from high-density, residential

and commercial areas. This is not an argument for building more roads to accommodate through traffic, long-distance traffic and freight, but rather for keeping this traffic off local and lesser roads, for controlling it better when it is on these roads, and for providing more alternatives to private vehicles. Research across the world has shown that cities with extensive freeways, for example, have just as much traffic congestion as those without such freeway development, because of the increased numbers of private vehicles that freeway building encourage onto the roads.[5] One device to assist in the planning of the location of routes and services for different modes of private and public transport is the origin-destination (or OD) study. This obtains information about origins and destinations of trips from personal interviews, mail interviews, licence plate tracking and a range of other means.[6]

It is important to recognise that, while roads are for travel, streets can also serve a range of other purposes. For example, consider this comment about kampung (urban neighbourhood) streets in Surabaya, Indonesia.

> The paths…are at once front yard, market stall, playground, meeting place and thoroughfare for the thousands of residents of each kampung. Kampung streets express that melding of transportation, social, economic and cultural functions that was common in the pre-automobile cities of the West, but has now been lost in favour of the street as merely a conduit for automobiles.[7]

Fortunately, developed countries are realising their mistakes and starting to change. Some transport experts now recommend designing 'complete streets' which safely accommodate the needs of all users, including pedestrian, cyclists, motorists, public transport and local freight vehicles.[8] Special attention is needed to protect pedestrians.[9]

In Surabaya, also, when it was realised that certain improvements were necessary in kampungs, great care was taken to ensure that the many aspects of street life just described could be retained. Under the Kampung Improvement Plan, there were improvements to streets and pathways, to garbage collection and recycling, to drainage and sanitation and various other facilities and services, but the basic character of street life as a site for many social, economic and cultural activities was carefully maintained, and keeping kampungs as basically car-free areas was an important part of this.[10]

In addition, the cities of Curitiba and Bogotá are both excellent examples when it comes to giving pedestrians safe and fair access to travel space.

Traffic calming measures[11]

'Traffic calming' measures can be introduced to restrict the number and speed of motorised vehicles – especially those vehicles that should be on other roads – and to help ensure that drivers respect other road and street users.[12] Such measures include:

- very low speed limits
- streets that are narrowed and/or have curves added to the lanes (e.g, see Figure 3.38, with the space freed up by these measures then being available to be used for trees, gardens, paths and seats)
- frequent pedestrian crossings (and if they are at the walkway level rather than the slightly lower road level it emphasises that this is 'pedestrian space' and doubles as a speed hump)
- streets shared with pedestrians and non-motorised vehicles (which have very low speed limits and often feature different paving materials and the absence of road camber and curbing, thus suggesting a driveway rather than a road and moderating driving behaviour accordingly)
- speed humps and 'rumble strips' (which make a noise when vehicles go over them)

Figure 3.38 In Brisbane, the narrowing of streets is intended to slow traffic

Picture Credit : Karl Fjellstrom, itdp-china.org.

- perhaps one-way or dead-end streets for motorised vehicles, but if these exist there should be two-way access open at both ends for pedestrians and cyclists.

Through such measures inappropriate traffic can be discouraged from using local streets and can be controlled and made safer if it does.

The allocation of road space to favour more efficient transport modes

When it comes to the allocation of space on particular roads and streets, lanes and space can be assigned to particular kinds of road users, with priority given to the most sustainable ones, including light-rail, buses, people practising car-pooling and other multi-occupant vehicles, taxis, bicycles and pedestrians. The use of distinctive colours and materials for dedicated lanes, as well as raised lane edging or even fencing, can keep inappropriate traffic off them and help to protect legitimate users.

Such measures can also deter private vehicle use on roads by restricting the space available to these vehicles.

Proper traffic control at intersections

In the interests of safety, fair access for all transport modes, and smooth flow of traffic, there needs to be proper control of traffic at intersections. Broadly speaking, there are five design options: uncontrolled intersections, priority controlled ones, staggered-T intersections, roundabouts and signalised intersections (that is, those with traffic lights), not including more expensive options like flyovers or tunnels. Staggered-T

Figure 3.39 In Kunming, these centre lanes are for buses only

Picture Credit: Karl Fjellstrom, itdp-china.org.

intersections are those in which there is a slight 'dog-leg' as a road crosses another road, such that vehicles travelling on the first road need to divert slightly at the intersection. This kind of intersection can bring about significant reductions in accidents, although it can be confusing to navigate for pedestrians and cyclists, and so should only be used in low traffic volume, low growth areas.

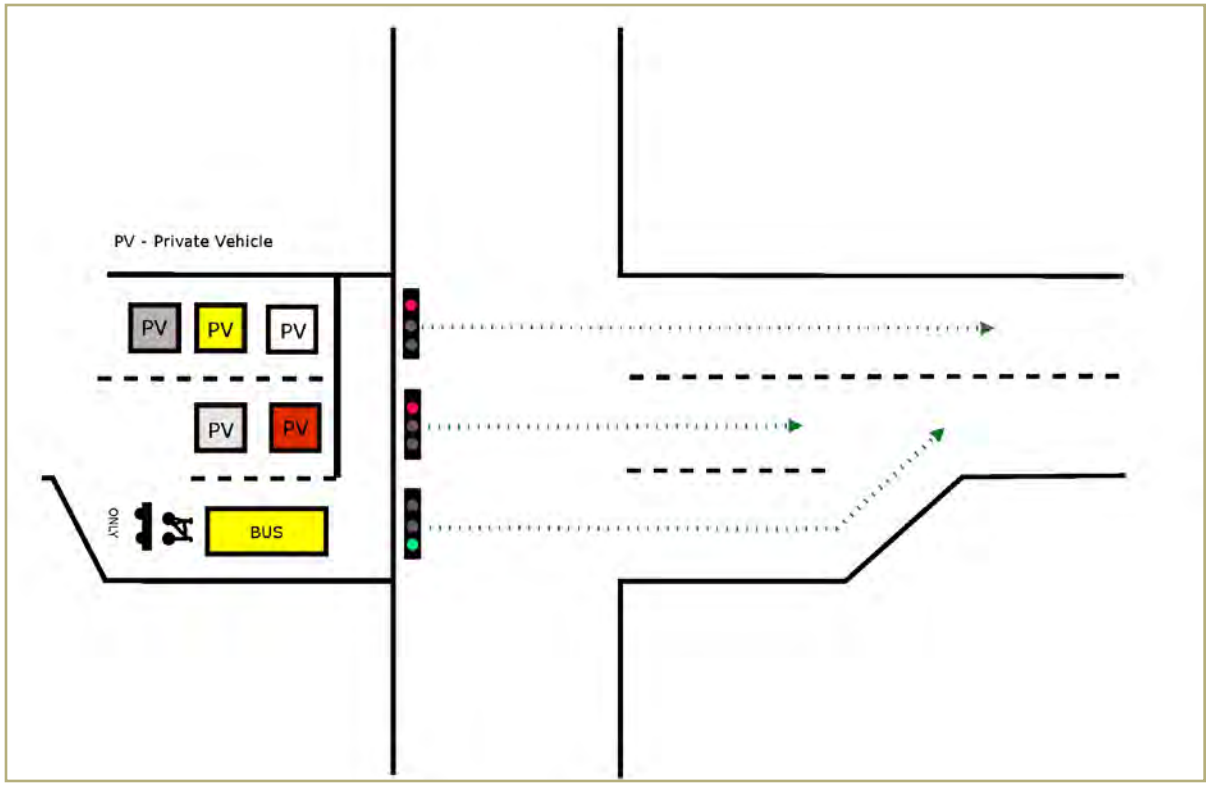
Roundabouts are a rational solution for lesser roads, but two (or more) lane roundabouts are very unsuitable for cyclists and other slow vehicles, as they may need to change lanes in quite fast traffic when turning. They are also undesirable for pedestrians because motorised vehicles are likely to turn without watching or stopping for them.

Signalised intersections are the best solution for pedestrians and cyclists on main roads. It is a good idea if a phase of the signals allows pedestrians to cross in both directions at once. There can also be provisions for a 'bus-jump' or a 'bicycle-jump', allowing these vehicles to take off before other modes (Figure 3.40).

There is also the possibility of bridges or underpasses for pedestrians and cyclists. These are safe if used, but pedestrians and cyclists often ignore them because they require them to travel further and to climb stairs or ramps. They also send a message that motorised vehicles are the 'normal' traffic that should be uninterrupted, with walkers and cyclists going over or under them. These type of facilities should be reserved for special roads, such as wide arterials or expressways. Signalised intersections are recommended for normal streets and arterials.

Slip lanes, which allow vehicles to 'cut the corner' (and often avoid the traffic light), can reduce the bank- up of vehicles at intersections, but they represent an extra hazard for pedestrians. Tight corners at intersections, on the other hand, require vehicles to turn more slowly.

Figure 3.40 This illustrates how traffic signal can give buses a head start at intersections



Source: Andrew Bossi.

Further details of intersection design are available from road design manuals.[13] But however well designed an intersection is, it will not be safe or effective unless drivers obey road laws. For example, pedestrians will not venture onto crossings in the face of oncoming traffic unless they are very confident that the traffic will stop for them. If failing to stop for pedestrians is part of the road culture, then heavy fines, strict enforcement and driver education will be necessary to change this.

Demand management measures[14]

In order to ensure that more smoothly flowing traffic does not have the adverse effect of encouraging large numbers of extra motorised vehicles onto the roads, it may be necessary to introduce countervailing demand measures, including pricing mechanisms, restrictions on road space and parking, and the development of alternative modes and encouragement of their use. These are described in other sections of this guidebook (Private vehicle demand management and Mass transit), so readers should consult those sections for further information.

There has been an unfortunate tendency for policy in many countries to go in a different direction: to build more roads and larger roads, in order to relieve traffic congestion. However, as already noted (and covered in detail in Chapter 2), rather than easing congestion, this policy simply encourages more cars on the roads, longer car trips and more urban sprawl, and over time congestion levels can remain the same (the 'rebound effect').[15]

However, such policies can be reversed. In Seoul, a large highway that completely covered the culturally significant Cheonggyecheon stream and an ancient bridge was demolished in 2003 (see Figure 3.41). The

Figure 3.41 Cheonggyecheon stream: The 6 km stream has now become a modern public recreational space

Picture Credit: Flickr, Wikimedia Commons, http://commons.wikimedia.org/wiki/File:Korea-Seoul-Cheonggyecheon-01.jpg viewed 22 March 2011.

stream its banks and the bridge were restored, an underground rail line and a bus rapid transit service were initiated, and measures were taken to reduce the need for travel. The result has been better transport services, less traffic, a restored river and environs, and a cleaner, less greenhouse-gas-generating locality.

Driver education and effective enforcement of road laws

Road designs and laws are only as good as road users' willingness to obey the rules. In countries where there is widespread flouting of road laws, stricter enforcement and harsher penalties may be needed in order to change this road culture. It is no use giving pedestrians and cyclists certain rights on paper if they are denied these in practice on the roads.

Given that drivers of cars and other motorised vehicles require a licence that involves passing a test, there is an opportunity here for a lot more emphasis to be put onto educating drivers about road laws that protect pedestrians and other road-users. If this is then combined with stricter enforcement and harsher penalties for breaking these laws, then a cultural change can be achieved that makes roads safer for everyone and ensures that pedestrians and cyclists have fair access to public travel space.

5. Costs and sources of finance

Traffic management measures vary greatly, depending on what is done, over what area or length of road or pathway (if it is a physical measure), and the degree of change necessary. Some of the major measures involved, as describe in this section, are alterations to roads for traffic calming, creation of dedicated

lanes for buses and bikes, better controls and safety at intersections, driver education, and stronger enforcement. These could be partly funded out of taxes and charges on private vehicles.

6. Conclusion

Public travel space is for everyone, not just for users of cars and other private vehicles. Achieving smoother private vehicle flows by giving such vehicles priority, or by building bigger and better roads for them, increases their numbers on the roads and the traffic injuries and deaths, air pollution and greenhouse gases they generate. In the end it does not even ease congestion, because vehicle numbers increase as a result. But effective traffic management can give all travellers good access to travel space, substantially reduce the adverse effects of traffic on communities, and contribute to the lowering of greenhouse gas emissions, if the measures described in this section are adopted.

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J) Electric Vehicles

Andrew Simpson*

1. Introduction

An electric vehicle (EV) uses one or more electric motors for propulsion, powered by electricity generated off-board the vehicle. Electric vehicles can include electric bicycles, electric motorcycles and scooters, electric cars, electric trucks, electric buses, electric trams and trains, and even electric boats and aeroplanes. However, this section focuses predominantly on private electric road vehicles (two, three and four-wheelers) since other transport modes have been covered separately in other sections of the guidebook.

Increased concern over the environmental impact of petroleum-based transportation, along with the looming economic impacts of peak oil, has led to a significant boom in the development of electric vehicles.[1] They have tremendous potential as a sustainable transport solution because:

- they can be recharged with electricity produced from local sources
- they potentially offer very low running costs in terms of energy use and maintenance
- they produce no direct tailpipe emissions during operation, offering significant air quality benefits
- they are more easily manufactured locally
- they offer a truly carbon-neutral transport solution when recharged from renewable sources.

There are, however, some significant remaining barriers to the widespread use of electric vehicles for private transportation, which include:

- the availability of recharging infrastructure to provide adequate utility
- the cost of electric vehicles – in particular the cost of their batteries.

Despite these barriers, many examples of road-going electric vehicles can be found around the world. In developed-world markets, automakers are now launching a new generation of high-performance electric passenger cars to capitalise upon the latest technology.[2] However, electric vehicles have been in use for over a century and the technology is available in many different forms that cover the full spectrum of size, performance and cost. For example, over 650 electric 'tempos' operate in the streets of Kathmandu[3] and over 5,000 electric rickshaws are in use in Bangladesh.[4] In China, the population of e-Bikes (electric two-wheelers) is reported to be nearly 80 million[5] having become 'the most popular transportation in towns'. In all cases the users are attracted to electric vehicles' inherent simplicity and low running costs. Furthermore, countries such as China, India, Thailand and Bangladesh have all successfully manufactured electric vehicles for their local markets for many years, while China, India, Brazil and South Africa are now also taking the next step to manufacture electric passenger cars for local use and global export markets.

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2. Benefits of using electric vehicles for private road transportation

Economic benefits

Energy Resilience: Electric vehicles differ from petroleum-powered vehicles in that the electricity they consume can be generated from a wide range of sources, including fossil fuels, nuclear power, and renewable sources such as solar, wind or biomass, or any combination of these, and most countries have such a combination. In contrast, vehicles powered by combustion engines usually only derive their energy from a single or limited number of fuels, usually from non-renewable fossil sources and often from a limited and concentrated supply. Furthermore, electricity can be produced at both large and small scales within both urban and rural contexts, and electricity is a form of energy that typically remains within the country or region where it was produced. As a result it provides a nation with a high degree of energy resilience. For example, Laos is currently pursuing the strategy of becoming the 'battery of South-East Asia' by developing a scheme of (albeit controversial) hydro-electric dams to supply renewable energy to the entire ASEAN region.[6]

Use of existing infrastructure: Electricity for transport can be distributed via established electrical infrastructure and transferred to the vehicle through overhead lines, wireless inductive charging, or a direct electrical cable connection. As such, electric vehicles typically do not require a 'new' energy infrastructure, but instead can be supported through augmentation of existing electrical energy infrastructure. This potentially alleviates one of the more commonly cited barriers to alternative transportation – namely the lack of distribution infrastructure for alternative fuels.

Energy efficiency: The electricity for an electric vehicle is typically stored onboard the vehicle using a battery, flywheel, or super capacitor with very high energy efficiency. Another key advantage is regenerative braking, that is, capturing the energy created by the momentum of the vehicle at the moment of braking, which would otherwise dissipate as heat. Therefore, electric vehicles offer superior energy efficiency that is typically about three times higher than an equivalent combustion engine vehicle.[7] This means they use only a third the energy (making them typically cheaper to run) and leave more energy available for other purposes.

Low cost of electric transport: When compared to global, regional and local prices for petroleum fuels, electricity is typically a very low cost form of energy for transportation. As such, more attention must be paid to the cost of the electric vehicles themselves, as well as the cost of supporting infrastructure, but it is often the case that a well-designed electric transport solution can deliver transport services at significantly lower total cost per passenger-kilometre than an equivalent petroleum-based system. For example, Weinert et al[8] estimated the lifecycle cost of electric two-wheelers in China to be US$3 per 100km less than equivalent gasoline motorcycles. Similarly, AECOM[9] estimated the lifecycle cost of electric cars to be up to US$2 per 100km less than equivalent petroleum vehicles, with the cost saving predicted to exceed US$10 per 100km in 2040.

Rapid uptake: On this basis, the global uptake of electric vehicles is expected to be quite rapid. The general consensus among industry forecasts is that electric vehicles could account for 5-10% of new vehicles sold in 2020,[10] [11] with the likelihood of significantly higher uptake beyond then. For example, the International Energy Agency's Technology Roadmap for Electric and Plug-In Hybrid Electric Vehicles[12] sets a target for electric vehicle uptake of at least 50% of light-duty vehicle sales worldwide by 2050. However, for many nations the high cost of electric vehicle technology could remain a significant barrier throughout this timeframe.

Figure 3.42 Indian Electric Cars: REVANXG is sold locally and also exported to Europe and Brazil (left). All electric version of Tata Nano is expected to come on the market in 2012 to become the world's most affordable electric car (right)

Picture Credit: RevaNorge for REVANXG. And Asier Llaguno for Tata Nano.

Local industry development: Compared to petroleum propulsion, electric-vehicle systems can be highly modular and mechanically very simple (in many cases they include only a single moving part – the motor). This has important implications for local manufacturing of electric vehicles. Their modularity and mechanical simplicity can accommodate lower-cost components, less-sophisticated production techniques and less-expensive manufacturing facilities, which lower the barriers to development of local manufacturing capacity. A wide array of electric vehicle components has become increasingly available on the global open market, and these components can feed into local assembly lines that utilise lower labour costs in lieu of highly-mechanised factories. Also, the simplicity of electric vehicle assembly is an ideal partner for vehicle retrofitting schemes, which can build upon a nation's existing vehicle stock rather than importing new vehicles. As such, the development of local electric vehicle production can provide a valuable contribution to broader strategies for local economic growth and local employment opportunities. For example, the emerging economies of China,[13] India, Brazil and South Africa have all made significant investments in their local electric vehicle industry capacity.

Reduced maintenance requirements and costs: The mechanical simplicity of electric vehicles also brings greater reliability, which translates into reduced maintenance requirements and costs.[14] This means less expense for the user, better operation in the absence of routine maintenance, and less chance of the vehicle breaking down due to lack of maintenance. Compare this with petroleum vehicles that typically require frequent maintenance – which can be expensive and require skilled mechanics – and if this is not carried out they can become unreliable or break down.

Social benefits

Low operating costs: While the purchase cost of electric vehicles must be addressed if they are to be broadly available across income groups, they are very economical to run. Users pay less both for the 'fuel' (electricity) and for maintenance, as has been described, which has important implications for social equity. If society as a whole uses less energy for transport then there is more energy – and money – available for other purposes. Furthermore, the potential lower cost of electric vehicles can improve the affordability and accessibility of private motorised transportation for certain users.

Employment opportunities: The possibility of local production of electric vehicles, as well as local retrofitting, creates opportunities for local employment, and this can have a multiplier effect and create further employment in the communities concerned. Governments can encourage the location of such industries in low-income, high-unemployment areas.

Reduced effects of pollution: Electric vehicles generate no local pollution and are very quiet, both of which lead to major benefits for the health and wellbeing of urban populations. In particular, low income communities stand to benefit from this, because they tend to live in the noisiest, most polluted localities, given that the land there is cheaper.

Environmental benefits

Less pollution: Electric vehicles emit no direct tailpipe CO_2 or other toxic air pollutants (such as carbon monoxide or particulates) during their operation. Pollution may be produced from the electric power generation used to recharge the vehicles, but it is typically easier to build pollution control systems into centralised power stations rather than retrofit enormous numbers of cars. Electric vehicles also typically have less noise pollution than combustion engine vehicles, whether at idle or in motion.

Carbon neutral transport: Electric vehicles can be recharged with renewable electricity, thus enabling their operations to be truly carbon-neutral. Energy is also required for their manufacture and disposal, but this could come from renewable sources as well (although if the vehicles are not being locally produced this cannot be controlled). Of the wide array of low-carbon transportation technologies under development today, there are very few other options that both deliver carbon-neutral motoring with this level of certainty, and are already technically and economically proven and in established commercial use. Furthermore, few competing technologies can offer the wide range of accompanying benefits listed above.

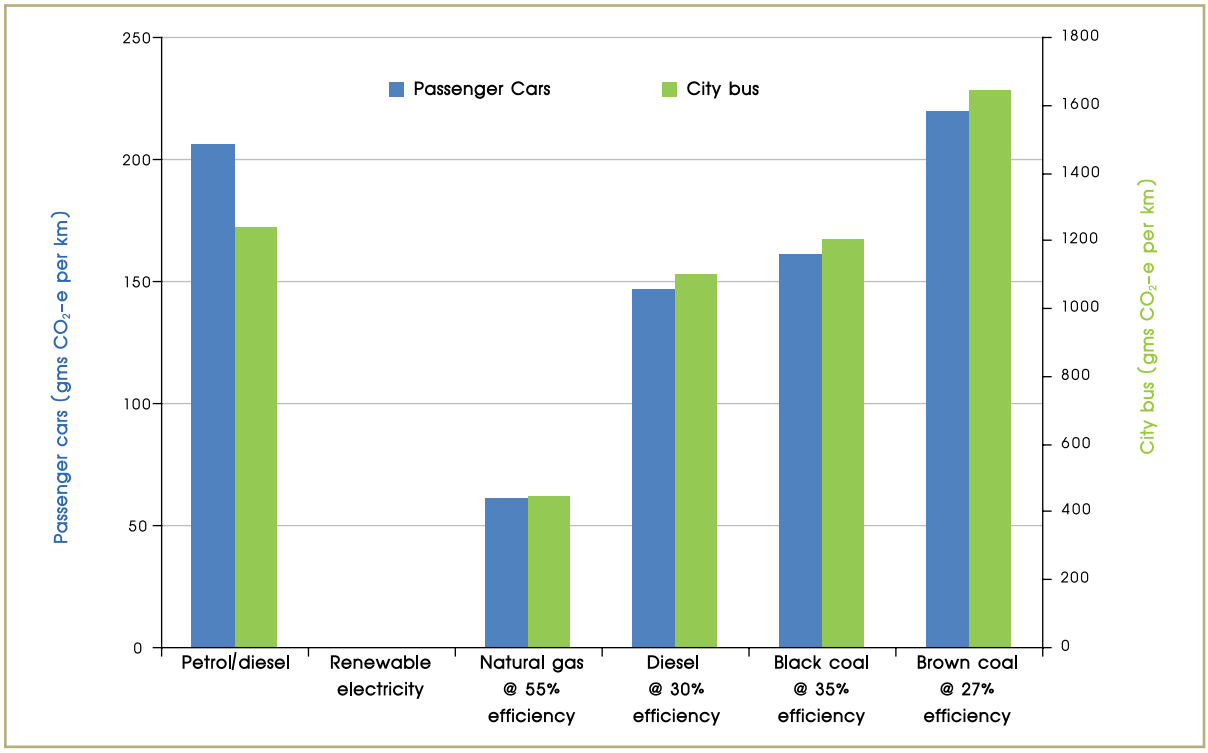
3. Greenhouse gas reduction potential

The greenhouse gas reduction potential of electric vehicles depends on:

- the relative efficiency of the electric powertrain, including its transmission, motor, inverter, battery and recharger, which is typically three-times as efficient as a comparable combustion vehicle
- the losses in the electrical transmission and distribution network, which are typically less than 10% for a modern, centralised energy grid, but could be many times that for an underdeveloped, sparse or weak network.
- the carbon intensity of the electricity generation (which for thermal generation includes the plant's thermal efficiency and carbon intensity of its fuel, whereas for 100% renewable energy the carbon intensity is zero).
- the carbon emissions of equivalent fossil-fuelled vehicles based on their vehicle efficiency and fuel production and distribution efficiency (for which the fuel might be petrol, diesel, propane/LPG, or natural gas/methane).

Figure 3.43 shows the calculated greenhouse gas emissions for four vehicles and, in the case of the two electric vehicles, a variety of electrical generation technologies are included with indicative values. The greenhouse gas reduction potential varies quite widely depending on the source of the electricity – in certain cases the emissions can be higher, but zero emissions are also possible if electric vehicles are powered by renewable energy.

Figure 3.43 Relative greenhouse gas emissions for petroleum vs. electric vehicles[17]



The vehicles are: a modern electric passenger car, the Renault Fluence ZE,[15] which has a rated vehicle recharging efficiency (on the EU test cycle) of 0.16 kWh/km; the petrol Renault Fluence, which consumes 7.8 L/100km of petrol on the same test; a modern electric passenger bus, the 40-seat 'Tindo' electric city bus manufactured by Designline Corporation in New Zealand,[16] with a recharging efficiency of approximately 1.2 kWh/km; and an equivalent diesel passenger bus that consumes 40 L/100km under similar operating conditions

4. Adopting electric vehicles

Where they can be used

Electric vehicles are on the road in many forms, including electric bicycles, electric motorcycles and scooters, electric cars, electric trucks and electric buses. Off-road vehicles include electrified forklifts, all-terrain vehicles, tractors, golf carts and airport ground vehicles. In many cases, electric vehicles can easily provide the transport functions that have traditionally been provided by petroleum vehicles, although there are some key differences that may affect electric vehicles' suitability as a direct replacement.

Range and refuelling time

Electric vehicles typically have lower operating ranges than petroleum vehicles, due to the lower energy density of batteries compared to petroleum fuels. For example, modern electric passenger cars using advanced lithium-ion batteries may have a range of only 100-200 km per charge, compared to 500+ km typical for a modern petroleum vehicle. Using less sophisticated batteries, the electric vehicle range can

be considerably less. Electric vehicles also have longer recharge times, compared to the relatively fast process of refuelling a tank. However, this issue is not as bad as it seems because most daily trips are well within the capabilities of electric vehicles. The term 'range anxiety' has been coined to describe the fear that electric vehicles may run out of charge, a fear that may deter people from buying electric vehicles, or from using them. However, continuing improvements in battery energy density are expected to help ease this fear over time, but there are three other very practical approaches to address range anxiety in the near term:

Expanded deployment of recharging infrastructure – Motorists will be less worried if there are more places for them to recharge. Different types of recharging infrastructure are discussed further below.

Driver information en route – Motorists will worry less if they receive regular updates on how much further they can travel before recharging, and how far it is to a recharging facility. This could be as simple as a roadside sign or a quite sophisticated system using GPS-based telematics to guide vehicles to infrastructure facilities en route. In either case, real-time guidance en route can encourage motorists to make the best use of the charge in their vehicle and of the recharging facilities available.

Education and experience – There is evidence[18] that motorists become more comfortable with electric vehicles and supporting infrastructure once they have had a chance to experience the technology for themselves, and to adjust their expectations and their behaviour to the new technology's capabilities. Most people in a Californian trial quickly adapted to recharging their vehicles at home or at work and did not need to use wider infrastructure. There is a clear need for further education programs and public trials to pave the way for greater use of the technology.

Recharging infrastructure

One of the key benefits of electric vehicles is that they can potentially be recharged using standard residential or commercial power outlets (in contrast to the high-cost, centralised infrastructure typical for petroleum vehicles). However there are a number of factors to consider when designing a recharging infrastructure network in order to balance the investment costs and benefits to users of the network:

Grid capacity – Too many electric vehicles recharging can overstress the local electricity grid. Due consideration must be given to the transmission and distribution capacities of the surrounding network, including where vulnerabilities might be and how the need for extra power may arise over time with increasing penetration of electric vehicles. One current example of electrical grid reinforcement is the Kenya Electricity Expansion Project[19] that will increase electricity access to Kenyans in urban areas, peri-urban and rural areas, as well as aid Kenya's geothermal power generation expansion.

Charging stations and rates – There are many kinds of charge stations (of both the conductive and inductive types) with different infrastructure costs and recharging times. Faster recharging tends to require more expensive charging equipment and installations, but fewer of these fast chargers would normally be needed to provide adequate coverage for vehicles in a network. Furthermore, if a mix of different charging configurations is planned within a network, it is important to ensure that the vehicles and infrastructure are all compatible, so that vehicles are not left stranded without recharging facilities they can use.

Battery swapping – This is an alternative approach to electric vehicle refuelling that involves physically replacing a discharged battery with a freshly charged battery. This approach potentially offers the fastest replenishment of electrical energy, but brings its own challenges in terms of grid impacts, infrastructure

costs and interoperability. A simple example of battery swapping is the Chinese motorist who lifts the battery out of their electric two-wheeler for recharging at another location.[20] A far-more sophisticated example is the fully automated system demonstrated by Better Place in electric taxis in Tokyo.[21] An interesting aspect to battery swapping is that it can enable the use of 'non-rechargeable' battery chemistries with higher energy densities (such as metal-air batteries) which provide greater driving range from a smaller, lighter package. In a battery swapping scenario, due consideration must therefore be given to how these batteries are replenished or recycled off-board the vehicle, as well as the compatibility of vehicles with such a system.

Batteries

Electric vehicles can be designed to use almost any type of battery, although some types of batteries are better for transport applications. Key factors to consider are:

Cost – Battery costs tend to dominate the cost of electric vehicles, and given current technologies tend to result in vehicles that are more expensive to produce than equivalent petroleum vehicles. Battery costs are therefore cited as the greatest barrier to electric vehicle uptake.[22] Automotive traction batteries (Figure 3.44) are still at a relatively early stage of development and are thus expensive at the moment, but they

Figure 3.44 A Lithium-ion battery is designed for propulsion applications and stores more than twice the energy of a lead acid starter battery, but costs over ten times as much

Picture Credit: Claus Albeiter[23].

are likely to get cheaper over time. In the meantime, however, approaches to dealing with high battery costs include the marketing of electric vehicles with reduced capabilities (via cheaper batteries), or the development of innovative business models (such as battery leasing) that shield motorists from the upfront battery costs and highlight the lower operating costs.

Life – Battery life is a separate but closely related matter to battery costs, since battery costs can be amortised over the life of the battery. Until very recently, traction batteries for electric vehicles were not resilient enough to last the life of the vehicle, and frequent battery replacement made it very expensive to run electric vehicles. However, the latest advanced lithium-ion technologies may well exceed the vehicle life, although these batteries also tend to be the most expensive. Alternatively, some shorter-lived batteries can be found to have the right combination of life and cost to be attractive in vehicle applications over the life of the battery.

Performance – not all batteries are well-suited to the requirements imposed by transport applications. A classic example is the lead-acid starter battery that is very low cost (around US $ 120) and common in today's petroleum vehicles. These batteries cannot deliver the repetitive high discharge rates and deep discharge cycles that are typical in traction applications, and will degrade severely and rapidly if used in this way. Thus, appropriate batteries must be chosen in order to ensure that a battery has the right combination of performance *and* cost *and* life.

Environmental footprint – The resource and energy use and emissions resulting from the manufacture and disposal of electric vehicle batteries is a separate matter from emissions during electric vehicles' operation, but it cannot be overlooked. Neither can the prevalence of highly-toxic materials in some battery chemistries. Some batteries, however, do not have a severe environmental footprint and it is these batteries that should be promoted for widespread use in electric vehicles. Frameworks are needed to evaluate the battery lifecycle (including raw material extraction, manufacturing, embodied energy/emissions, recycling and disposal, and toxic wastes) and this should be accompanied by an awareness that the lifecycle attributes and suitability vary enormously across different battery chemistries.

Electric vehicle safety

Occupant safety is always of paramount importance in vehicle design and use, and electric vehicles present some unique hazards that must be addressed. These hazards include electrical shock/discharge, occupant protection, battery protection and fire safety. Best practices and regulations have been developed within the electric vehicle industry to manage these risks (for examples see the Society of Automotive Engineers[24]), but there is always a trade-off between the level of safety and engineering scrutiny, on the one hand, and the cost of protective design features, design testing and regulatory enforcement, on the other. This trade-off occurs at all scales of production, but can particularly be an issue for small-scale producers who may not have the capacity to manage these risks appropriately.

Another key risk relates to the handling of electric vehicle batteries when they are not installed in vehicles. Like any high-energy-storage device, batteries are vulnerable to mishandling (particularly when not within the protective confines of a vehicle) and this can be a significant issue in the logistics chains for supplying and disposing of batteries. Appropriate regulations and procedures for the safe handling of batteries are outlined in the UN Recommendations on the Transport of Dangerous Goods – Manual of Tests and Criteria.[25]

Incentives to encourage use

Incentives can encourage new users of alternative technologies. Incentives for electric vehicles can be both financial (e.g. discount registration fees) and non-financial (e.g. priority access to parking facilities). Alternatively, governments may choose to penalise existing technologies to encourage the shift to electric vehicles. For example, many Chinese cities have banned gasoline two-wheelers which has promoted electric vehicle uptake in those regions,[26] and Denmark recently increased taxes on petroleum vehicles relative to electric vehicles.[27] Governments need to consider (a) whether the incentive/disincentive schemes should be technology neutral and/or revenue-neutral, (b) what level of uptake is targeted and (c) whether the incentives will cease once the targets are met.

Regulations and standards

As electric vehicles become more common on the road, governments will recognise the need to regulate them. Regulations and standards can be required for a number of reasons, such as vehicle safety and fleet monitoring. However, experience shows that unregulated electric vehicle deployments can often hamper market development. For example, the Bangladeshi experience[28] has shown how regulatory authorities can become annoyed by electric vehicles as a "nuisance" unregulated vehicle category, and in other markets (such as some Chinese cities[29]) demand has been stifled as a result of perceived hazards from unsafe vehicles. It is generally considered best practice to create a regulatory and standards framework for the initial deployment of the new technology, and then work with all stakeholders to implement and evolve this framework as more experience is obtained.

Infrastructure planning

As electric vehicles become more popular they will have a significant impact on energy infrastructure (from the recharging loads), transport infrastructure and recharging infrastructure. Consideration should be given to the parallel development of grid capacity and renewable energy sources that the electric vehicles will ultimately rely upon, and also how electric vehicles might exacerbate growth in private vehicle travel and the associated problem of transport congestion. Planning will be required to predict the placement and expansion of electric vehicle related infrastructure in a cost-effective manner, and governments and planning authorities will need to adjust their planning frameworks and tools accordingly.

Education and public awareness

Consumer awareness of electric vehicles is increasing but has started from a very low base. Much misinformation and misperception exists in the community, and this can distort the development of incentives, regulations, standards, infrastructure and other measures designed to underpin the electric vehicle rollout. Educational/awareness programs can be a key step for myth-busting and encouraging a common viewpoint amongst stakeholders. Another positive step is to facilitate the development of electric vehicle associations or other NGOs to educate the community and advocate for the technology on its merits. For example, Bangladesh has a Dhaka District Battery-Operated Three-Wheeler Owners' Association.[30]

New business models and vehicle ownership schemes

The different cost structure for electric vehicle use (higher capital cost and lower operating cost) will promote alternative consumer models for electric vehicle uptake. Vehicle leasing, battery leasing, vehicle-

sharing and rental are all mechanisms to assist with initial electric vehicle deployments, helping to build scale and promote natural market demand.

Local industry development with particular attention to supply/disposal chain and workforce skills

Electric vehicles are a promising candidate for local industry and economic development as was already discussed. Decision-makers should recognise that as such industry develops it will become a valuable contributor to local supply/disposal chains for electric vehicles and their components (especially batteries), as well as providing on-the-job training to build workforce skills. Lastly, local industry development promotes competition with imported products that can help improve electric vehicle affordability in the local market.

Links to broader sustainable transport agenda and initiatives

Electric vehicles are one of many possible approaches for improving the sustainability of transport. While they are an appealing option for private travel, transport planners should also recognise that private electric vehicles must integrate with the overall transport system and be included in broader transport planning. For example, due consideration should be given to how electric vehicles might:

- take up road space and require further road development
- affect the urban environment and the safety of other travellers
- compete with other transport modes for government and private funds
- but, on the other hand, play a useful role in multi-modal transport solutions.

5. Costs and sources of funds

Private electric vehicles will normally be financed by individual motorists and the upfront cost can pose a significant barrier to their uptake. However, where they can be afforded, electric vehicles provide a number of compelling financial and environmental benefits to justify the investment of both private and public funds.

Vehicle and fuelling costs

As a general rule, electric vehicles cost approximately 2-3 times as much as an equivalent combustion vehicle. For example, the electric Nissan Leaf currently sells in America for US$32,780 compared to the equivalent Nissan Sentra SL that costs only US$18,850. In India, the REVA sells for approximately Rs 340,000 (US$7,600) compared to the petrol Tata Nano which sells for approximately Rs 113,000 (US$2,500).[31]

However, electric vehicles' higher upfront costs can be recouped over time by their tremendously low running costs. For example, the Leaf uses electricity costing only 2-3c per mile compared to 10c per mile for gasoline for the Sentra, which would save the typical American motorist over $1,000 per year. Similarly, the electric rickshaws that sell in Bangladesh for Tk 125,000 (US$1,800) use electricity costing only Ts 20k per day,[32] and the electric tempos in Nepal that cost Rs 550,000 to buy cost less than Rs 3 per kilometre to run.[33]

Societal benefits and public investment

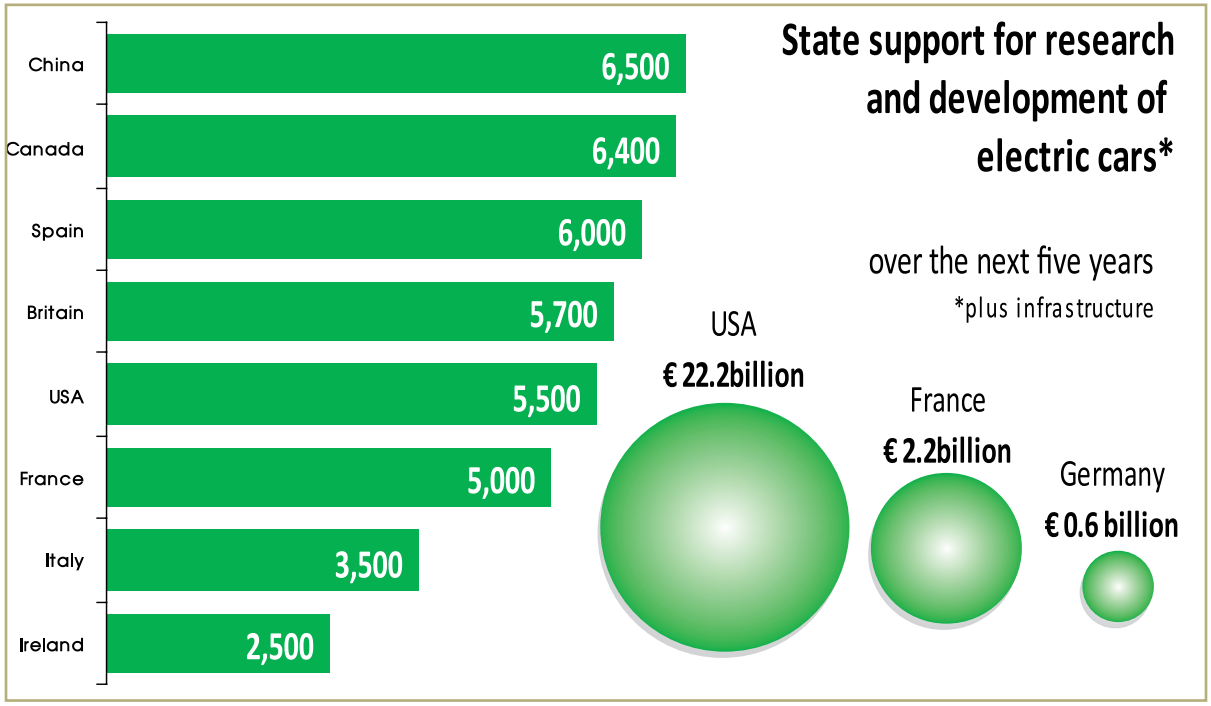
Electric vehicles bring a number of valuable benefits to the public. Many of the world's largest cities are plagued by the health costs of severe urban air pollution, and electric vehicles can eliminate the number

one cause – tailpipe emissions from motor vehicles. Since electric vehicles require no petroleum to operate, they can contribute to strategies for oil independence, particularly for nations that are majority importers of oil with the resulting foreign debt. Electric vehicles can be linked to renewable energy to provide true zero-emissions motoring in a carbon-constrained world. Lastly, electric vehicles can be manufactured locally to provide economic development and attract local investment.

Despite electric vehicles' numerous expected benefits, there are those who would prefer technology-neutral approaches to public investment in sustainable transport and those who would suggest that incentivising electric vehicles is economically inefficient or socially inequitable. These perspectives must be balanced by the recognition that, compared to most other alternatives, electric vehicles are still at a relatively immature stage of commercialisation. If EVs are believed to be a strategically desirable technology as part of a broader sustainable transport agenda, they may require early incentives to initiate industry supply and stimulate consumer demand in pursuit of a truly competitive market in the longer term. For example, the International Energy Agency Roadmap clearly advocates for 'coordinated strategies to support the market introduction of electric-drive vehicles.'[34] This is not to say that EVs cannot be supported through a neutral framework, nor that EVs should be pursued blindly at the expense of other alternatives. But without specific incentives for electric vehicles, market failure could occur for this technology based on a lack of 'critical mass' and incumbent technologies' entrenchment in society.

For all of the above reasons, many governments around the world have embraced electric vehicles by providing significant incentives for both their manufacturing and purchase. Figure 3.45 lists some of the subsidies provided by OECD nations to promote the development and uptake of private electric vehicles. Of course the subsidies are commensurate with the cost of the vehicles themselves,

Figure 3.45 Financial incentives for electric cars in euros in selected countries



Source: McKinsey in Electric Cars, http://www.spiegel.de/international/business/bild-718867-82532.html, viewed 20 Feb 2011.

with current subsidies typically falling in the range of 10-30% of the electric vehicle purchase cost. However, there are still many jurisdictions that do not provide any level of subsidy for electric vehicles and this is frequently cited as a policy barrier to their adoption. For example, the Indian electric vehicle industry has been particularly vocal about their lack of government support.[35]

Infrastructure investment

Investment in EV infrastructure may be required at either the private or public level or both. Private infrastructure investment is typically required when a household does not have sufficient electric supply capacity to recharge an electric vehicle, or if the existing supply and physical outlets are incompatible with the electric vehicle being used. This cost can range from a few dollars ($US) for a different socket configuration up to thousands of dollars ($US) for sophisticated recharging equipment (for example, American buyers of the Nissan Leaf pay an additional US$2,000 to get their home charging station installed, but are eligible for a 50% government rebate of this amount[36]).

Public infrastructure investment will normally be required for publicly-accessible recharging infrastructure and/or utility grid reinforcement to handle the increased load from electric vehicles. Public recharging infrastructure currently sells for at least a few thousand of dollars ($US) per installation since it includes necessary features for customer identification, metering, billing and anti-vandalism. 'Fast' or 'rapid' charging equipment for public use costs in the tens of thousands of dollars ($US) per installation and would normally be financed by commercial providers, such as the traditional operators of refuelling stations. Grid reinforcement is a much broader issue in that supplies must be bolstered not only for electric vehicles, but also for growth in demand from other electrical appliances. 'Smart grid' solutions are being developed and promoted to use information and communication technology (ICT) to manage grid assets more efficiency and economically, thereby reducing the overall cost of the grid to society. In particular, 'smart charging' is a specific smart grid concept that will utilise ICT to manage the scheduling of EV recharging and mitigate network impacts, and this is expected to offer significant value to utilities and society as a whole.[37]

6. Conclusion

Electric vehicles have a bright future in a low-carbon world. They are efficient, quiet, non-polluting at their point of use, economical to run and the power to operate them can be obtained from many sources, including 100% renewable energy. EVs are currently experiencing a massive surge in their popularity, but the technology still requires a number of issues to be addressed for true mass-market uptake, such as vehicle affordability, range and recharging infrastructure. Furthermore, the promotion of private electric vehicles will require decision makers to consider many broader issues in sustainable transport policy such as 1) projected growth in private versus public transport, 2) social equity relating to the affordability of various transport technologies and modes and 3) the merits of incentivising specific technologies or modes vs. a more neutral approach. However, given the rapidly growing popularity of motorised private transport in the developing world and the undeniable need for low-carbon vehicles in a low-carbon society, it is likely that these challenges will be far outweighed by the benefits electric vehicles can potentially provide.

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K) Vehicle and Fuel Technologies

Boyd Milligan*

1. Introduction

This section describes a broad range of vehicle and fuel technologies for motorised transport that are currently available or in development. Their characteristics, advantages and disadvantages are outlined, with particular attention to the:

- rate of fuel consumption (sometimes referred to as the efficiency)
- carbon content of the fuel.

Both of these underlie the carbon emissions of a motorised vehicle.

The section outlines the major technologies being contemplated for both vehicle (Part 4) and fuel technologies (Part 5). Part 4 concentrates on the vehicle drive train - that is, those vehicle components concerned with the conversion of fuel to useful energy - not the myriad of other technologies which will indirectly increase efficiencies and/or reduce negative impacts.

Part 6 provides an indication of greenhouse gas impacts of a variety of fuel and technology combinations. Part 7 identifies some major cautionary issues and tradeoffs. Countries which are successfully implementing strategies to suit their own requirements are outlined in Part 8.

This section does not provide exhaustive coverage of the range of available options or of issues to be considered, but it should provide a useful introduction to drive train and fuel technology options.

All technologies discussed within this section are feasible and reasonable to consider for implementation, being either mature technologies, in the process of being implemented, or under serious consideration for implementation in the short term.

Traditionally petrol or diesel fuelled engines have underpinned mechanised transport with over a billion such vehicles on the road today. The automotive industry has responded with a well accepted move towards smaller, more efficient engines and towards the use of more efficient diesel. Responses to regional or global issues have meant that some technologies have achieved market penetration in the past few decades, for example, simple engine technologies like CNG and LPG conversions, or more recently some biofuels. Some have achieved a degree of market acceptance, for example, hybrid, e-hybrid and full electric vehicles, while others have held promise for a long period but have yet to achieve any market share at all, such as hydrogen fuel cell vehicles.

2. Benefits

Judicious choice of fuels and drive train technology may have a significant impact beyond the direct benefits of more effective transport and the reduction of greenhouse gas emissions.

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Economic benefits

Fuel is a significant component in the whole-of-life cost of a vehicle. Increased efficiency reduces the burden this places on the owner and on the economy as a whole. In many cases transport fuel is an imported commodity and thus can place a significant strain on the national balance of payments. Use of more local fuel sources reduces this impact. Reductions in local pollution and greenhouse gases from the use of these fuels and technologies also have economic benefits.

The adaptation of appropriate technologies to suit regional circumstances may also lead to development of new industry. Several successful examples of this are identified in Part 8.

Social benefits

The emissions described in the environmental benefits section below create smog and impact on population health through respiratory related diseases (asthma and infection), and through other serious health problems such as liver disease and cancer caused by noxious emissions.

Environmental benefits

Airborne transport emissions can have a detrimental environmental impact apart from climate change. They can be generated at the vehicle exhaust, at the power station or at production facilities. The technologies described in this section can have positive environmental benefits including the reduction of:

- airborne emissions such as particulates, nitrous oxides, carbon monoxides and other organic compounds generated by many fuels
- acid deposition, which causes infrastructure degradation and may lead to acid rain;
- soot deposition on both natural and human infrastructure.

Similarly emissions from many of the liquid based fuels contaminate wetlands and groundwater resources.

Local supply of fuel also reduces the impact of production and transport of fuels over vast distances and from increasingly more difficult locations that have resulted in disasters such as the Exxon Valdes and the Gulf of Mexico drilling rig.

3. Greenhouse gas emission reduction potential

The implementation of these drive train and fuel technologies, if done successfully, can significantly reduce the greenhouse impact of a growing transport sector. However, poor implementation may also lead to increased greenhouse gas production, for example, liquefied hydrogen fuel cell transport based on coal fired electrical supply will significantly increase overall emissions.

Immediate support for smaller vehicles based on natural gas or diesel instead of petrol can have some impact, but hybridised vehicles will have a considerably larger impact. In the longer term renewably supplied natural gas and electricity offer the opportunity to virtually eliminate greenhouse gas emissions.

As noted, the potential greenhouse gas emission reductions from these technologies are examined in more detail in Part 6.

4. Drive train technology

Primary drive train technologies in use and in development include:

Spark ignited internal combustion engines

This engine type powers the vast majority of vehicles on the world's roads, and is particularly suitable for scooters, motorbikes, cars and smaller vehicles. It is perhaps the most versatile of engines, and may be configured to operate on a range of fuels, including petrol, LPG, natural gas and ethanol.

This technology is one of the least efficient at converting fuel to mechanical energy, with typical automotive efficiencies being about 15-20%. Practical peak efficiencies at best can be about 32%.[1]

This is a mature mass produced and economic technology. Most drive train innovation is designed to replace this technology.

Compression ignition internal combustion engines

This engine powers the majority of heavier duty vehicles such as trucks, buses and trains. Its key characteristic (compression ignition) limits the fuels on which it operates, primarily to diesel, but enables a significant increase in efficiency to around 22-28%. Its peak operating efficiency is about 43%.[2]

Recent, but as yet uncommercialised, technical development is enabling this engine type to operate on other fuels, such as petrol, LPG and natural gas, at nearly equivalent efficiencies.[3]

A mature truck and bus market ensures it is a mass produced and economic engine, whilst its rapidly expanding small vehicle market is driving down production costs.

Micro turbines

Micro turbines are an emerging internal combustion technology, very similar to its much larger technological cousin the combined cycle gas turbine for city wide electricity production. Its key advantage is simplicity, in that it has few moving parts, and may provide competition to the spark and compression ignition engines. Its peak efficiency at about 26% is normally combined with the advantages of hybrid technologies.[4]

There is no evidence of wide scale commercial production.

Fuel cells

Fuel cell technology has more in common with the electric battery than the internal combustion engine it competes with. It uses an electrochemical process instead of a thermal one to convert its fuel to electricity, and some heat. In recent years it has been linked with hydrogen as its primary fuel source, though with on-board convertors, other fuels including methanol and natural gas have proved technically effective and easier to provide.

Its efficiency at 36% is high, and its on-board emissions of oxygen, water and little else is attractive at first glance, though the source and derivation of its fuel impact heavily on its overall environmental credentials.[5, 6, 7]

There is currently no mass produced vehicle, though extensive demonstrations have occurred with passenger cars and buses. There remains some question about the timing of realistic commercial scale vehicular fuel cells.

Batteries and electric motor vehicles

Battery electric vehicles are discussed in more detail in Electric Vehicle section. The technology involves charging a battery on board the vehicle and using this stored electricity to drive electric motors which in turn drive the wheels.

The on-board efficiency (up to about 85%[8]) of this technology is the highest of those contemplated and on-board emissions are virtually eliminated. However, like the fuel cell, the source and delivery of the electricity determines the overall efficiency and environmental impact of the technology, including its greenhouse credentials.

Global manufacturers are now beginning to mass produce for the passenger car market.[9, 10] Mass transit vehicles already in use include light and medium rail trains and some battery electric buses.

Catenary electric motors

In some circumstances catenary (wire) fed electricity may be used with electrically powered vehicles. This provides all the advantages of electric vehicles without the problems of battery installations. Typically metro medium duty rail systems operate with this type of technology as well as trolley buses and most new intercity fast trains.

Hybridisation

Many passenger vehicle manufacturers are now delivering or about to deliver hybrid technology in their vehicle offerings, as noted for electric vehicles previously. It involves the installation of an electric motor drive and battery system in combination with a fuel source and/or engine. The primary advantages of hybridisation include:

- enabling the internal combustion engine to operate at its peak efficiency all the time. Operating at peak efficiency will increase the range and decrease the impact of emissions of greenhouse gases in comparison to traditional internal combustion engine (ICE) configurations for all vehicles
- the ability to turn off the engine at idle and at other inefficient times
- the recapture of energy expended in accelerating the vehicle and in navigating hilly terrain (regenerative braking).

The regenerative braking capacity is most effective in stop/start traffic or rolling hills. It will not work so well on extended climbs and descents, or for rural trips, as the battery required for this would be otherwise too large. Diesel/electric hybrid technology is in common use in freight rail as its preferred motive option.

5. Fuel choices

The diversity of fuel choices is expanding at a remarkable rate. The following segments briefly outline the key fuels for transport use.

Fossil fuels

Traditionally oil has driven the world's transport needs, but as the world has realised that it is a finite commodity, other sources of energy from fossil fuels have emerged. Though the International Energy Agency state 'The world's oil resource base is sufficient to meet demand until 2030, although the cost of supply will increase',[11] other sources already referenced in this section note that peak oil may have already occurred, with peak natural gas and coal to follow in the first half of this century.

Table 3.1 Comparative vehicular fuel energy Storage rate

Fuel	Relative Energy Content per unit weight (Petrol = 1)
Diesel	1.20
Petrol	1.00
LPG	0.73
Methane	0.38
Hydrogen	0.09[12,13]
Battery	0.02[14]

Source: Author estimates except for hydrogen and battery.

The bench mark against which all fuels and related technology are measured is petrol and diesel, which have very high energy content per unit of weight compared to almost any other fuel. Table 3.1 indicates the relative energy content of a variety of fuels, benchmarked against petrol.

Thus diesel may be considered to have about 20% more energy per unit volume than petrol, whilst batteries have only 2% of the volumetric energy content of petrol in its current compressed storage format.

Greenhouse gas emissions from fossil fuels can be reduced through efficiency improvements, the most significant of which may be hybridisation.

Natural Gas

Traditionally fossil natural gas systems have played an important role in general energy supply. It is a versatile fuel, being a feed for electricity production, a source of thermal heat, and a transport and storage medium.

Although there is much debate as to how long natural gas reserves will last, it is touted as a bridging fuel to a renewable future.[15] Natural gas's versatility sees it being advocated as an economic and clean replacement for coal and nuclear power. It produces up to 54% less greenhouse gas than coal.

It also has a significant and growing infrastructure base in many economies. Its wide availability and reliability of supply in most urban areas provides many oportunities to extend its use beyond domestic, commercial and industrial energy supply to include transport.

By far the major source of natural gas is from fossil gas and oil fields, but unconventional sources such as shale and coal seam gas are having a big impact on supply. On a small scale, biogases are currently produced from municipal waste sites, and liquid manure is a very environmentally beneficial source, as use of either also alleviates greenhouse gas emissions to the atmosphere, not just by replacing the more intensive greenhouse gas producing fuels of petrol and diesel, but also enabling the natural gas to be burnt rather than being emitted directly to the atmosphere with its multiplier impacts. Methane emissions have around 21 times more greenhouse impact than carbon dioxide by volume, hence its release to the atmosphere should be avoided.

Figure 3.46 New dedicated SI CNG truck with fuel storage for about 200 km[17]

Picture Credit : Boyd Milligan.

Larger scale direct production of renewable natural gas (methane) from solar, algae, or other similar renewable sourceis now becoming attractive, primarily for its:

- environmental benefits
- capacity to act as a storage medium as well as an energy carrier
- pre-existing handling, transport and storage infrastructure
- relative energy density in comparison to other alternatives such as hydrogen and batteries
- compatibility with current and future internal combustion technologies.

Production of renewable natural gas also acts as a carbon sink for sequestration of carbon dioxide, much the same as plantation timber.[16]

In the following review of the other alternative fuels, it is noticeable that many are derived from natural gas, which means that their energy efficiencies are always less than that of the original natural gas.

LPG

Liquid petroleum gas (LPG) is a relatively internationally tradeable automotive fuel mix of propane and butane, generally used for light duty vehicles such as passenger vehicles. It is sourced from either natural gas production facilities, where the propane and butane occur naturally within the feedstock gas in small quantities, or from the fossil oil refining process. It is used as a domestic heating source in many countries which do not have access to natural gas, as it is more easily transported in smaller quantities.

Synthetic diesel

Synthetic diesel is a diesel replacement manufactured from either coal or gas with technology dating back to the 1930s in Europe.[17]

Natural gas is generally the feedstock of choice due to its yield, availability and process simplicity compared with coal. Natural gas to synthetic diesel has a poor conversion efficiency (the amount of energy in the end product divided by the amount of energy in the feedstock), in the range of 60 - 65%. Coal to synthetic diesel has efficiencies significantly less than even this.[18] Countries that are vulnerable to oil imports have resorted to synthetic diesel but it is not a long term solution due to its reliance on limited supplies of coal and gas based fossil fuels, poor conversion efficiencies and poor climate change outcomes.

Biodiesel

Biodiesel is a fuel manufactured from a variety of biomass sources, the major ones being rape sunflower seed and woody products. The woody production process is similar to that for synthetic diesel, though it is less efficient. In most cases biodiesel can be used as a substitute or blend for diesel fuel.

The advantage of biodiesel from a climate change point of view is that, though the biodiesel emits carbon dioxide at the point of combustion, the biomass sources used in its manufacture recapture an equivalent amount during growth, so the overall lifecycle carbon account is almost zero.

Regional differences in sourcing the biomass may bring its production into competition with natural biodiversity or other uses of biomass products, including carbon sequestration and food production.

Ethanol

Ethanol may operate as a minor substitute for petrol in most vehicles, and in many places is limited to about 10% of the petrol mix. Where specifically adapted vehicles are available this proportion can be increased to about 85%.

Ethanol is generally manufactured from biomass - either directly from crops such as sugar cane and beet, or indirectly from grains such as corn, rye, wheat and barley. Agricultural residues, forestry residues, grasses, municipal wastes and plantation trees can also be used. Some believe that these cellulosic sources rather than the direct sugar sources will form the backbone of supply in the future due to food security conflicts.

Like biodiesel, the overall life cycle emissions of ethanol for greenhouse gases are virtually zero.

Also like biodiesel, regional differences in sourcing the biomass may bring its production into competition with natural biodiversity and other uses of biomass products including carbon sequestration and food production.

Electricity

Electricity is an exciting new frontier for some parts of mainstream automotive use. It is generally used in either a dedicated battery electric vehicle or, in more recent times, an e-hybrid, a vehicle using both the plug-in electricity supply and more conventional fuels to share the task of providing energy for the vehicle.

It is also used in mass transit systems such as metropolitan medium and light rail systems.

Like natural gas, its wide availability and reliability of supply in most urban areas provides many opportunities to extend use beyond its traditional role in buildings to include transport.

Electricity sources are extensive and diverse, and range from coal and natural gas to nuclear and renewables. Its primary advantages include zero on-board fuel based emissions, though the energy efficiencies of, and emissions from, its production and transmission to the vehicle must also be considered.

Electric vehicles section highlights its use in transport.

Hydrogen

Hydrogen is not yet in commercial use within the transport industry. The technology of choice for this fuel is the fuel cell, because of its on-board efficiency.

It holds promise as a renewable 'energy carrier' as it may be produced from a vast range of original energy sources. The primary form of production today is from natural gas. It can also be produced from biomass, including algae (for which current research is indicating promising results), or from solar directly, through electrolysis of water.[19, 20] Electrolysis, like electric battery systems, is heavily dependent on the source of the electric power used in its production for its environmental performance.

The implementation of this technology is likely to be revolutionary, effectively overlaying a complete and new energy delivery system on a scale and timeframe unprecedented in modern times. Its maturation as a viable technology may take some time and will be highly dependent on significant research and development. As there are no pre-existing storage and distribution systems for hydrogen, costs for infrastructure may significantly outweigh costs of the vehicles and fuels and therefore serious reconsideration of the 'hydrogen economy' is occurring.

Dimethyl Ether (DME)

Dimethyl ether (DME) is a colourless liquid or compressed gas traditionally used as an aerosol and normally produced from either natural gas or coal, though it may be manufactured from renewable sources such as woody biomass. It has the advantage of being more energy efficient to produce than synthetic diesel.[21]

Some early work suggests it may also be used as a blend with diesel with some environmental benefits. It is primarily used to reduce dependency on LPG, and it requires a transport infrastructure similar to that for LPG.

As with all biologically derived fuels, regional differences in sourcing the biomass may bring its production into competition with natural biodiversity or other uses of biomass products including carbon sequestration and food production.

Methanol

Methanol in some cases can be used as a substitute or blend for petrol, although its future transport use may be as an energy carrier for fuel cell vehicles. Its use in conventional vehicles has diminished to the stage where few current vehicles can operate on it.

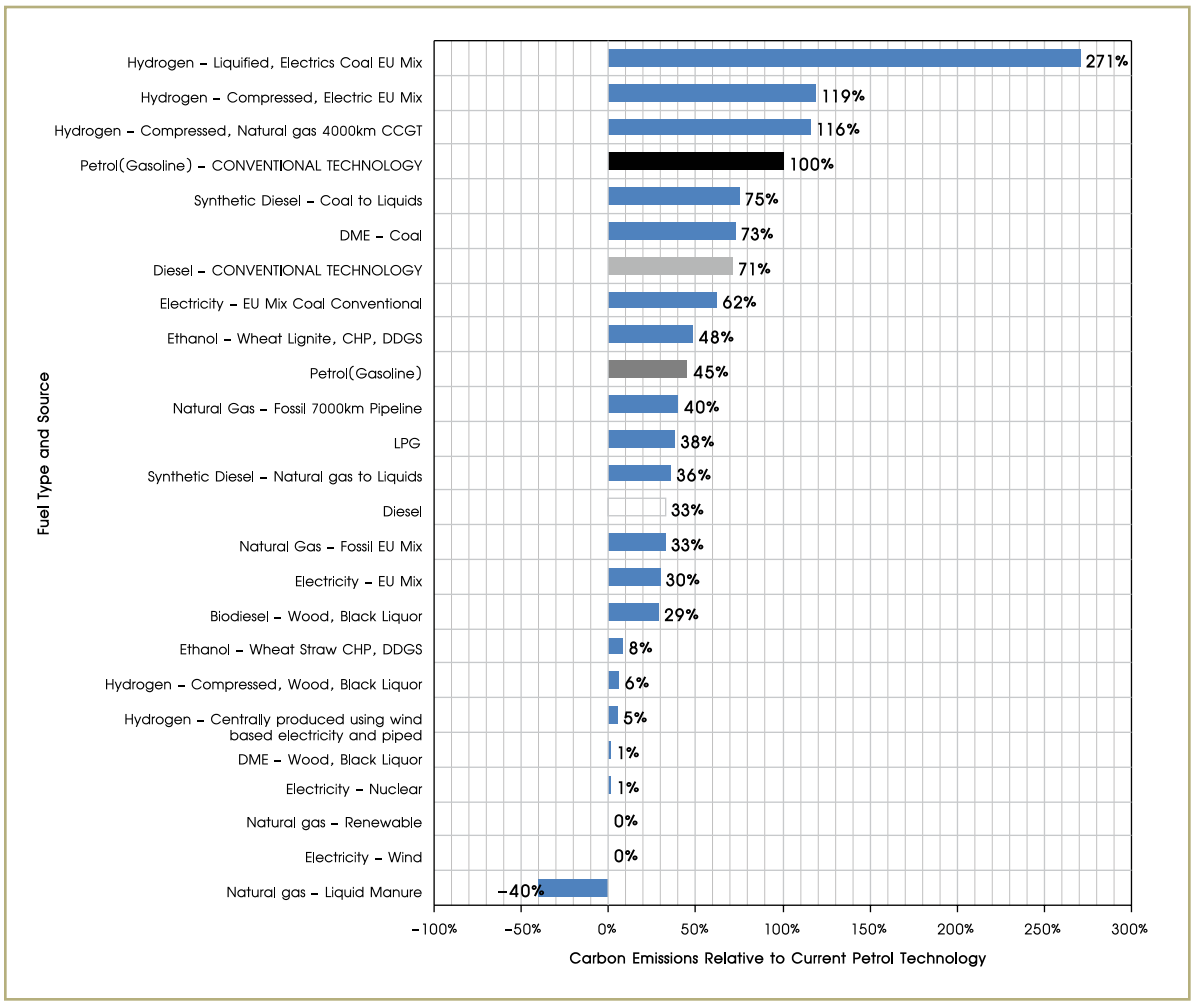
Methanol is a colourless liquid energy primarily manufactured from natural gas or coal to be a feedstock for the manufacture of MTBE, a petrol additive which benefits the combustion process. Depending on the original energy source, the greenhouse balance of methanol can vary from extremely poor (coal base) to very good (biomass black liquor base).[22]

6. Vehicle and fuel carbon impact

Carbon emissions from the variety of fuels, their sources, and vehicle technologies vary considerably. Figure 3.47 below indicates the relative carbon emissions of a select range of fuels.

The vertical axis shows both the fuel type and its source, whilst the horizontal axis shows emissions of carbon dioxide from each of these as a percentage of emissions from conventional petrol with current drive train technology.

Figure 3.47 Ranked well-to-wheel carbon emissions for a variety of fuels, fuel sources and best vehicle technologies relative to conventional petrol[24]



Note: 'EU Mix' means that particular source of energy has the characteristics of that source as used in the European Union, 'CCGT' refers to electricity supplied by a combined cycle gas turbine power station, 'CHP' means combined heat and power production from the same plant, 'DDGS' stands for Dried Distillers Grains with Solubles, a co-product of the ethanol production process and is a high nutrient feed valued by the livestock industry, 'Black Liquor' is a feedstock for the energy industry from the paper industry.

For example, both petrol with optimised technologies (striped graphic) and diesel (white graphic) are represented using a full hybrid technology optimised for fuel efficiency. The only exceptions to this (included purely for comparative purposes) are conventional petrol and diesel matched with current technologies, indicated with the black and 'diamond' graphics respectively.

In Figure 3.47 the combined fuel type and source, selected as representative fuels, are ranked from least emitting at the bottom to most emitting at the top.

Key points to note include:

- New drive train technologies for conventional diesel and petrol fuels will make a significant difference in the carbon emissions of vehicles in comparison to conventional technologies of today.
- The relative efficiencies gained through the use of diesel continues to outperform that of conventional petrol, even under optimised technologies, justifying the continued drift towards diesel in industrialised countries' passenger car markets.
- The wide diversity of outcomes possible from ethanol, DME, synthetic diesel, hydrogen and electrical supply is based entirely on the source of the original energy, and the efficiency of production and conversion processes. If managed well, all such fuels and technologies can significantly reduce the greenhouse gas emissions due to mobility, but if handled poorly can increase them. For example, the implementation of a hydrogen fuel cell program based on liquefied hydrogen and derived from coal shows a greenhouse gas impact in the order of 271% of the current and conventional petrol based Drivetrain, a poor result, whilst fuel cell vehicles fuelled by hydrogen derived from a central production facility using wind powered electrical energy supply and piped to site will produce a greenhouse impact of only 5% of that of conventional petrol, a well managed outcome from this perspective.
- Natural gas fuel generally outperforms petrol and diesel in almost all circumstances and in its renewable form can be carbon neutral.[23] In special cases natural gas, along with some other energy carriers, may actively reduce the overall carbon load.
- For complete replacement of petrol and diesel with ultra low or zero net carbon emissions the clear options are renewable electricity, natural gas or hydrogen. Ethanol and DME are generally used as a blend with conventional fuels, and hence may not completely replace them.

7. Other important considerations

Selection of appropriate vehicle and fuel technologies should depend, not only on greenhouse gas impact and the matter of oil depletion, but also on a variety of other factors, including the following:

Mass movement versus flexibility

The choice of transport technology initially depends on the population density. In urban areas the population density and thus demand for freight and passenger services ensures mass movement in trains, light rail and buses is viable. On the other hand, wealth creation enables more private vehicle ownership, which may add to congestion and other poor transport outcomes.

In rural areas low population densities limit viable mass transport options and thus may favour the more flexible of these options such as buses.

Energy infrastructure: investment needs, competition and energy security

Fuel delivery systems depend on long supply chains and complex life cycles for each stage of the process. For example, the life cycle for the energy extraction stage of the supply chain includes: exploration, technology development, construction, production and decommissioning of exhausted energy resource fields. There are similar life cycles for conditioning and conversion of the raw products. As well as these stages, the supply chain also includes: transport (sometimes on a global scale); secondary conditioning and conversions (such as at petroleum refineries); distribution and tertiary processing; delivery of final products to retail outlets; and, finally, use by end consumers.

The traditional delivery systems are those for petroleum fuels, electricity and fossil based natural gas.

These delivery systems represent a vast investment. This includes investment in the education of designers, installers, maintainers and energy users, which is important for the safe implementation and use of new transport energy and vehicle support systems.

Traditionally, interaction between these three vastly different systems has provided a level of competition and a high degree of energy security. A reduction in the viability of a delivery system, for example, away from oil distribution as oil costs increase, will lead to increases in energy supply risks and reduced regional resilience. Both for transport needs and general power supply a more resilient and diverse set of energy options is advantageous.

Incremental investment for transport use is that which adds to existing energy and vehicle infrastructure, for example, extra investment in oil, electricity and natural gas systems. On the other hand, the complete overlay of a new infrastructure with related fuel production and supply and vehicle technology, such as that needed to implement hydrogen fuel cell vehicles, will require significant investment. No country in the industrialised world has made significant inroads into replacing distribution systems associated with petrol and oil, but that is the challenge that needs to be faced in the next few decades. Several emerging economies are making such changes as set out below.

Range versus efficiency

The need to store fuel on-board most vehicles imposes some limitations. The key trade-off is between the range of the vehicle (how far it can travel on a tank of fuel) and how much fuel it may economically store on-board.

A vehicle that has to travel for significant distances or times between refuelling opportunities needs to carry more fuel. On the other hand, the urban private vehicle environment requires less storage of fuel due to easier access to refuelling and, at most times, less distance covered.

Electric vehicles clearly target this latter market. There are many electric bicycles and small passenger cars available to meet short urban travel requirements.

Due to its energy density, natural gas fuel on-board storage combined with vehicle hybridisation is now able to directly compete with current petrol ICE based ranges without the fuel taking up too much space. This is the most difficult task ahead for more climate friendly fuels such as hydrogen and electricity that at present cannot provide such competition. An internal combustion engine can drive up to 40 times further than an electric vehicle per kg of energy stored with technology available today.[25]

Maturity of underlying technologies

Current transport technologies are changing fastest in the passenger vehicle market, which will eventually be reflected in road-based freight vehicles. The technical options are multiplying for both engines and fuel, without any obvious winner. What appears clear is that regions will have the opportunity to influence and guide technical options in order to meet their own requirements.

All options for vehicle technology are subject to intense innovative efforts and incremental improvements. Such is the pace of innovation that most technological opportunities are nowhere near their full potential, including:

- the aforementioned hybridisation, with the potential to change many aspects of the industry
- battery research and development (This continues to promise an impressive rate of improvement in both energy density and resilience.)
- the incumbent internal combustion engine technology, which is similarly responding to the competitive environment and decreasing environmental impacts
- fuel cell technology coupled with natural gas, methanol and hydrogen, which continues to make steady progress
- the simplicity of micro turbines, which have not as yet fully tested the market
- natural gas (methane) technologies, which are achieving a renewed level of interest due to:
    - the relatively recent expansion of known world reserves through unconventional resources
    - widespread deployment of distribution networks for homes and industry, which make it suitable for easy transition to transport applications
    - a wide diversity of regional reserves
    - the emerging promise of renewable natural gas.

In this state of flux, it is important to ensure that a roadmap for the development of regional transport options is robust enough to take advantage of this rate of development, but doesn't head down a dead end with any individual technology.

Global industry versus regional needs

Both the fuel supply and vehicle supply industries are global and well entrenched. It can take significant effort to get these large suppliers to change and adapt to a regional need.[26]

Vehicle cost and social and environmental impact

The Nano, reputed to be the world's cheapest production car, is produced by Tata for its home market in India. When it was launched it was selling for about US$2500 equivalent, about half the cost of its nearest rival, and a lot less than most other vehicles.[27]

From an owner or driver's perspective, the purchase of such a car may be driven by aspirations of status and power, mobility needs and possibly safety. However, it generally adds a significant financial burden to owners through fuel and maintenance costs, and in most Indian cities may not get them to their destinations any faster.

On a societal scale, its introduction may increase national fuel consumption, put stress on fuel supply chains, emissions, repair and maintenance systems, and road infrastructure requirements.

Thus it is clear that there are important social and environmental issues to be considered when the increasing affluence of a community and the continually reducing vehicle costs meet to enable wider private vehicle ownership.

8. Implementation

A 2007 estimate indicates worldwide annual consumption of about 1,300 billion litres of petrol and about 1,400 billion litres of diesel, the majority of which is used to fuel the 1 billion vehicles on our roads. The following provide examples of nations changing their fundamental transport mix to ease away from dependence on oil and limit greenhouse gas emissions from transport.

Over the last two decades a variety of countries such as Argentina, Pakistan, Iran and Brazil have shown how to diversify the supply chain for fuels, with natural gas in use in Argentina, Pakistan and Iran, and both natural gas and the biofuel ethanol in Brazil. Pakistan, Italy, Argentina and Brazil have successfully implemented after-market vehicle conversions with natural gas. China is also making significant progress, leapfrogging some of the current technologies to join in the production of newer ones.[28]

The compression ignition internal combustion engine's efficiency and recent advances in small high speed versions has enabled it to supplant the petrol option in passenger vehicles in the industrialised countries, particularly in Europe and more often now in Australia and the US.
Natural gas is currently used as a fuel in about 10 million vehicles worldwide, the majority in Argentina Brazil and Italy.[29]

Reputedly the vehicle LPG market has grown from about 7 million vehicles worldwide in 2000 to about 13 million today. Major users include South Korea, Australia, Italy and Japan.[30]

The European Union is producing up to 7 billion litres of biodiesel annually. Plants are primarily located in Germany, Italy, Austria, France and Sweden,[31] whilst the USA produced about 1.3 billion litres in 2009 (up from 38 million in 2001).

The USA consumed about 41 billion litres of ethanol in 2009, replacing about 28 billion litres of petrol. The European Union produced about 3.7 billion litres in 2009, primarily in France, Germany and Spain, with a further 1.7 billion litres capacity under construction. The EU production sources are generally from cereal crops and waste biomass.

In more recent times some countries such as China have been using DME as a blending agent or substitute for LPG.

Germany and the US are planning complete development of new transport infrastructure with hydrogen and fuel cell technologies supplemented by biomass fuels competing directly with diesel and petrol systems. They are implementing the first stages of an entirely new vehicle technology and supply infrastructure within their communities.

The capacity of developing societies to further advantage their economies through their fuel and related automotive industry is also demonstrated by Brazil, which – using its local market, location, alliances, indigenous fuel supply (natural gas and biofuels), resources, and labour market – has over more than a decade become a regional hub for automotive supply, producing approximately 3 million vehicles in 2009.[32]

Figure 3.48: Fiat launched the Ducato commercial van for natural gas fuel in 2008[33]

Source: Rudolf Stricker.

9. Costs

The following briefly outlines the incremental costs of each fuel and drive train option when compared with its traditional petrol equivalent.

A small proportion of the passenger and commercial vehicles sold annually may meet 'value' market requirements, such as the aforementioned Nano, and most operate only on traditional petrol and diesel fuels.

More buyers are choosing diesel vehicles. These tend to be slightly more expensive than petrol equivalents, and the diesel fuel price is also trending upward as a result of this increasing demand.

Most current vehicles may also be able to operate on biofuels such as ethanol mixes or biodiesel at little or no additional cost.

Electric vehicles are generally more expensive, with those currently in production for the motor vehicle market being targeted at the Northern consumer and typically costing in the order of 20-50% more than their ICE equivalent, typically about US$30,000 or more each.

On the other hand electricity is one of the cheapest and most efficient ways of transporting and acquiring energy. This of course is highly dependent on tariffs on, and subsidies provided to, the various fuels, which vary from country to country.

Alternative fuel vehicles are common in the passenger vehicle market, with factory fitted and commercial pre- and post-market conversion technology available for LPG and natural gas adding some capital cost. In most Northern societies this typically amounts to US$500-4,000, and such conversions are popular where local fuel supplies and/or government incentives allow them.

The use of gaseous fuels, primarily natural gas, to replace diesel fuel is more commercially difficult for larger vehicles such as trucks and buses. Depending on supplier and technology, these technologies add between US$5,000 and 100,000 to the cost of a diesel equivalent vehicle[34].

Hybrid electric vehicles fall somewhere between the traditional IC powered vehicle and the electric vehicle in terms of capital cost, and may be closer to the electric vehicle when it comes to operational costs.

Fuel cell based vehicles on the other hand are currently both very expensive to buy (if commercially available) and very expensive to operate, particularly with regard to fuel supply and maintenance.

10. Conclusion

New automotive technologies in combination with a variety of new fuels are capable of delivering significant benefits to any society seeking to create a more resilient transport system with lower carbon impacts. Developing countries that are growing have the ability to make such changes through judicious choice of fuels and technologies related to their local resources and needs.

A variety of technologies vie for market share. Long term, the fuel cell in combination with a variety of feeder fuels may gain market share. In the short to medium term electric and hybrid technologies will provide substantial benefits, especially when coupled with renewable sources of fuel. In the face of energy infrastructure constraints, biofuels, renewable electricity and renewable natural gas enable a clear path forward.

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L) Motorised Three-Wheeler Taxis

Paul Barter*

1. Introduction

In certain parts of the world, most notably South Asia, small motorised three-wheeled passenger taxis are a significant component of the urban transport system. Besides South Asia, three-wheeler taxis are also common in Indonesia, Thailand, coastal Kenya, Ethiopia, and increasingly Tanzania, Egypt, the Gambia, Cambodia, Laos, Philippines, Cuba, Guatemala and Peru, with small numbers in the Netherlands and Britain. In certain places, especially parts of Southeast Asia and East Africa, motorcycles – sometimes with a side-car or trailer – are also used as taxis. Three-wheeler taxis have a variety of names in different countries, including auto-rickshaws, tuk-tuks, trishaws, autos, rickshaws, autoricks, bajajs, ricks, tricycles, mototaxis and baby taxis.

Figure 3.49 The three-wheeler taxi has new possibilities in a modern multi-modal transport system

Picture Credit: Muhammad Mahdi Karim.

These vehicles are often seen as a problem, as a source of unacceptable air pollution with their two-stroke engines, and as a cause of traffic congestion, given their slow speeds and the stops they make to pick up or to drop off passengers, or to wait for new customers. In some cities and countries there has been discussion of banning them, and in some places they have been banned, like in central Mumbai.

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This section presents readers with the option of retaining them – with attention to better technology, maintenance and regulation – on the grounds that they perform a valuable role in the localities where they exist, and if they were removed the vehicles and travel practices that replaced them would produce increased, congestion, road injuries and fatalities, air pollution and greenhouse gas (GHG) emissions. On these grounds, localities that do not have three-wheeler taxis might even consider introducing newer, cleaner-technology versions of them.

The section has two parts. The first outlines how new or better technologies, improved fuels, better maintenance, better integration with other modes and improved traffic management can bring about reductions in local pollution and greenhouse gas emissions, as well as addressing a range of other problems. The second part considers how the retention of these vehicles, in a cleaner form, can benefit the transport system and bring about overall GHG reductions, or at least help avert rises.

In most cities three-wheeled taxis constitute only a small proportion of motorised travel.[1] Even in India they generally account for no more than five percent of passenger travel,[2] although their role may be bigger in certain towns, and they may make up a large proportion of the traffic within busy commercial areas. However, when it comes to reducing GHG emissions, local pollution and other problems associated with transport, even small proportions matter. Transport systems consist of many different kinds of vehicles, technologies and practices, but these all need to be addressed if the necessary overall improvements are to be achieved.

2. Benefits

Economic benefits

Cleaner vehicles have reduced fuel use and therefore lower running costs, as well as reduced health costs caused by pollution. However, the extent of these direct economic benefits depends on the extent to which lower running costs outweigh possibly higher up-front costs for the vehicles or their conversions. Some projects discussed below seem to meet this market-test criterion.

Retention of a flourishing small-vehicle taxi industry means there is a low-cost individualised transport alternative, including for those who do not own a private vehicle. This should have significant, although difficult-to-quantify economic benefits.

Social benefits

Cleaner vehicles lead to improved health and quality of life as pollution is reduced, while retention enables a range of urban services and locations to remain more accessible.

In many cities, the operators of small taxis are a vulnerable and powerless low-income group. Project implementation needs to be careful not to worsen their position. Better conditions and livelihoods for drivers can and must be one goal of regulatory and enforcement reforms aimed at raising the quality of the service provided by this industry.

Environmental Benefits

Cleaner vehicles lead to reduced local pollution, greenhouse gases and noise, while retention of a successful small-vehicle taxi industry should lead to lower GHG emissions overall by helping to avert rises in the numbers and usage of vehicles with higher emissions.

3. Overall greenhouse gas emissions reduction potential

Although three-wheelers have fewer passengers and therefore higher emissions per passenger kilometre than well-used public transport, they produce far fewer GHG emissions than private cars or full-sized four-wheeled taxis. In India, GHG emissions per kilometre from auto-rickshaws are about a third of those from four-wheeled taxis or cars.[3] Thus, in the context of all vehicles, they already have relatively low GHG emissions per passenger kilometre. At the same time, they provide individualised urban transport, often in very narrow thoroughfares, which mass transit cannot do, and they also complement mass transit by providing feeder transport to it. If three-wheeler taxis have a third the GHG emissions of full-sized cars or taxis, that means they can save 85-115 grams of CO_2 equivalent GHG emissions for each passenger kilometre, assuming the same number of passengers in each vehicle. From a wider perspective, this estimate may actually be conservative. Although empty cruising by small taxis would worsen their average emissions per passenger kilometer, a vibrant taxi industry helps slow increases in ownership of private motor vehicles. Since vehicle ownership dramatically increases household vehicle kilometres and GHG emissions, slowing motorisation can avert a significant amount of emissions.

4. Technology and fuel changes to reduce local pollution and GHG emissions

In places where small taxis are common, it is extremely important and urgent to reduce their local air pollution impacts (together with those of private motorcycles). Considerable policy effort has therefore focused on reducing these emissions. Policies and programs to reduce local air pollution often also reduce GHG emissions.

Until quite recently, most three-wheelers and motorcycles in developing countries have had two-stroke petrol engines, in which lubricating oil is mixed with the fuel and burns with it. Such engines have contributed significantly to unhealthy local air pollution. In Delhi in the late 1990s, for example, almost half of particulate emissions and two-thirds of unburned hydrocarbon emissions from transport were attributed to two- and three-wheelers, with each such vehicle emitting almost as much fine particulate matter as a light diesel truck.[4] In several countries, very low-octane fuels, adulteration with subsidised kerosene and over-use of lubricant in the fuel mix further multiplies the unhealthy smoke produced by two-strokes, and reduces their fuel efficiency.[5]

Technological interventions for small taxis have focused especially on conversions to CNG or LPG (via retrofits or with new purpose-designed vehicles), and on shifts to four-stroke engines and to engines with modern fuel injection. A small number of projects have introduced hybrid or fully electric three-wheelers (as discussed later). Maintenance and inspection programs are another important aspect of tackling noxious pollution from these vehicles, and these tend to improve fuel economy and reduce GHG emissions.

5. Greenhouse emissions reduction potential of these changes

There is potential for these technological interventions to reduce greenhouse gas emissions. Taking account of various interventions, reductions in GHG emissions per km travelled of around 20% have been estimated in studies.[6]

Projects to shift three-wheelers from petrol to CNG can reduce GHG emissions by about 20% per vehicle-kilometre when the new vehicles are designed and manufactured to run on CNG, but retrofitted former gasoline vehicles can have higher GHG emissions than before.[7] There is also a risk that natural gas may

leak from poorly maintained re-fuelling and vehicle tanks, which would worsen GHG outcomes, since methane is a strong GHG.

Conversions to four-stroke engines offer significant air-pollution benefits, and reductions of about 10 to 15% as long as larger, heavier vehicles are not used.[8] Conversion of carbureted two-stroke to direct-injection appears to offer greater gains of up to a 30% improvement in fuel efficiency.[9]

Poorly maintained vehicles are responsible for much pollution, and inspection and maintenance programs are a proven intervention to reduce this. Such programs are important in order to maintain emissions reductions over the life of each vehicle, especially for high-use commercial vehicles.[10] Without adequate maintenance the benefits of the other technology interventions can easily erode. Fuel economy and GHG emission reductions can be improved by up to 17% in the case of very poorly maintained vehicles.[11] Vehicle maintenance is covered in another section of this guidebook.

Opinion is divided on the prospects for shifting three-wheeler taxi fleets to electric operation. Most commentators argue that the costs remain too high for adoption on a scale large enough to make a significant difference to GHG emissions.[12] However, electric vehicles are an arena of rapid technological change and this judgment may need to be reviewed often. Small-scale electric three-wheeler taxi projects are emerging in areas such as in Bangkok, and in Agra, where the Taj Mahal is located and polluting vehicles are thus forbidden. Electric vehicle projects seem to be most compelling in contexts where local pollution reductions are urgently needed and politically well-supported. There can be significant GHG emission reductions from conversions to electric vehicles, but of course such benefits depend on the source of electricity.

An exception to the widespread caution over electric three-wheelers is the reaction to Kathmandu's shift from diesel three-wheelers to electric ones in the late 1990s and early 2000s. Factors leading to this shift included:

- a groundswell of concern about the pollution from old diesel vehicles
- government policies that waived import taxes and annual fees for electric vehicles
- the use of cheaper off-peak electricity for recharging
- a ban on diesel powered three-wheelers, which eliminated the competition.[13]

Although this project was not motivated by climate change considerations, the GHG reductions in this case are much higher than would be the case in most countries because Nepal's electricity supply is mainly hydroelectric. It has proved difficult to replicate this success elsewhere in South Asia, except in certain circumstances such as the Taj Mahal environs as just mentioned. These two examples do show, however, that given the will there can be rapid changeover to electric three-wheelers.

Hybrid electric three-wheeler taxis also have promise, with the possibility of 30% GHG emission reductions, but so far such vehicles have only been proposed.[14]

The feasibility of these technological improvements

Conversions of three-wheelers to CNG and to LPG are well established for three-wheelers (but not feasible for two-wheelers). For example, tuk-tuks in Bangkok have been operating on LPG for many years. Delhi's CNG conversion is said to be operating satisfactorily and other Indian cities are following this now.[15] CNG auto-rickshaws have rapidly become the norm in Bangladesh, Indonesia and Pakistan, countries

Figure 3.50 The traffic on this street would be much less congested and produce much less pollution and greenhouse gas if there were fewer cars, and instead improved, cleaner technology auto-rickshaws delivered passengers to bus and train services

Picture Credit: Shyaulis Andrjus , Wikimedia Commons, http://commons.wikimedia.org/wiki/File:Kyiv_traffic_jam.JPG viewed 22 March 2011.

where CNG prices are subsidised and therefore low.[16] But a policy of subsidising fossil fuels – even those fossil fuels that are cleaner than others – is questionable. Shifts in the vehicle population from two-stroke to four-stroke have proceeded smoothly in many countries, a shift often accelerated by tightening emissions standards.[17]

6. The place of three-wheeler taxis in the overall transport system

There is often concern about the impact of three-wheeler taxis on traffic flows and congestion, given their low-speeds and the fact that they are often stationary while waiting for passengers or while picking them up or dropping them off. Such concerns often lead to restrictions on their numbers and even calls for them to be banned altogether. It is claimed not only that they increase congestion, but also that this increased congestion increases GHG emissions. However, there are three problems with this line of argument.

Firstly, expectations of smoothly flowing traffic are likely to be illusory or short-lived, because the improved traffic flow encourages more people to drive and own vehicles, which means that the congestion rapidly returns.[18]

Secondly, if three-wheelers are restricted or taken off the road the passenger demand that they once catered for is likely to be satisfied in two other ways: by an increasing number of four-wheeled taxis, and by increasing purchases of private vehicles (either cars, motorbikes or motor cycles). Looking first at four-wheeled taxis, these have much higher air pollutant and GHG emissions than do three-wheelers (depending on the size of the four wheeler, as four stroke engines are more efficient than two strokes but only if in a similar sized vehicle), and they take up more area and therefore contribute more to congestion.

Figure 3.51 People often associate auto-rickshaws with congestion, as in this photo, but imagine how much worse the congestion would be if these were all car-sized taxis

Picture Credit: Paul Barter.

If, on the other hand, households buy their own car or two-wheeler because fewer taxis are available, especially cheaper three-wheeler taxis, then their mobility patterns are likely to change drastically. Partly out of habit and partly to justify their major purchase, they will tend to ignore other transport modes and solely or predominantly use their private vehicle. Of course, if that vehicle is a car, it also produces more GHG emissions than a three-wheeler taxi does. If it is a motor cycle, it may generate as much local air pollution as an unimproved three-wheeler taxi.

Thirdly, restricting the number of three-wheeler taxis can raise the cost of operating licences, because such licences become a scarce commodity in great demand. This creates a risk of corruption and the involvement of organised crime in the industry. Furthermore, when drivers face a cost squeeze their on-road behavior often deteriorates, as seen for example in Delhi compared with other Indian cities.[19] Singapore, on the other hand, abolished quantity limits on four-wheel taxis, a measure which, combined with effective regulation of quality, has improved taxi service and kept costs low.

Thus, it is probably a bad idea to restrict or ban three-wheeler taxis. Nevertheless, it does seem plausible that a program of providing convenient and well-designed waiting ranks for three-wheeler taxis could reduce GHG emissions and reduce fuel consumption by reducing empty cruising for fares, and by reducing the traffic disruption arising from ad hoc waiting and stopping. Auto-rickshaw operators in Delhi for example are reported to be forced to do significant cruising without passengers due to an absence of stands and prohibitions on parking.[20] Improved waiting places may also help reduce disruption to buses and non-motorised vehicles.

An added benefit of three-wheeler taxis is that they are especially suited to playing a feeder role for mass transit. As cities improve their main trunk transit facilities, they often face a period in which ordinary bus

systems are not yet well integrated with the newer high-speed, high-capacity systems, whether MRT, LRT or BRT. However, low-cost taxis such as three-wheelers can fill this 'last kilometre' gap, along with motorcycle taxis, private motorcycles, non-motorised pedicabs and bicycles.

This section has argued that small taxis, such as three-wheelers, can be a positive factor in a city's transport system. However, more policy effort will be needed in most countries to achieve regulatory arrangements and industry structures to better foster a healthy, efficient industry with lower emissions and with better conditions for both passengers and drivers.

7. Costs and sources of funds

Diverse interventions have been mentioned so it is difficult to be specific about costs and sources of funds. Care must certainly be taken that mandated transitions to cleaner technology take account of costs imposed on the industry itself. Economists have argued that setting emissions standards would generally allow lower-cost compliance than mandating specific technologies. However, special circumstances (such as rampant adulteration of fuels) may sometimes modify this conclusion.

The most promising vehicle and fuel technology interventions are those which have a reasonable payback period, so that the upfront cost is recovered via lower operating costs. In such cases, technical assistance, regulatory nudges and accessible financing are likely to be more important than high levels of funding. In some case, fleet transitions have been market driven, although there are concerns that some of these have only been possible due to fuel subsidies that may prove unsustainable (such as for CNG in South Asia). There has also been debate about the cost-effectiveness of gas-powered three-wheelers, for example, CNG vehicles and their maintenance in Delhi, where CNG use has been mandated for auto-rickshaws and buses since 1999.[21]

For many of the technological interventions mentioned, GHG reductions are a co-benefit of projects that are justified on air pollution grounds. They may therefore attract funding associated with clean air priorities, at local, national or international levels, as well as funding targeting GHG reductions.

8. Conclusion

To sum up, then, there is certainly a place for three-wheeled taxis in the transport systems of cities and towns. They use less fuel and emit less greenhouse gas than larger four-wheeled taxis and private cars, which would to a great extent take their place if they were banned or restricted in number. Three-wheeled taxis have a useful role in providing individualised passenger transport for short distances, and this can often involve taking passengers to or from mass transit stations, so they support a good transit system. Congestion and unnecessary cruising can be reduced if they have taxi stands and places to park, which are still rare.

It can also be highly beneficial if changes are made to their engines and fuels, and if they are better maintained, so that they emit fewer local pollutants and GHGs, and are more fuel efficient. Experience in several countries has shown that such changes can already be feasible, including in some cases the switch to electric vehicles. The reductions in GHGs can occur as a co-benefit of efforts to reduce their emissions of particulates and other pollutants, a problem that is keenly felt in the cities where these vehicles are common.

Endnotes

1. For example, in Bangkok tuk-tuks carry only about 40.5 m passenger kms per year and 57 m are carried by motorcycle taxis. This compares with 572 m by taxis, 3,672 m by cars and 1,490 m by motorcycles. See 'Promoting Reduction in Travel Demand in Transport Sector of Asian Cities: Case of Bangkok, Thailand', in *Air Pollution Control in the Transportation Sector: Third Phase Research Report of the Urban Environmental Management Project,* Institute for Global Environmental Strategies, March 2007, p 101.
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Low Carbon Freight

M) Freight Transport

Robert Salter*

1. Introduction

This section covers the transport of any kind and quantity of goods, on land or water and over any distance (although it focuses on domestic freight). It includes, for example:

- freight transported by road, rail or ship
- facilities enabling freight to be switched from one mode to another
- trucks and vans delivering to local warehouses and businesses
- small boats taking rice or other farm produce to market
- goods tricycles selling textiles or food in an urban neighbourhood.

The section provides information about how governments and national leaders can implement policies to ensure that the nation's goods can be transported effectively, promptly, and between any two locations while reducing greenhouse gas emissions generated by freight. Seven objectives are offered here to achieve this. A number of measures are suggested to achieve each objective. Some measures are quite distinct and can be effective even if implemented on their own, while others need to be introduced in conjunction with other measures in order to be effective. This will be explained. The seven suggested objectives are as follows:

- more freight carried by rail, and increased efficiency of rail freight
- more freight conveyed on water, and greater efficiency of water-based freight
- effective linkages that enable multimodal freight transport to happen efficiently
- less freight moved by road, but improved efficiency of road freight
- better logistics and driving practices to reduce road trips and fuel used
- the use of appropriate small-scale and non-motorised vehicles and vessels to transport goods
- reducing demand for freight transport through urban planning and production processes.

2. Benefits from these measures

Economic benefits

These measures will result in less use of energy and reduce vulnerability to depleting supplies of fossil fuels. They will result in greater energy efficiency, reductions in unnecessary freight transport, and reductions in road-building and repairs. Finally, they will reduce pollution and accidents and the health and other costs these impose.

Social benefits

People will benefit from fewer accidents, less pollution, less noise and visual intrusion, better health and better quality of life.

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Environmental benefits

As a result of the measures described here there will be less local pollution, fewer greenhouse gas emissions, less use of non-renewable fossil fuels, and less land used for freight transport.

3. Greenhouse gas emissions reduction potential

Table 3.2 sets out energy use and emissions figures for different transport modes. The figures are from a developed country (Australia), but it serves to illustrate the stark differences between modes when the technologies are relatively modern and well-maintained, as they would be in this case. Such differences highlight the importance of switching freight transport modes, and of setting up freight centres and terminals that make this process more efficient and competitive. Other measures here focus on reducing the amount of freight transported and the distance transported, and in these cases the greenhouse gas reductions will be directly proportional to these reductions in distance and amount. Yet other measures cover the use of non-motorised transport, or transport with very small motors, and here emissions will be zero or very minimal. Lastly, there are measures to reduce greenhouse emissions through better technology and maintenance, and in many of these cases specific emissions reduction figures are included in the text.

Table 3.2 Energy and emissions intensity for road, rail and shipping transport of freight for Australia in 2005

Mode	Energy Intensity (MJ-FFC/tkm) [a]	Emission Intensity (g CO_2-e/tkm) [b]
Road Transport		
Light Commercial Vehicles	21.07	1532
Rigid Trucks	2.95	209
Articulated Trucks	0.98	71
Rail		
Hire and Reward	0.32	24
Ancillary	0.09	6
Coastal Shipping	0.17	15

a Megajoule per ton km (MJ/tkm) on a Full Fuel Cycle (FFC) basis. A 'full fuel cycle' includes feedstock production, extraction, fuel production, distribution, transport, storage, and vehicle operation, including refuelling, combustion, conversion, permeation, and evaporation.

[b] Grams of carbon dioxide equivalent (g CO_2-e) per ton km.

Source: Data drawn from Ernst von Weizsäcker, Karlson 'Charlie' Hargroves, Michael H. Smith, Cheryl Desha & Peter Stasinopoulos, Factor Five: Transforming the Global Economy through 80% Improvements in Resource Productivity, Earthscan, London, 2009.

4. The seven objectives and the measures that can help to realise them

A greater proportion of freight carried by rail, and increased efficiency of rail freight

As Table 3.2 shows, there can be large energy and emission reductions when goods are transported by rail – or by water, which is considered in the next part – rather than by road. In general terms, rail can be very competitive with road on price and delivery time over long distances. A German food company reported saving 40% of its energy consumption by switching to rail for long-distance transport.[1] Multimodal trips (those combining two or more transport modes) can also be cost effective and reliable, as well as reducing greenhouse gas emissions. The aim should be to have as great a proportion of medium to long distance freight as possible transported by rail or water, leaving road freight to handle just the local pick-up and delivery legs of the total freight journey.

In order to shift a greater volume of freight to rail, a range of measures may need to be taken, including improvements to rail routes, improvements to train technology, the establishment or upgrading of multimodal freight terminals, and the proper pricing of both rail and road freight – so that rail is advantaged, instead of disadvantaged as it is now.

Improvements to rail routes include the separation of freight and passenger rail tracks – especially in urban areas – and the straightening and strengthening of freight tracks. These measures enhance freight speed, which is important if rail is to compete with the speed of road freight.[2] Grade separations to eliminate level crossings – again, particularly in cities – also enhance rail speed and competitiveness and reduce accidents.

On the matter of train technology, hybrid diesel-electric motors that power many freight trains today are very efficient and exemplify improvements in rail efficiency over the past few decades. US rail freight company CSX claims to have improved fuel efficiency 80% since 1980, while Swiss railways – already one of the most efficient in the world – predicts further improvements of up to 60% in their rolling-stock, flowing from better engine efficiency, energy recovery from dynamic breaking, more light-weight materials, and reduced drag and friction.[3]

If freight rail services are government-owned, then governments can invest in these efficiency improvements themselves, provided they can raise the funds. If governments contract the services out to private operators, they can stipulate that greenhouse gas emission levels or fuel efficiency standards will be taken into account in the competitive tendering process, or set minimum acceptable standards.

There is a strong argument for subsidising both passenger and freight rail because of the many benefits they generate,[4] but governments have to decide what, if any, level of subsidy is financially feasible. For more on rail services, see also the Mass transit section.

Figure 3.52 Rail is normally a highly efficient mode for freight transport

Picture Credit: Jamie Cox.

A greater proportion conveyed on water, and more efficient water-based freight

Water freight generally is more energy efficient than road freight, as has already been noted. The factors that can make it more competitive with road freight are the same as those that advantage rail freight: improved routes, improved technology, better freight terminals or centres, and more favourable pricing arrangements in relation to road freight. On the matter of routes, domestic water transport services can travel along coasts, rivers or canals, across lakes or between islands. In countries that have water transport routes, it is important that they are integrated, well-maintained and free of obstructions in the form of low bridges, and weirs or irrigation devices without locks. Water transport routes are described in more detail in the Water transport section.

Water freight requires multimodal terminals so that freight can be transferred to or from rail or road, and such terminals are discussed in the next part. Containerisation offers big advantages, and an efficient centre will have gantries or cranes to shift loads, whether containerised or not. The technology that is going to do this fastest and easiest is also likely to be more expensive and energy consuming. One large gantry, for example, can use as much energy as three buses,[5] so it is preferable if the power source is low or zero carbon.

On the question of technological improvements, major improvements identified in one report included anti-fouling coatings to reduce drag, improved hull design, air floatation, propeller design, wind propulsion and the use of renewable energy in port.[6] The report was mainly considering larger freight vessels, but they would be relevant for medium sized vessels as well.

The UN Economic and Social Commission for Asia and the Pacific (UNESCAP) has produced a *Manual on Modernization of Inland Water Transport within a Multimodal Transport System,* which provides much

Figure 3.53 Water-based freight is also highly efficient, especially if containerised and using loading technology

Picture Credit: Dana Smillie, World Bank Photo Collection.

practical information on water-based freight transport,[7] some of which is described in the Water transport section. This manual also highlights the importance of water-based freight transport in Europe, and increasingly in China.

Over many routes, particularly those on inland waterways, water freight competes with road freight, and so it is important that it is not disadvantaged because of road transport subsidies, and that road transport is priced as discussed later. Water transport is generally slower than road, though not always so. This is one reason that it produces less greenhouse gas, in that boat emissions are proportional to the speed of the vessel squared. However, if the time required for water-based freight is planned for, delays can be avoided. In areas such as eastern Peru and the deltas of Bangladesh and Vietnam, water transport has an advantage in that roads are poor or non-existent, but this lack of competition can also be a disadvantage for passengers and those sending or receiving freight, as it is in eastern Peru, where the state of the vessels and the docks leave much room for improvement.[8]

Freight centres and linkages that enable multimodal freight transport to happen efficiently

Rail and water transport cannot take freight from point of origin to destination, and so must rely on road transport for these first and last legs. Moreover, there may be one or more transitions from water to rail transport, or vice versa, in a freight journey. For this reason, and particularly in the context of competition with road transport that may not need these linkages, it is vital that there are efficient multimodal freight centres or terminals at which freight can be transferred from one mode to another quickly and smoothly. As noted earlier, the technology at such centres can be expensive, energy consuming and potentially greenhouse gas producing, but this has to be balanced against the economic, social and environmental costs of relying on road freight alone, and, as just noted, there is always the possibility of the energy coming from low or zero carbon sources.

Such centres need to be carefully located so that road traffic to and from them does not constitute a social or environmental problem, as it would, for example, in a dense urban area.[9] Even if a freight trip is entirely by road, freight centres located outside a city centre are needed to allow freight to be transferred from large long-haul trucks to smaller trucks for city or other local distribution. If properly planned – especially through the use of logistics technology - this means reduced emissions, noise and congestion in city centres, better health and safety, and less fuel use and cost for the companies.[10] Moreover, consolidation of freight deliveries within a limited number of centres increases the amount of freight that has the same origin and destination, and thus increases the chance of return loads and of different consignments in the one load, thereby reducing the number of vehicles used.[11]

There is also an argument for locating freight centres and production facilities near each other. In Japan, freight centres also function as wholesale markets, especially for food, from which the food is distributed to smaller wholesalers and retailers.[12]

Freight centres can benefit from both public and private investment,[13] but experience indicates that they are much less likely to be viable if their development and location do not take into account market factors.[14]

Less freight moved by road, but improved efficiency of road freight

In order to reduce the proportion of road freight, and increase the proportions conveyed by rail and water, pricing issues have to be addressed. Road freight usually enjoys public subsidies because fees and taxes

do not cover its full public costs, with trucks responsible for much more wear and tear on roads than are cars and other small vehicles. This needs to be reversed. Road freight should pay the full cost it imposes on society, the economy and the environment, or at least a much greater share of this. Pricing will also deter trucks from using certain roads, although simply banning trucks from these roads is an alternative. Pricing will also make road freight less competitive in relation to rail and water, and thus lead a greater proportion of it to be carried by these alternative modes – if the modes are available and if the balance of their benefits and costs make them at least as attractive as road transport.

On the question of how road freight can be priced, the options are:

- registration charges
- fuel taxes
- tolls on particular freeways, roads or bridges
- congestion taxes in selected urban areas.

Tolls and congestion taxes (and bans on freight transport on particular roads) can be for all times or just for some times of the day or week, or there can be higher charges in busier periods. If tolls are to be imposed, electronic toll collection can avoid the generation of additional emissions that would otherwise result from stop-start traffic and vehicle idling when traffic banks up before manual toll collection points, and such technology can be financed out of the tolls. Fuel taxes will encourage better vehicle maintenance and use of more fuel efficient vehicles, and there can also be subsidies or tax concessions for electric or hybrid vehicles.

Governments can also give preference to lower carbon freight modes and technologies through its own procurement policies, directly generating business for these modes and technologies and setting an example for the private sector to follow.

Differential pricing for larger and smaller trucks, or bans on larger trucks in certain areas, will deter or prevent larger truck pick-ups and deliveries in busy city centres, and instead encourage large trucks to

Figure 3.54 Local urban streets are not the place for road freight

Picture Credit: Megananne.

deliver to or pick-up from freight centres further out, with smaller trucks undertaking the first or last leg. These extra stages also remove the door-to-door advantage that road freight can have over other modes.

The trend for businesses to keep reduced volumes of stock in storage, and to have more just-in-time delivery, unfortunately results in more freight deliveries with smaller loads. If road freight companies have higher costs for delivering these small loads – costs that they can pass on to the businesses – then these businesses can be encouraged to order in larger quantities, and to thus enable road freight to be more efficient.

Trucks also need to be more fuel efficient and thus less greenhouse gas generating and this leads to the question of vehicle maintenance and the adoption of better technologies and fuels. On the matter of vehicle maintenance, there is another section on this, Improving private vehicle operating standards, which applies to trucks as well as other private vehicles and therefore can be consulted. Governments need to look at ways of encouraging or requiring vehicle owners to maintain their vehicles, and a range of measures are covered in that section, specifically:

- setting standards for vehicle fuel economy
- setting standards for vehicle emissions
- vehicle inspections
- mandatory adoption of particular technologies in extreme cases
- taxation and pricing measures relating to emissions, vehicle age and fuel economy
- requiring the inclusion of emissions standards in vehicle warranties
- schemes to get older vehicles off the roads
- standards for fuel quality
- driver or owner education about vehicle maintenance.

On the matter of better truck technologies, many improvements can increase fuel efficiency, including improvements to truck shapes to reduce aerodynamic drag, reduction in truck weight, alterations to tyre tread and tyre configuration, and a range of improvements to engines, transmissions, cooling systems, and other components and systems, as well as alternative fuels and engine technologies. Further reading on these possibilities is available and recommended,[15] and another section in this guidebook, Vehicle and fuel technologies, has extensive information on this.

The Green Trucks Pilot Project in Guangzhou, China, sought to improve fuel efficiency and reduce greenhouse gases emissions and local pollutants through the retrofitting of new technologies and driver training. Adoption of particular tyre and aerodynamic technologies alone paid for itself in 1.8 years through improved fuel efficiency, and, if adopted by all of the 826,000 heavy trucks in Guangdong Province, this would save 8.6 billion litres of fuel a year and reduce CO_2 emissions by 22.3 million tons a year, equal to the emissions of a large city.[16]

Better logistics and driving practices to reduce road trips and fuel use

A range of technologies can help to plan the shortest, quickest and least congested routes, match up the supply of and demand for freight carrying capacity so that loads are fullest (including on return journeys), keep track of and manage vehicles, and improve driving.

In China, Japan and the Philippines, 30-40% of truck trips are empty.[17] Reducing the numbers of empty or only partially full loads has a significant impact on greenhouse gas emissions. And research has shown that mixing light and heavy products in a load can maximise the load's efficiency. If the heavy products alone are packed, they soon reach maximum load weight while leaving empty space in the trailer, while the light products take up available space before reaching the most efficient load weight. But a blend of the two can align volume and weight capacity.[18]

A transport company in Thailand is using a traffic flow database called Road Net Program, which calculates the fastest, most cost-effective route by processing traffic volumes, route restrictions, and other data.[19] One analyst, writing in the context of Korea, has suggested subsidies and loans to switch to green logistics, the establishment of an integrated national information centre for logistics, and a green logistics certification plan.[20]

Driving practices that increase fuel efficiency can be achieved through information provision, driver training and real-time performance monitoring technology.[21] 'Eco-driving' schemes in Japan have resulted in 12% savings in fuel consumption, through things like proper use of gears, switching off the engine when the vehicle is stationary, and avoiding heavy acceleration.[22] Owner drivers have a material incentive to improve their driving in these ways; companies can consider offering efficiency bonuses for employed drivers so they too can have such an incentive.

Overall, the main incentive for road transport companies to adopt better driving practices, better logistics, newer, more efficient technology and improved maintenance practices are that these measures will save a lot of money, and the importance of such savings can be sharpened if road freight becomes more expensive through pricing mechanisms. But it can also be useful if governments make this industry more aware of these potential savings, and offer further information, training programs, and subsidies and loans to adopt the necessary measures. Moreover, It has to be recognised that increasing the pricing of road freight, while leading some operators to become more efficient and low carbon, will also drive other less efficient and sustainable operators out of business in the overall shift to increased proportions of rail and water freight. For this reason it is important to have plans in place to re-deploy truck-drivers and others working in the trucking industry into other, more sustainable forms of employment in transport or elsewhere.

The availability of appropriate small-scale and non-motorised goods vehicles and vessels

The transport of smaller volumes of goods over shorter distances on land or water can be done effectively in small, often non-motorised vehicles and vessels. This is particularly the case where there is little space, as in dense, crowded urban areas with narrow roads, lanes or canals. Such transport can be especially suitable for small producers and traders, most of whom have little capital for more expensive vehicles or vessels.

Non-motorised vehicles are sometimes seen as 'backward', which is unfortunate as they often are the most greenhouse efficient as well as playing a vital role in the total transport system. Modern, efficient solutions to transport needs are those that achieve the greatest benefits for the least costs (both private and public) and sometimes this means simple, traditional technologies. Handcarts, goods bicycles and tricycles, animal drawn vehicles, and boats propelled by paddles, oars, poles and sails can have a range of advantages for either the owner or the community. They can be cheap to buy and run, easy to maintain and repair, quiet, compact, not dangerous to other vehicles or pedestrians, flexible in limited spaces or if frequent stops are required, non-polluting and non greenhouse gas producing. Compare this environmental record with that of light commercial vehicles in Table 3.2 earlier, which produce CO_2 emissions per unit of

weight carried that are more than 250 times those of a freight train.[23] Non-motorised vehicles and vessels can double as a 'stall' from which goods can be sold. And draught animals can be sources of milk, and of fertiliser and building material from dung.

Examples of non-motorised vehicle use can be found all over the world: handcarts in Africa transporting goods to and from markets,[24] adapted bicycle rickshaws in Bangladesh carrying bolts of cloth,[25] couriers delivering business parcels in inner-city Australia, goods bikes in New York City or Amsterdam,[26] and sellers in floating markets in Bangkok or on the Mekong River. A tricycle (Figure 3.55) can transport up to one tonne of goods on flat terrain without the aid of an engine.[27] When a bakery in Colombia was unable to fund the replacement of its 135 ageing trucks, a non-motorised transport option seemed impossible given the distance of the bakery from retail outlets. However, its solution was to buy 50 trucks to take the products to satellite warehouses, from where 904 cargo-tricycles took them to stores. Distribution costs fell from 27 to 8% of total costs, and employment increased substantially.[28]

Governments and non-government organisations can help small producers and traders to purchase such vehicles and vessels through loan schemes, and loans, information and business advice can support businesses to manufacture them. Designs can be updated with attention to lightweight, sturdy materials and specially adapted cargo areas for particular kinds of goods. Attention can be paid to parking needs for such vehicles.[29] And goods bicycles and tricycles can incorporate auxiliary electric motors. There should be a much bigger future for non-motorised goods transport.

Figure 3.55 Urban cargo tricycle, Hangzhou, China

Picture Credit: Karl Fjellstrom, itdp-china.org.

Reducing demand for freight transport through urban planning, production processes and product design

As described in the *Reducing the need to travel* section, if urban areas are denser, have more mixed land use and greater self-sufficiency, then there will be less need for people to travel, and the same is true for freight. Self-sufficiency means more local production and this can be increased in both urban and rural areas, but the efficiency of the production process also needs to be considered. Economic orthodoxy argues that larger scale production is more efficient, but this is increasingly being challenged in the age of decentralised, networked businesses and ICT. It may also be less relevant in developing countries where labour is more plentiful and capital is scarcer.

In developed countries, the notion of buying locally has become popular, particularly in relation to food, and talk of 'food miles' is common. However, it cannot be assumed that the use of locally produced goods generates fewer greenhouse gases because of the shorter distance transported. With reference to Table 3.2 again, it is not clear if the figures in the table are based on average loads or maximum capacity, but either way, a kilogram of oats taken to a farmers' market in a partly full van may be producing 50-100 times the CO_2 per kilometre travelled of a kilogram of oats on a full goods train. So attention has to be paid to the distance freight travels, the loadings, the energy efficiency of the mode of travel, and the carbon intensity of any fuel used.

Even if products are to be sold further afield, increasing the proportion of processing or production that occurs locally can produce large emissions savings by reducing the volume and weight to be transported. This particularly applies to agricultural, mining and timber industries. For example, if milk is to be turned into powdered milk, extracting the water at the individual dairy or dairy cooperative will result in dramatic reductions in the weight and volume of the product to be transported, and this also increases business and employment in regional areas.

The volume of goods to be transported is also reduced if products are designed to be more durable, if packaging is minimised, and if attention is paid to what has been called 'reverse logistics', that is, the process of planning and implementing the efficient re-use or disposal of products and packaging once they have ceased to be used for their original purposes.[30] We tend to focus on the transport of goods to producers, retailers and consumers, but an almost equal volume of matter then has to be re-transported once it has been 'used'.

5. Costs and sources of funds

The costs of freight are a major driver in infrastructure decisions as productivity gains can be very large once good freight access is provided. Sources of funds can often be found from the private sector in both road and rail, as freight transport is much more able to fully pay its way than is passenger transport. Thus Public Private Partnerships are preferred when freight projects are put to governments. As the economic flow-ons are so good, the extra benefits of reducing greenhouse are likely to be only a small part of the benefit-cost ratio. Nevertheless, it may make the difference between being funded or not, especially when targeted greenhouse funds can be found.

6. Conclusion

According to Mehrick,[31] governments can influence freight practices in four different ways. They can:

- **Regulate:** setting vehicle standards, making planning laws, and limiting vehicle access for various purposes
- **Incentivise:** through taxes, pricing, grants and subsidies
- **Persuade:** through information provision and social marketing
- **Facilitate:** through infrastructure development, education and training, promotion of intelligent transport systems, and research and development support.

Through these means, governments and national leaders can assist large and small businesses to adopt more low carbon freight transport: to switch to lower carbon freight modes, to maintain vehicles and vessels better, to invest in lower carbon technology, to use logistics technologies, to eliminate unnecessary trips, and to drive efficiently. In this way they can reduce both their transport bills and their greenhouse gas emissions.

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Low Carbon Air and Water Transport

N) Air Transport

Robert Salter*

1. Introduction

Worldwide, air transport is a constantly growing transport sector. The total distance passengers have travelled has increased every year except two since the International Civil Aviation Organization first began keeping statistics in the 1940s. Between 1988 and 2008 it more than doubled, from 1.7 trillion to 4.3 trillion passenger-km.[1] It is now growing at about 5% annually, but in China it has been growing at 12%.[2] As economic growth accelerates in other developing countries air travel is on track to sharply increase there as well unless measures are taken to reduce this.

Air travel uses 11.6 % of all energy used in the transport sector, and produces 2% of global greenhouse gas emissions, but these emissions could be as much as 10 times greater by 2050 given the growth in the sector.[3] There have been significant improvements in aircraft engine design, aerodynamics, the lightness of materials and navigation technology. These have meant that, according to the IPCC, aircraft are 70% more efficient now than they were 40 years ago. And further improvements are in the development stage, included blended wing bodies, even more efficient engines and more lightweight materials, improved logistics systems and second generation biofuels.[4]

These may yield 40-50 % improvements in fuel efficiency by 2050,[5] but considering that, as just noted, a 10 fold (or 1000%) increase in emissions is possible by 2050 (without efficiency improvements factored in) the anticipated improvements will go nowhere near to keeping up with the growth in air travel. Thus, a range of measures are needed to reduce greenhouse gases generated by air travel worldwide, including reductions in air travel itself, in the emissions it generates per passenger kilometre, and in emissions generated by activities associated with air travel.

Despite this overall problem with aviation two positive things can be said about the industry: first, it is a highly regulated industry due to safety concerns and hence regulations that begin to factor in carbon are coming from a long history of government concern; second, the aviation industry due to its growth and dynamism has been showing considerable innovation in addressing carbon as will be shown below.

The focus of this section is on what developing country governments can do to reduce greenhouse gas emissions from domestic aviation within their countries. Most governments have little control over the process of increasing efficiency in aviation. International air travel is not yet included in any inventory of greenhouse gases as it is not clear to whom responsibility should be directed. Even if they own national airlines, these airlines are constantly crossing borders, and they must choose from globally available aircraft technologies and fuels rather than having the many local options that land transport has available. Governments can regulate the types and ages of aircraft permitted to fly on their countries' domestic air routes – and this measure is advocated – but again they are limited to technologies that airlines are willing to invest in and operate in their domestic markets.

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Moreover, any government action needs to be based on a recognition that, although domestic aviation is a significant greenhouse gas producer, it also plays an important part in meeting a country's transport needs, specifically by providing fairly rapid transport for people and goods over medium to long distances.

Accordingly, this section focuses on five options, which can be adopted separately or collectively. These are ways in which governments can reduce greenhouse gas emissions associated with domestic aviation while still ensuring that people and goods can move fairly rapidly over medium to long distances. These options for government are as follows:

- providing higher-speed trains as an alternative form of longer distance transport that has lower GHG emissions, while at the same time refraining wherever possible from building additional airports or runways, and providing a suite of incentives and disincentives to encourage the switch from air to train travel
- assisting and encouraging the use of information and communications technology (ICT) as an alternative to travel for work-related and personal purposes
- ensuring, where airports already exist or must be built, that surface transport to and from them is as low-carbon as possible, by increasing mass transit services, and discouraging private vehicle use
- reducing greenhouse gas emissions generated at airports through a range of changes to designs, technologies and practices employed there
- regulating – to the extent that it is possible within a country's domestic aviation market – the types and ages of planes that are permitted to operate services.

Through the adoption of such measures, developing country governments can significantly reduce greenhouse gas emissions associated with air travel, while at the same time ensuring that citizens can undertake efficient travel over medium and longer distances for personal and work purposes, and that goods requiring rapid delivery can also be transported over these distances.

2. The benefits of these five measures

Economic benefits

The first four options can all provide new employment and stimulate new business enterprises. **Option One's** emphasis on the development of rapid train services rather than air travel can lead to the saving of space devoted to airports in urban areas and reinvigorate urban centres through station construction or upgrading. If rapid train services stop at towns along the route they provide better longer-distance alternatives for individuals and businesses in regional and rural areas situated between major cities. In some cases, rapid train trips may be faster than air, if one considers the time taken to get to and from, and to wait at, train stations (which are usually centrally located) in comparison to time taken getting to and from and waiting at airports (which are normally on the outskirts of town and are notoriously time consuming due to scheduling uncertainties). Also, greater reliance on transit and less on air and road travel prepares a country or locality for increasing oil prices.

Option Two (promoting the use of ICT) can save individuals, businesses, governments and community organisations time and money, as can **Option Three** (mass transit to and from airports in place of cars). **Option Four** (greener airports) can reduce operating costs for government or private operators of airports. **Option Five** (mandated standards of aircraft efficiency) can also save airlines money on fuel, once initial investments in newer technology are made.

Figure 3.56 Higher speed trains can often get passengers to their destination in comparable time, when all aspects of the journey are considered

Picture Credit: (left) Alex Needham (right) http://www.deletefearofflying.com/testimonials.htm.

Social benefits

These options, between them, offer diversity of transport, reduced road congestion, and provide better access from city centre to city centre (a particular benefit, in the last case, for those without private vehicles). They lead to reduced road travel, which is less safe than train or air travel, better transport services for regional areas, and less noise for communities living near airports or under flight paths. More sustainably designed airports are also healthier and more pleasant for air travellers and those employed in the airline industry.

Environmental benefits

These options, in quite different ways, can all significantly reduce greenhouse emissions, as has been established, as well as reducing other pollutants such as oxides of nitrogen. As well, trains can operate on diverse kinds of fuel, including renewables, whereas aviation fuel is derived from oil. There are currently no fully developed alternative aviation fuels that do not pose additional threats to the environment or food production. Thus air travel is very vulnerable to the expected depletion of oil supplies. Options One and Three can save land – that might otherwise have been airports or freeways – which aids urban consolidation and perhaps conserves farmlands or natural areas on urban fringes.

3. Greenhouse gas emissions reduction potential

Flights of up to 300 miles (483 kilometres) emit 0.19 kg of CO_2 per passenger-km, while those over 700 miles (1,126 km) emit 0.09 kg of CO_2 per passenger-km.[6] So flying is in general better than car use (0.209 kg per pass-km) though short flights emit more than twice as much CO_2 per km as long flights do, and it is short flights that are most common on domestic air routes. The reason for this is that so much fuel is used to get a plane airborne so long trips average out at much less fuel per passenger-km. Air travel is also responsible for nitrous oxide emissions, and for water vapour emissions at high altitudes, now also thought to worsen climate change. The combined effect of jet exhaust emitted at high altitudes has two to five times the climate change impact of the CO_2 alone emitted at ground level.[7] Even without considering all these other greenhouse equivalents the trip between London and Nice by Eurostar and TGV (fast train) is estimated to emit 36 kg of CO_2 per passenger while flying emits 250 kg per passenger.

Option Two (substituting ICT for travel) has almost no greenhouse gas emissions, so its emission reductions are virtually equal to the emissions of the travel saved. The emission reductions of Option Three (more low-carbon travel to and from airports) are equal to the difference between those of car travel (0.219 kg/passenger-km) and those of train travel (0.0047-0.327 kg/passenger-km) or buses (0.118 kg/passenger-km).[8]

The measures described in Option Four (reducing greenhouse gas emissions at airports) are highly diverse and so will vary greatly from airport to airport, but as one example, Leeds airport achieved 12% energy savings, and thus an equivalent emissions reduction. With regard to Option Five (regulating the types and ages of planes permitted to fly on domestic air routes), it was noted earlier that aircraft are now 70% more efficient than they were 40 years ago, so this measure would result in greenhouse gas emissions savings equalling some portion of this, depending on the types and ages of the planes concerned and the stringency of the regulation.

4. The five options and their implementation in more detail

Providing rapid train travel and discouraging domestic air travel

The rapid train service, Eurostar, has now captured more than 70% of the London-Paris transit market from the airlines. This is because, all things considered, it is as fast as flying between the two cities, and more reliable at arriving on time.[9] Since commencing a high-speed route between Seoul and Daegu in 2004, the Korean Train Express (KTX) has been in part responsible for a 34-75% drop in domestic aviation in that time. With the success of this first KTX, other services have now been introduced from Seoul to Busan and Mokpo.[10] Rapid trains are thus a very feasible alternative to air travel, especially between cities up to 500 miles apart. Apart from the speed of modern trains, two aspects of train travel that make it competitive on travel times are that:

- stations are normally in central city areas, as opposed to urban outskirts, which normally means less travel to and from stations than to and from airports
- there is much less unavoidable waiting time at stations than at airports.

As well, rapid train stations are usually more accessible via local mass transit than airports are. And as already noted, rapid trains can be a more convenient form of longer distance transport for populations living between major cities, if those trains make stops along the way. Thus, rapid train services have much to recommend them, but they will not happen without the wholehearted support of government.

They are not cheap, as described in the cost section below. Government can contract out to private enterprise any aspect of their construction or operations (although it is strongly advised to maintain overall control of the service). Because they are expensive to build, fares will be expensive if they are not highly subsidised by government (which most governments cannot afford to do). If they are viewed as an alternative to air travel, which is also expensive for the average citizen in the developing world, then the cost of the fare may be not such an issue. Lower cost fast trains such as Tilt trains are able to use the present rail tracks rather than build whole new lines.[11] But it is vital that rapid trains do not displace the slower and cheaper trains that so many people of all income levels rely on for their longer distance travel. This has recently emerged as a problem in China, where a survey of travellers in Shanghai found concern about the affordability of the new Shanghai-Hangzhou rapid train, at a time when rapid train services in China are replacing some of the slower, cheaper services.[12] This is something to be avoided. Trains that are not quite so rapid can be promoted as another possible alternative to air travel – not so competitive on

speed, but more affordable for nations to build and for citizens to travel on. This may be the most feasible alternative for many low income nations.

If governments have clear and firm commitment to improving the speed and quality of train services over distances up to 500 km at least, then they will be better able to resist the inevitable calls from businesses and influential citizens for additional airports and extra runways at existing airports. In the twenty-first century it may not be necessary or desirable for cities to expand commercial airports, when other forms of longer distance travel can be as fast and convenient as well as being more sustainable. In the same way that freeways have become much less of an option in cities this century due to a realisation that other options may work better and save carbon, the awareness of air travel's inevitable and constant growth may also be questioned.

Governments can discourage air travel and encourage train travel through price mechanisms. They can tax flights, aviation fuel or airport use, or air travel can be taxed as part of a more general price on carbon. Funds raised can also help to finance the development of rapid and lesser-speed train services that provide an alternative to air services.

It is also necessary to ensure that train travel is able to project an image of a modern, efficient, fast, punctual, clean and comfortable travel mode, so that air travellers see it as an attractive alternative. This means that stations as well as the trains need to conform to this image, and that ticketing and information services need to be accessible online or by phone.

Encouraging and enabling the use of information and communication technology (ICT) as an alternative to air travel

This has already been discussed in the *Reducing the need to travel* section. When it comes to reducing the need for air travel, one of the purposes of travel that can be reduced through ICT are meetings and conferences for business people, government officials, health or education professionals or members of community organisations, as well as family meetings.The German company Deutsche Telekom is one of many companies that have saved time, money and greenhouse gas emissions through videoconferencing. With its subsidiary T-Mobile it has conducted over 40,000 videoconferences between 2004 and 2007, saving 7,000 tons of CO_2 emissions, mainly through reduced air travel, and 200,000 hours of employees' time.[13]

Making travel to and from airports more sustainable

If a journey involving a plane fight is considered to include all travel from point of origin to destination, then it also includes the transport to and from the airport. From this perspective, greenhouse gas emissions can be reduced if lower-carbon forms of transport are taken in these legs of the journey. This chiefly involves travellers switching from private cars or taxis to mass transit. If transit is to be at least as fast as private vehicle travel it needs to be either a rapid (or faster than normal) train service, or BRT with dedicated lanes. These services do not have to run just from the city centre to the airport (or vice versa). They can have stops in between or stops beyond the airport, but unless they are very direct and have only a few stops between city centre and airport, they will not be competitive with private vehicles.

Given the uncertain future of air travel in the face of oil depletion and the pricing of carbon, governments may need to invest in a train or BRT service rather than making a much larger investment in further road capacity (most rail or BRTs can replace 8 to 12 lanes of traffic equivalent, as discussed in the *Mass transit* section). If this means taking one lane of an existing highway or freeway as a train or dedicated BRT

lane, then private cars will have less road space and this can act as a demand management measure, encouraging car travellers to switch to mass transit. Road tolls can also encourage this switch. In addition, many airport authorities themselves are encouraging more low-carbon transport to and from airports.

Reducing greenhouse gas emissions associated with airports

Greenhouse gas emissions generated at airports, and by their staff and the travelling public when at airports, are also part of the total emissions output from air travel. Fortunately, things are changing on this front. According to an Airports Council International report, as of May 2008, at least 45 airports around the world have been taking a wide variety of measures to make airports more sustainable, and most of these measures involve significant reductions in greenhouse gas emissions. They include:

- solar and wind power generated on site, solar water heating, and cogeneration of electricity and thermal energy from gas
- reduced energy use through insulation, use of natural light and ventilation, and 'smart' building systems that regulate lighting, climate control and other energy uses on the basis of ambient light and temperature, the presence or absence of people in particular areas, and other variables
- recycling of water, garden waste, food waste, food and drink containers, paper products, concrete and materials from demolished buildings, and batteries
- airport vehicles, including shuttle buses for the public, powered by alternative fuels
- facilities to enable planes to switch to airport power sources as soon as they land, so that they don't need to remain powered up to maintain internal operation conditions, as well as pre-conditioned

Figure 3.57 Airport Express Ticket Counter, Hong Kong

Picture Credit: Mailer Diablo, Wikimedia Commons, http://commons.wikimedia.org/wiki/File:HKStation-AETicketCheckIn.JPG viewed 22 March 2011.

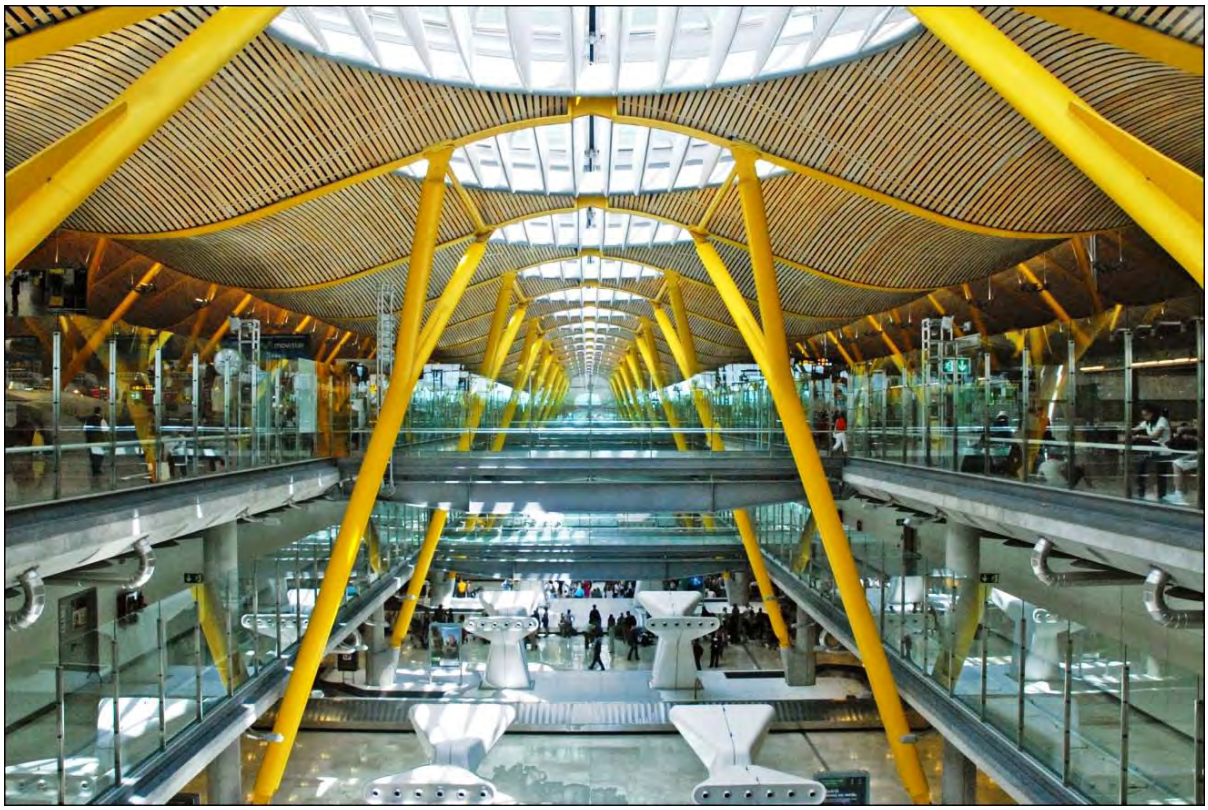
air units to provide ventilation, cooling, dehumidifying, filtering and (if necessary) heating of air for parked aircraft

- airport assisted aircraft landing by gliding or 'coasting'
- towing of aircraft to the runway
- measures to encourage the public and staff to reduce private vehicle use getting to and from airports, including free and discounted public transit tickets, and encouragement of car-pooling
- priority parking for hybrid or otherwise energy-efficient taxis and cars owned by staff or the public
- noise and pollution reduction in vehicles and machinery.[14]

A number of airports have now declared themselves carbon neutral as a result of adopting these kinds of measures. Dublin Airport has published its own sustainability report to outline measures it has taken.[15]

Most new and sustainably designed airports have been fitted with advanced mechanical systems to increase the circulation of fresh air, and have large windows installed to maximise daylight. These are two elements that create a healthier and a more enjoyable experience for travellers. For example, terminal three at Changi Airport in Singapore has been fitted with floor-to-ceiling glass walls and 919 skylights as well as a five-story vertical garden. These sustainable adjustments have created a more pleasant waiting area for travellers.[16]

Figure 3.58 Madrid Barajas Airport maximise natural daylight while reducing solar gain through extensive external shading



Picture Credit: Jean-Pierre Dalbera.

Mandating efficiency standards for aircraft

Any country, through its government, can set standards about the types, ages and conditions of aircraft that are permitted to fly on its domestic routes. At the moment such standards are set for safety, and for emissions of carbon monoxide, hydrocarbons, oxides of nitrogen and smoke.[17] There is no overriding reason why they cannot also be set for fuel efficiency, and thus greenhouse emissions, and in fact the IPCC mentions this as a policy option.[18] Governments could either give a date in advance – for example, five years – by which time commercial aviation services were required to conform to new standards, or they could require airlines to meet the new standards for any new planes in their fleet.

Aircraft being manufactured today are about 70% more fuel efficient per passenger-km than they were 40 years ago.[19] So there is much fuel efficiency to be gained from the use of more recent aircraft, and good reason for governments to mandate newer and more efficient aircraft. What's more, a further 20% fuel efficiency improvement is predicted by 2015, and a 40 to 50% improvement by 2050 relative to planes produced today.[20] So if governments begin to set efficiency standards, then they can update these as newer aircraft demonstrate even greater efficiency.

5. Costs and how funds can be obtained

The costs of all these measures are highly variable in most cases. With regard to the various costs of a rapid train service, one report put the cost of a 500 km line at €9,900 million, line maintenance at €30 million, a train at €30 million, annual operating costs at €25 million and rolling stock maintenance at €1.5 million.[21] However, these are based on developed world costs, and costs for line construction, train operations and maintenance of both tracks and rolling stock would be substantially less in developing countries. However, if the establishment of train services leads to airports or runways not being built then this is a cost saved. With regard to the costs of ICT, as noted in the *Reduced need to travel* section, the hardware, software and services are private costs, with sufficient variation to allow even low-income earners to participate to some degree, and infrastructure costs also vary greatly such that different levels of technology can be implemented to suit government budgets. The costs of transit services in comparison to the cost of private vehicle travel are covered in the *Mass transit* section. The designs, technologies and practices at airports that can save greenhouse gas emissions are so diverse that it is hard to generalise about costs, and the costs of regulating aircraft permitted to fly on domestic routes would be minor.

At least a proportion of these costs can be met from faster train and local transit fares, from airport fees, from cross-subsidisation of transit costs using funds generated by pricing of airline and private vehicle travel, and from charges for the use of ICT infrastructure. Multilateral funding may also be available, particularly if a sound case can be made for the emissions-saving potential of these measures, and this is discussed in Chapter 4.

6. Conclusion

Air travel has grown dramatically in recent times, much faster than increases in aircraft efficiency, and as a result, greenhouse gas emissions from air travel have also seen substantial increases. In order to reduce these, a number of measures are suggested in this section: building higher-speed rail services that can compete with domestic air services, avoiding the building of new airports and runways, and encouraging travellers to switch from air to rail trips; encouraging the use of ICT in place of air travel; providing low-carbon transport to and from airports; making airports and their operations more low carbon; and regulating the types and ages of aircraft permitted to fly on domestic routes. Through these measures

developing countries can achieve significant reductions in greenhouse gas emissions while still providing rapid transport for their citizens over longer distances.

Endnotes

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O) Water Transport

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1. Introduction

Water transport includes all kinds of vessels from canoes to container ships. It thus covers those carrying passengers and goods, in urban and rural areas, and whether motorised or non-motorised. This section focuses on inland water transport – on rivers, canals and lakes – while including some consideration of coastal and inter-island vessels, but it does not deal with ocean-going or inter-country transport. It considers not only the vessels themselves but also the waterways, the docking facilities, and the planning, financial and regulatory regimes within which water transport operates. It is as broad in its coverage of water transport – its vessels, technologies, purposes and sites – as are all the sections combined that deal with equivalent aspects of land transport. Consequently, it can only briefly cover the many issues to be considered, and so you may wish to consult the further information sources listed at the end of the section to find out more.

Water transport is an important (and sometimes the only) form of transport for people and goods in many parts of the developing world, and some examples illustrate this. Bangladesh's 1.5 million 'country boats'

Figure 3.59 A floating market in Bangkok

Picture Credit: Dennis Jarvis.

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provide the only reasonable transport for an eighth of the nation's rural population, and are a significant form of transport for a much larger proportion.[1] In the Mekong Delta 90% of rice exports depend on river vessels.[2] Water transport provides a lifeline for Amazonian communities in eastern Peru, for folk living around the lagoons behind Nicaragua's Atlantic coast, for the floating Kampong Lourng commune of Cambodia, and for fishing villages on islands in Uganda's section of Lake Victoria. It is also vital for island-to-island and inland transport in Indonesia, and for the farmers and fisherfolk of southern Côte d'Ivoire. Rivers are the sites of floating markets on the Mekong, and a critical link in passenger and freight (even container) transport networks in China. In Vietnam annual river boat passenger numbers grew by 10.7% between 1995 and 2000, reaching 175 million, and in the Moc Hoa region of the country there are estimated to be a million boats.[3]

Bangladesh has 24,000 km of rivers, of which 6,000 km are navigable in the wet season.[4] Amazonian Peru has 9,000 km of navigable rivers,[5] while estimates of navigable waterways in the Mekong Delta range from 6,000 to 27, 000 km.[6]

Yet in spite of the critical importance of water transport to many communities in the developing world, and to national economies, it tends to be a highly neglected part of transport systems.[7] It is often seen as outmoded, and is therefore poorly documented and researched, and lacks the official attention and resources it deserves. This can become a vicious circle, as a lack of awareness of its importance, its problems and its potential lead to deteriorating water transport facilities, which in turn leads to fewer users and then to even less government attention and support.

However, this situation is likely to change as the advantages of water transport come to be recognised. And these advantages are clear:

- The waterways necessary for water transport are generally already in place, and improvements to them can usually be made at much less cost than can improvements to road and rail infrastructure.
- The development of waterways is not likely to damage sensitive coastal, riverine, wetland and forest areas in the ways that land-based transport infrastructure can.
- Many forms of water transport uses less fuel and emits fewer pollutants and greenhouse gases, given equivalent loads and technologies, than land-based vehicles do (although other forms do not have such a good record and need to be improved, as shown in Chapter 2).
- There is great potential for water-based freight transport, particularly containerised freight, as part of an efficient, sustainable, multimodal freight system.
- As carbon comes to be priced globally, and as public and private funds are increasingly channelled into more sustainable forms of transport, a greater proportion of such funds are likely to be directed to improvements to water transport.
- Finally, given that communities highly dependent on water transport tend disproportionately to be poorer communities, their governments – if they are committed to lifting the living standards of all their citizens – have little choice but to improve these transport facilities.

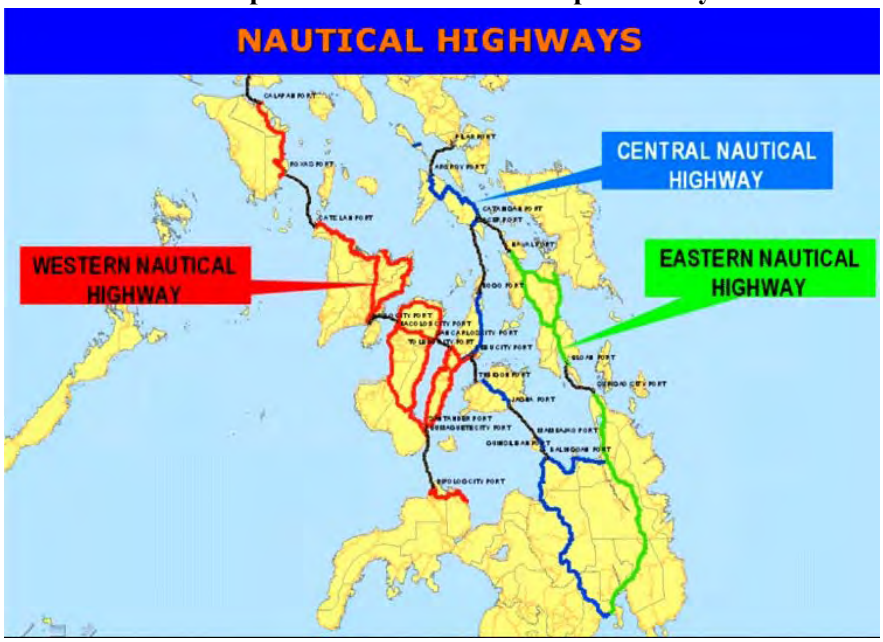
2. Development Contribution

Economic

It is much less expensive to improve existing waterways than it is to build new roads and other land-based transport infrastructure, especially when one considers the cost of both land acquisition and construction.

In some localities road construction can be especially expensive, for example, in the Moc Hoa region of Vietnam because the soil bed is soft and road construction materials have to be transported a long distance.[8] However there are costs for improvements to water transport infrastructure, including for docking facilities for passenger and freight vessels and for transfers to other modes, channel maintenance and improvements, locks, regulation of water levels, provision of adequate bridge heights to allow boat clearance, and possible linking of waterways (e.g., see Figure 3.60). But when such improvements are made they can contribute substantially to economic development.

Figure 3.60 The Philippines' Strong Republic Nautical Highway (SRNH) is a network of multimodal transport routes that connect up the many-island nation



Source: Government of the Philippines[9].

Investment in keeping waterways in good condition does not just advance transport objectives. It also furthers many other objectives that all have an economic impact. These include water provision for agricultural, industrial, domestic and civic purposes; power generation; flood control; fishing; recreation; beautification; and tourism. Many specific measures to maintain and improve waterways will advance multiple objectives at the same time, for example, measures to prevent bank or shore erosion, to remove obstructions, to prevent water pollution, to regulate maximum and minimum water levels, to ensure adequate land access to waterways, and to put in place management regimes that simultaneously allow for different uses of waterways.

In cases where water transport uses less fuel than equivalent land transport – such as in modern freight – this means cost savings. Sometimes water-based passenger or freight transport charges are higher than land-based charges, but this is largely because road transport providers do not have to meet the significant costs of road construction and maintenance and are thus publicly subsidised.

Water transport is vital to the economic wellbeing and development of communities for which alternative transport modes are few or non-existent, and a disproportionate number of such communities are poorer than average.[10] In countries with high rainfall, roads may be impassable in the wet season.[11] Water transport enables farmers, fisherfolk and artisans to obtain supplies and get products to market, and is

vital for many construction, mining and forest industries, as well as for traders, commuters and consumers in communities located on waterways.[12] Water transport is also a key source of employment in itself, for example, employing 60% of Bangladeshis working in the transport sector.[13] And the income of communities living close to water can be supplemented by water-based tourism.

And though water transport has a reputation for being slow, this is not necessarily the case. For example, the average speed of a rail freight wagon in Asia is often slower than that of a freight barge,[14] vehicles on unsealed roads are often no faster than boats,[15] and the longtail boats of Thailand, Cambodia and Peru can carry passengers and goods at great speed.[16] Many rivers run through or close to cities which means that they are close to markets and production sites. And water transport often benefits from lower insurance premiums because there is less theft and breakage.[17]

In contrast to cars and other land-based vehicles, boats of many kinds and sizes can easily be manufactured domestically, often by local artisans, even if the motors that power them need to be imported.

Social

The same water transport that enables often poor communities to advance themselves economically also enables them to access education, health care and other services. In Vietnam water ambulances bring health services to remote villages, and other vessels take children to and from school. In the Amazon forests of Brazil floating courts bring justice services to isolated communities.[18] Water transport is responsible for fewer accidents. Rivers and other waterways are also important to communities for spiritual, aesthetic and other cultural reasons, and so protection and maintenance of those waterways and the provision of good transport services on them is in keeping with their cultural significance.

Environmental

The low fuel use of much water transport means less emission of greenhouse gases and pollutants. In Bangladesh the use of water-based instead of land-based transport is estimated to save 58.5 million litres of diesel and reduce carbon dioxide emissions by 155,000 tonnes per year.[19] Less infrastructural development means less resource and energy use in construction, and fragile environments are not threatened as they can be with road construction. More transport on waterways means less traffic and noise on roads. For example, the Thai Government has expanded commuter services on waterways around Bangkok to relieve the extreme road traffic congestion.[20]

3. Greenhouse gas emissions reduction potential

As indicated, the size and characteristics of water transport vary enormously, and thus general statements about current greenhouse gas emissions or the potential for reducing these cannot be made. The two main types of vessels to be considered here are passenger ferries and cargo ships, and they present contrasting pictures. As figures in Chapter 3 indicate, ferries actually have quite high emissions per passenger. For example, in low-income Asia, ferry energy use – which correlates with greenhouse gas emissions – per passenger (2.34 MJ/pass-km) is higher than for private car passengers (1.78 MJ/pass-km), and energy use per passenger for ferries in this region are actually the least in all regions cited, with Western European ferries using the most energy per passenger (5.66 MJ/pass-km). However, ferries often use very old technologies and do not carry sufficient passengers to make them a viable option. Therefore there is potential for significant reductions in energy use in boats, as is discussed later. On the other hand, efficient water freight has much lower energy use and greenhouse gas emissions than land-based freight. For

example, Australian coastal shipping is responsible for 22% of the country's freight movement by volume but emits only 4% of all freight transport's greenhouse gases[21] (although it should be acknowledged that boat sizes are likely to be smaller on average on inland waterways and therefore the efficiencies may not be as great). Smaller boats are either non-motorised or have only small motors so their greenhouse gas emissions are not great.

4. Steps to be taken to improve water transport

As has been described, there are many economic, social and environmental benefits to be derived from water transport. However, for it to maintain and increase its share of transport journeys, and for those journeys to be faster, more efficient, more pleasant for passengers, and more sustainable, a range of things need to happen.

Improvements to waterways

Waterways can be obstructed by the hand of nature or humans. An example of the latter is the Sukkur barrage on the Indus River in Pakistan which has no lock and this prevents vessels travelling from the sea to Kalabagh. (This is equivalent to a 2000 km highway being rendered unusable for long-distance traffic by one obstruction.)The Farraka barrage in India constituted the same problem but a lock has now been built, as has one between China's Southern Grand Canal and the Qiantang River.[22] The following kinds of improvements may be required to make waterways navigable:

- dredging and channel widening, and marking (or improved marking) of channels
- maintaining banks or shores

Figure 3.61 Bridge heights must account for rising water levels and different size boats

Picture Credit: David Long

- ensuring bridges built over waterways are high enough to let boats pass under, even when waterways are at their highest level, and allowing for growth in vessel sizes
- flood control, and ensuring that water levels are high enough for navigation in dry seasons
- ensuring that passage along waterways is not blocked by irrigation and water management structures, and locks are provided where necessary
- linking of waterways where necessary.

UNESCAP has produced a useful manual with details of the dimensions of waterways, locks and bridge clearances that are required for vessels of particular dimensions, as well as much other relevant practical information.[23]

Development of freight facilities

In countries with navigable inland or coastal waterways close to population and production centres, it makes economic and environmental sense to incorporate water freight transport into multimodal freight transport systems, along with rail and road freight. Boats will rarely be able to carry freight from source to destination, so one or more other modes are required. The efficiency, speed and cost of such multimodal transport , and the degree to which it can compete with less sustainable road-only freight transport, will depend on the dock facilities for transferring freight from one mode to another, and these facilities include the quay apron, the gantries or cranes, and the space and facilities for road or rail transport. Some ports, such as the Pearl River Delta, can operate without cranes because the barges themselves can transfer the cargo.[24]

It is desirable to have docks located away from the densest urban areas so that road and rail freight do not add to urban congestion. Water terminals can be part of major freight centres that are discussed in the freight section of this guidebook. With modern phones, GPS and other information and communication technology, it is easy to track water freight movements, to communicate with vessels and terminals, and to have direct contact between boat operators and customers. The use of e-commerce technology also increases the visibility of water transport in the marketplace.[25] Technologies like radar and GPS can make night navigation more possible and allow water transport to be faster over the duration of a trip and thus more competitive with land transport.[26] Multimodal transport facilities also need logistics technology to ensure that, for example, vehicles and vessels are as fully loaded as possible (including on return journeys) and trucks take the shortest, least congested routes. Logistics is also covered in the Freight transport section of this book.

The efficiency of water freight also depends on the extent of containerisation. Many developing countries with extensive waterways have little or no containerisation, but in China, for example, it increased fourfold between 1998 and 2001.[27] India's rivers are said to also have great potential for the further development of containerised freight transport, and it is a distinct possibility for many other developing nations.[28] The rapid growth of containerised freight on the rivers of Western Europe in recent years strongly suggests that this mode has a bright future,[29] and there is thus potential for containerisation to grow in any country that has extensive waterways near population and production centres.

In some locations, such as the Amazon region of Peru, more basic improvements to freight loading and unloading facilities are needed – not containers and gantries, but small cranes and better docks and freight storage facilities to replace the makeshift facilities that currently exist.[30]

Passenger boats

Because there has been little official attention given to water transport, standards can be very low, and this certainly applies to passenger boats. Common problems are overcrowding, a lack of safety and environmental standards, poor conditions at docks and for boarding and alighting, and poor or non-existent toilet facilities on boats and docks. Women and elderly people may be reluctant to travel for these reasons.[31] Ferry engines are often inefficient or poorly maintained, and thus may emit high levels of greenhouse gas. There is a need for regulation and support to improve all these areas. It may be necessary to subsidise water transport services and improvements to them, as many customers may not be able to afford the fares of an unsubsidised service, and it must be remembered that private and public land-based transport is generally subsidised in some way. Governments may also need to investigate whether the supply of passenger boats in water-based communities meets the demand and – if it does not – they may need to provide these services themselves or contract or assist private operators to do so.

Figure 3.62 Boats of all shapes, sizes and purposes are part of the fabric of life in Dhaka, Bangladesh

Picture Credit : Karl Fjellstrom (left) Ahron de Leew (right).

Development of technologies and local manufacturing

Boat engine technology can benefit from the same sorts of advances in efficiency and in the use of more sustainable fuels to power it as can technology used in land-based vehicles (as described in the Other engine technologies and fuels section). For ocean going vessels, it has been estimated that a combination of existing knowledge and emerging innovations can yield up to 80% reductions in energy use, through options like fuel cells, anti-fouling coatings, improved hull design, air floatation, propeller design, harnessing wind for propulsion, and the use of renewable energy in ports.[32] Some of this will be applicable to larger coastal and inland vessels. Solar-powered boats are being developed and applied in diverse situations.[33] An example of this on a small scale is the introduction by a Bangladeshi organisation, Shidhulai Swanirvar Sangstha, of a series of locally-made boats powered by photo-voltaic panels that visit poor, remote communities. The boats function as classrooms and libraries, and bring to these communities health and agricultural training, low-interest loans, and access to mobile phones, the internet, and basic solar-powered home technologies (Figure 3.63).[34]

Local manufacturing is more feasible for boats than it is for most land-based vehicles, even if imported engines have to be added, and it can be encouraged by government and community agencies through training and low-interest loan schemes.[35]

Figure 3.63 Boats supplied by Bangladesh's Shidhulai Swanirvar Sangstha function as children's classrooms, but also provide learning and facilities for adults

Picture Credit: Ashden Awards

Documentation and research

As has been noted, water-based transport has tended to be under-valued, under-recognised and unsupported by government. A major task, therefore, is to reverse this trend, starting with greater attention to documentation and research in each country in which water transport is, or might be, a significant mode. This needs to include attention to:

- the extent and types of water-based transport
- its social, economic and environmental advantages
- the problems it faces, including safety and environmental problems, and how these have been addressed in different countries and localities
- the degree to which supply matches demand
- to the extent that it doesn't match, how this can be assisted to occur, drawing on experience from around the world.

Planning, coordination and regulation

For water transport to work well, three sorts of integrated planning are necessary:

- **Integration across connected waterways,** which may include lakes, coastal waters, canals and different river catchments, bearing in mind that most of these are natural water systems that may cross (or form) the boundaries of regions, states and nations. Such integration should aim for the harmonisation of navigation aids, laws, regulations and capacity to carry vessels of certain dimensions. This may lead to linking waterways, adding locks and re-building bridges to achieve greater clearance.
- **Integration across transport modes,** so that passengers and freight can switch quickly and efficiently from one transport mode to another for different legs of a journey.
- **Integration of different water uses** in a way that allows all of them to function effectively and sustainably, and in the context of this section, does not see water transport as less important than other water uses, or as less important than land transport routes that span waterways via bridges. It

is also necessary to clarify who is responsible for building locks when dams and irrigation barrages are constructed.

WaterWiki.net suggests the creation of a Masterplan for an Inland Transport System, and Zoran Radmilovic has outlined ten key areas for such a plan, while the Philippines has developed a 'Nautical Highway System' (Figure 3.60).[36] All this requires coordination between different levels of government, different governments at the same level, and different government departments, as well as between government, business and community organisations.

Between 2000 and 2002 the UN Economic and Social Commission for Asia and the Pacific (UNESCAP) and the Mekong River Commission undertook a study on the harmonisation of navigation aids on the Greater Mekong River and made recommendations that involved the governments of Indochina as well as China.[37] UNESCAP has also proposed a trans-Asia transport network, integrating rail, water and road transport modes. While integration between levels of government is vital, there is also a need for flexibility with regard to the most appropriate level of government to deal with water transport in particular regions. For example, in the Amazon region of Peru, which is geographically isolated from the capital and the more populated west of the country, more local governance of water transport is important because it can draw on local knowledge and is likely to respond to local concerns more readily and effectively.[38]

Because water transport tends to be officially ignored and is therefore under-regulated, boats can be very unsafe and conditions on them poor compared with land transport. Proper regulation of waterways, vessels, drivers and dock facilities – and especially of larger passenger and freight vessels – can enhance safety, quality control and environmental standards (including reduced greenhouse emissions), and protect the rights of consumers, boat owners, employees and other water users.

5. Costs and sources of finance

Vessels, whether passenger or freight, are normally owned by companies or individuals, in which case this is not a cost to the government. The cost of docking facilities can vary greatly because the facilities and technology involved are highly variable. Government may consider contracting out the building and operation of docking facilities to private businesses. Water transport is able to compete better with road transport, and thus operate more profitably, if road users pay a greater share of the costs of road building and maintenance and other road transport related costs. Some of the extra public funds thus generated can be used to improve water transport infrastructure such as docking facilities. Overall, though, water transport routes are much cheaper to maintain and improve because the waterways are mostly pre-existing natural features that require little upkeep. For example, in Vietnam the cost of dredging a waterway is about one-seventh the cost of rehabilitating a road.[39] The operating costs of water transport may need to be publicly subsidised on an ongoing basis as it is in China, Europe and the United States – but this is little different to the situation with road and rail transport. Water transport has been strongly supported by the World Bank – for example, in Bangladesh, China, Thailand and Vietnam[40] – and other multilateral funding sources discussed in Chapter 4 can also help to finance it.

When it comes to costs associated with smaller vessels, many individuals are able to afford these. In Vietnam, for example, a family boat with a new engine will cost about the same as a new motorcycle, while a second-hand motorised boat will cost about half that.[41] Others may need assistance through low or no interest loan schemes for small and micro businesses. It is reasonable for water transport users to contribute some of the funds necessary for improvements to waterways. As well, other non-transport users of waterways can also contribute to the costs of maintaining them, for example, hydropower companies

Figure 3.64 Hong Kong ferries provide low cost public transport. With efficiency improvements ferries can also become a more low-carbon form of transport

Picture Credit: www.workinginhongkong.com.

or consumers or, as in Vietnam, farmers, through the irrigation fees they pay, and these farmers also help to clear and dredge small waterways.[42]

6. Conclusion

Water transport cannot be ignored. Whether carrying passengers or goods, it is an important component in the mix of transport modes in many countries, and an essential form of transport for communities – often low-income communities – that live around waterways and have little access to other modes. Though the efficiency of water transport varies greatly, on average it has the potential to emit less greenhouse gas per passenger or unit of freight than do private passenger and freight vehicles. Water-based freight can be an efficient, low carbon component of a multimodal freight system, as is being demonstrated from Europe to China. Moreover, the waterways on which water transport operates are already in place and require little improvement or maintenance, and therefore their cost, greenhouse gas emissions and local environmental impacts are small in comparison to land-based transport routes.

The smallest boat with the simplest technology can be efficient and appropriate in its context, but for motorised water transport there is frequently a need for more efficient engines, better boat designs, and the adoption of lower carbon fuels and even electrics. This will happen much more broadly and effectively if governments take more notice of water transport and provide more support. Government have important roles to play: in any necessary improvement and maintenance of waterways, in setting standards and regulations, in facilitating coordination with other transport modes, and in providing financial support and

information. Funds can be obtained from multilateral sources, including new funds flowing from carbon pricing arrangements. If water transport does not get the recognition and support it needs, passengers and freight are likely to increasingly shift to less satisfactory and often less sustainable land-based modes, or simply put up with less than adequate services. There is great potential for water transport to be a more efficient, more low-carbon transport mode, and governments have a key role in enabling this to happen.

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4. Implementation of Technologies and Practices

The sections in Chapter 3 describe the technologies and practices that can meet people's transport needs while at the same time reducing or eliminating transport's greenhouse gas emissions. These sections also consider how you, leaders in government, business and communities within your countries, can encourage and assist in the implementation of these technologies and practices. In this chapter the question of implementation is considered in more detail.

Your country, city or locality has similarities with others, but it is also likely to have significant differences. Every locality has its own physical, historical, cultural, economic and social particularities, and these mean that its transport solutions will be to some degree different from those of the next locality. Some things will be easier and some things harder but the core basic principles will be the same: shifts to mass transit, walking and cycling; reductions in private vehicle use and domestic air transport; better maintenance and the use of more low carbon technologies for private vehicles; and reducing the overall need for transport. The model is similar for both passenger and freight transport. But your country or locality's particular circumstances mean that you must consider its particular transport possibilities and needs. For example, water transport may be important, auto-rickshaws may be an established urban mode, electric bicycles may be becoming popular, or a rural area may require road upgrades so that buses can be introduced.

Research and consultation

You and your colleagues may know a great deal about your locality's transport needs, but a lot more information can be obtained through research and consultation processes, which can be carried out by universities, private consultants, non-government organisations or the government itself. Such investigations will need to:

- **Observe what is happening now:** through analysing transport records, making direct observations and measurements, conducting surveys, and consulting existing research about your transport systems, you can find out:
  - How many people travel along what routes by what transport modes.
  - What travellers think of the current transport system: Does it allow people to go where they want to go? In what ways are they satisfied or unsatisfied with the existing facilities and services? What would they like to see introduced?
  - How financially sound the whole system and the different modes are.
  - What greenhouse gas emissions and other pollutants are emitted.
- **Learn what other areas are doing:** What kinds of transport are currently available in comparable countries and localities? For example, do they have well-used BRT or regional higher speed train services? Have they improved their pedestrian facilities? Do they have new technology auto-rickshaws? Have they introduced stronger parking policies?

- **Consider the possibilities:** What forms of transport are possible and practical in the city or locality in question: For example, are there car lanes that could become dedicated lanes for BRT? What are the possibilities for building new rail lines? For improving or extending walking and cycle ways? For pedestrianising inner city streets? Are other modes possible, such as water transport, light-rail or electric auto-rickshaws?
- Consider the budget implications: What will these measures cost? Are there more and less expensive options? Will they be privately or publicly funded? What proportion of costs can be recouped through fares and charges? Are there bilateral or multilateral sources of funding? How have other countries and localities funded them?
- Consult with experts and stakeholders: There will be organisations with a particular interest in transport, or in the development of particular neighbourhoods and localities. There will be experts in universities and research institutes, as well as a wealth of accumulated information, much of it available on the internet.

This kind of investigation can be broad or narrow in its brief. It can look, for example, at the transport needs of a city generally or at the desirability and feasibility of a BRT service. It can be a good idea to produce a preliminary report and put that out for public comment, and then, taking these comments into account, producing a final report. But even if such an investigation is considering a specific transport option, it needs to do this in the context of the broader transport picture. Transport is the most important aspect of a built environment so it must be always planned in this context: what will it do to make that environment work better?

The need for an integrated approach

It is crucially important that the transport needs of a locality are considered as a whole. Transport as an area of government policy can be notoriously fragmented, yet its impacts are profound as the locality is built around transport infrastructure. What are needed are approaches that consider transport needs as an integrated whole – in other words, approaches:

- that provide well-connected modes and routes for shorter and longer distance transport that people can switch between seamlessly
- that ensure some transport modes do not adversely affect others
- that make sure transport modes that have not in the past been a central concern of particular government departments, like walking and cycling, have strong government advocates to represent them (as discussed in the section, The walkable locality) because increasingly the knowledge economy is associated with dense walkable localities
- that recognise the causal relationships between transport and urban form, for example, that low carbon transport modes work best in denser, more mixed use localities and linkages between them,
- that recognise those aspects of transport that can harm or benefit the quality of life and interactions in localities
- that bring to the discussion and decision-making table not only government departments and non-government voices dealing with transport and urban planning issues, but also those able to represent broader social and environmental perspectives and interests
- that ensure relevant government departments, government authorities, levels of government and private contractors are working together in a coordinated way
- that make sure any particular departments – such as the roads department – do not wield inordinate power or become captive of private interests such as the car or petrol lobbies.

Piloting innovations

It can be a good idea to try out particular innovations on a small-scale, whether it is a BRT route, a pedestrianised street, a form of traffic calming, or a policy of keeping freight trucks out of congested areas that are important for pedestrian interactions. Trialling the innovation in a small area and carefully studying the results is a way of ensuring that policy implemented on a larger scale is well-considered and well-tested, based on lessons learnt from one or more trial applications. It can ensure that the community is brought along with any change thus making it politically successful. Also, external funding may be easier to obtain if the innovation is undertaken in this staged way, with a small amount of funding for the trial, and full funding once the viability and details of the innovation have been established.

Ownership and management

A critical question, when it comes to major investments in new or upgraded mass transit services, is that of the ownership and management of the service. Governments are increasingly contracting out once wholly government services, or parts of them, to private operators. They are also exerting greater control over previously privately run services in the interests of higher standards and better coordination, frequently offering some level of public subsidy in return, and there is ample scope for this to expand. For example, many bus services in developing countries are wholly privately owned, uncoordinated, only very minimally regulated, and barely profitable. As a result, they frequently offer a poor service, with old, inefficient, polluting and often unsafe vehicles, service duplication in some areas and a complete absence of services in others. However, governments can enter into competitive contractual arrangements with bus companies, bringing about better whole-of-transport-system coordination and higher standards. This was the key to the very successful Trans Millenio bus service in Bogota where private bus operators were given a stake in the new BRT and hence reorganised their local bus services to feed into the new rapid service.[1]

There are many models of public private partnerships that can enable governments and contractors to work together well, drawing on the particular strengths that both have to offer. For example, private operators can design and build a facility, such as a train service, for an agreed fee. Private firms can also operate and maintain a service, either retaining the revenues generated and paying government an agreed fee, or splitting the revenues with government. Another option is for private operators to build and operate a service for an agreed period of time before it is transferred into public ownership. These and many other models are described in more detail in an online publication, Financing Sustainable Urban Transport,[2] which is well worth consulting. Private contractors can be engaged to operate any part of a transport service or maintain any infrastructure. For example, one contractor might operate a train service while another is responsible for cleaning. Such contractors should be chosen through a competitive tendering process, with the government maintaining overall control of the whole service. There can be major advantages to public private partnerships:

- Competition between potential operators for contracts can improve efficiency and the meeting of customer needs. Private operators who do not perform up to agreed standards can be subject to penalty clauses, or lose the contract to a competitor when it comes up for renewal, and they will normally be required to pay any cost overruns out of their own funds.
- Private sector involvement can bring to the service additional capacity and expertise, as well as a culture of innovation and risk taking.
- Private contractors can bring in private finance when government finance may be in short supply.
- Many global sources of finance are now conditional upon on public private partnerships.

However, there are also some very good wholly government owned and run transport systems, and not all services contracted out to the private sector work well. Other considerations with regard to public private partnerships include the following:

- Governments can normally borrow money at a lower rate of interest than the private sector can, although if a loan from a multilateral lending facility for a transport project has government backing there may not be any difference, or it may even be at a concessional rate.
- There are additional transaction costs when government is dealing with private contractors.

Whatever form of contract is chosen government needs to ensure that it manages the whole process properly – both the awarding of contracts and day-to-day oversight of the system. But most importantly, if committing to a mass transit project, the contract must meet the government's overall objectives for a transit service:

- to deliver a particular level of service within a particular budget,
- to keep carbon emissions below a certain level,
- to involve land use around the transport system as a means of revenue for the project,
- to link in with other associated modes,
- to design in walkable station precincts
- to seek to build in a component of local manufacturing for job creation.

These factors should be clearly incorporated as mandated minimum standards in the contracts, and as selection criteria in the competitive tendering process.

When factors such as these are considered and included in any contract, it will usually result in much better public private partnerships, and can ensure a good outcome for any low carbon transport projects.

Legislation and governance

Transport goes beyond just the provision of infrastructure and services. Like any other aspect of life, it exists in an environment of laws and regulations and their enforcement by police, other government officials and the court system. If the services and infrastructure are not accompanied by appropriate rule-making and the enforcement of these rules, then outcomes will be flawed. For example, if a city attempts to increase space for walkways and reduce space for road lanes and parking, and cars continue to drive or park in what have become unauthorised areas, then the intended effect of the change is nullified. Similarly, if pedestrian crossings are created to improve the walkability of a locality, and motor vehicles do not give way to pedestrians, then the crossings may as well not be there. In such cases penalties and enforcement need to be increased to bring about a change in entrenched road culture. They may be resisted by vehicle owners, but experience in the developed world has shown that persuasive public awareness campaigns can, over time, radically change public attitudes on issues like drink-driving, speeding and the wearing of seat-belts. Such changes to public attitudes and behaviour can be essential if a better, fairer and safer transport system is to be achieved.

Many measures suggested in Chapter 3 relate to the setting of minimum standards for engine efficiencies, emissions levels and fuel quality for private road passenger and freight vehicles, and similar standards for aircraft. These standards require legislation and inspection facilities. There will also need to be changes to laws or regulations governing matters as diverse as urban planning, parking policy, road and vehicle pricing, and waterway management.

In addition, legislation may be required to protect the rights of travellers, who can receive poor service or unfair treatment at the hands of transport officials, sometimes because of their ethnicity or social status, or because they have not paid a bribe. One way of increasing the chances that the interests of travellers will be safeguarded is to appoint an ombudsman for transport, or to include transport in the brief of an ombudsman with broader areas of responsibility. Travellers can appeal to such an official if they believe they have not received satisfactory treatment or service. The ombudsman's office then takes up the case on their behalf, and very often achieves an outcome in their favour. Furthermore, ombudsmen usually produce an annual report, which is delivered to the parliament, not the government, so it receives a public hearing and cannot be suppressed by government, and this process puts pressure on government to lift its performance.

The operation of transport systems may involve violation of other laws or even the articles of a nation's constitution. For example, Delhi's transport system was deemed by India's High Court to be violating residents' rights to breathe clean air, and as a result, the court mandated certain changes to the technology of buses, auto-rickshaw, motor cycles and other vehicles.[3] In a similar way the Indian Supreme Court ruled that Mahatma Ghandhi Road in Pune was too polluted and should be pedestrianised. The Pune Cantonment Board was then able to act to achieve pedestrianisation of the road from 4 to 10 pm every Saturday and Sunday. Despite initial resentment from the traders its popularity with the people has meant increased trading activity and hence happy traders.[4]

So a safe, fair, efficient and low carbon transport system is a system of rule-bound behaviours as much as it is a system of services and physical infrastructure. Governments, courts, police and other officials all have ongoing roles in ensuring that behaviours enable the system to be this way.

Public oversight

Community organisations also have an important role to play in overseeing the transport system, identifying areas in need of improvement and suggesting how they might be improved. Such organisations may, for example, represent public transport travellers, residents of a particular locality, people with disabilities, or cyclists. They may also represent car drivers, trucking companies or other business interests. Community oversight is healthy and helps to keep governments accountable, but that does not mean that governments must heed what such groups say (they cannot always do this in any case, because the views of groups can vary greatly). Governments will be guided by their own values and priorities, but if they are seeking to make their transport systems more environmentally sustainable, and more accessible to all sectors of society, then it can help to have certain community organisations as allies who can keep them informed and articulate particular perspectives. But good lines of communication with organisations representing opposite interests and views can also be important, because moderate compromises or concessions – which groups can broker on behalf of larger sections of society – may be the price that has to be paid to have major changes accepted. Community organisations can be represented on any transport consultation or management structures that governments choose to set up. Best of all is when deliberative democracy techniques are used to ensure a wide spectrum of the community and stakeholders are engaged from the start and can then own the project when it is fully ready for financing.[5]

The status of sustainable transport

When it comes to introducing low-carbon transport, there is a lot of attention to the physical and financial aspects of the task to the provision of the infrastructure and services, and to ensuring that these are financially viable and affordable for travellers. However, an important but under-recognised challenge is

that of raising the status of low-carbon transport. Mass transit, walking, cycling and other sustainable modes can be made as efficient, convenient and affordable as possible, but if people think these modes are beneath their status or don't match their self-identity, then they won't take them up. It is notable that, with increased economic growth in the developing world, more and more well-off people are driving cars instead of walking and taking public transit.

Private vehicles, especially cars, are associated with glamour, excitement, prestige, speed and easy living, while other modes can be associated with poverty, ordinariness, hardship, slowness, dirtiness, congestion and lack of safety. These images and associations can be challenged in several ways and have been in some of the wealthiest cities in the world. The best ways to challenge stereotypes about modes include:

- the provision of low-carbon transport alternatives that are high quality, clean, modern, attractive, stylish, fast, punctual, regular, safe and convenient, with these features characterising not only the trips themselves but also the means of gaining information about them and buying tickets
- providing information and promotion campaigns that point out the disadvantages of private vehicles, such as their costs, their worse safety record, and the problem of traffic congestion, and the advantages of alternatives, such as those just mentioned – campaigns that can highlight the high-income, high public transit cities in the developed and developing world that embody style and quality of life
- the staging of events connected with good transport that associate it with positive things like exercise, healthy living, fun and social connection.

The power of persuasion, education and support

These measures to raise the status of low-carbon transport involve using techniques of persuasion to change public attitudes. Many of the measures outlined in Chapter 3 aim to persuade or educate people in particular ways: driver education to bring about more efficient driving of trucks or greater awareness of how to maintain a car in good condition; behaviour change programs to encourage people to walk, cycle, and use mass transit; campaigns to alert businesses to the cost advantages of ICT in place of staff travel; and training for small businesses in the manufacture or repair of small-scale transport vehicles and vessels. Experience around the world has demonstrated that people can be persuaded, informed, skilled up and even inspired by well-designed awareness-raising and training programs. Strategic government financial support for enterprises and initiatives related to transport – for example, small grants or low-interest loans – can also leverage inputs of time, money and other assets from individuals, businesses, commercial lenders, non-government organisations, and bilateral and multilateral funding sources.

Funding transport improvements

This leads to the broader question of transport funding. The development of better transport can be very expensive, and almost all transport is publicly subsidised in some way in order to help facilitate the economy, reduce externalities and ensure cultural interaction. It especially needs to be subsidised for those on low incomes so they can participate in the economy and culture. Developing country governments may have limited funds to make improvements, but it is important to recognise that many developing cities and localities in this position have radically improved their transport systems in recent decades. They do this by tapping into a variety of funding sources, and by eliminating unnecessary costs. It is now necessary to continue this process but to add to it the need for low carbon options.

Looking first at funding sources, the following are some that can be considered:[6]

Public-private partnerships: As already described, these bring in private finance through the private contractors that are hired, as well as leading to cost savings in transport provision.

Mass transit fares: In different localities around the world these cover different proportions of operational costs, from over 100% in Hong Kong, Tokyo and some Latin American cities to 7% in Lahore, Pakistan. Most cities are closer to 50%. Interestingly, there appears to be little relationship between levels of subsidy and whether cities are in the developing or the developed world. Fare subsidies are discussed later.

Taxes and charges for private vehicle transport: These can be increased for the purpose of (a) covering more of the costs of private transport infrastructure and other social and environmental costs this transport imposes on society, (b) cross-subsidising low carbon transport modes such as transit services and walking and cycle routes, and (c) acting as a demand management measure that reduces private vehicle use. The main forms of tax or charge on private vehicle use are fuel taxes, vehicle taxes, road use taxes and parking fees, which are described below.

Fuel taxes: Globally, 80-90% of revenues that come from the transport sector come from fuel taxes. They are simple to apply and are automatically related to usage. They have the advantage of encouraging people to drive less and to use more fuel efficient, less greenhouse gas emitting cars, because less fuel tax is paid on such vehicles. Some countries go in the other direction and subsidise fuel, which, for all the reasons described here, is highly undesirable.

Vehicle taxes (or annual registration charges): This is the second largest contributor to revenue. These taxes can vary according to the type of vehicle (with lower taxes for more efficient vehicles) and the level of congestion in the road system (with higher taxes in cities that can absorb little extra traffic). Singapore, for example, decides on the number of Certificates of Entitlement it can offer each year, and then auctions them off.[7] Prices paid can be more than the cost of the car.

Road charges: These can take the form of tolls – for example, for freeways, bridges or tunnels – and they are normally designed to recoup the cost of building these structures. Then there are congestion taxes, intended to discourage vehicles from entering a congested city area. These charges can be lower for more low-carbon vehicles, and can vary according to the level of congestion at different times of the day or week.

Parking fees: These can be raised during peak hours and be higher in inner city areas. On-street parking should cost more than off-street parking, and as a rule of thumb an hour's parking should be more expensive than an average bus fare, if transit is to be encouraged.

Employer contributions: In some localities employers are required to pay a tax as a contribution to the cost of local transport use by their employees. Brazilian cities, on the other hand, require employers to buy transit tickets for employees or provide transport direct to them.

Funds from land development: Good transit services increase the value of property in an area because it becomes a more desirable place to live and work. This added value can be captured and channelled into funds to cover transit costs by (a) a tax on property near transit, (b) a mandatory contribution by developers to the costs of providing transport to meet demand generated by the development, and (c) arrangements whereby developers pay costs of both building and transport development. Examples of (c) are Transit

Oriented Developments (described in their own section of Chapter 4), and a Japanese private railway company's ownership of property adjacent to stations, which earned it much more than revenue from transit fares. Governments can also undertake such developments near transit stations and use returns to fund transit.

Advertising: Governments or private contractors can raise money from advertising in or on transit stations and transit vehicles, as well as in internet and phone based transport information services.

Foreign assistance: Developing country governments can obtain concessional loans or grants through the bilateral aid programs of developed country governments and through multilateral agencies like the World Bank,[8] the Asian Development Bank,[9] the Inter American Development Bank,[10] the African Development Bank[11] and other regional development institutions such as the Latin American Development Bank (CAF).[12] While the record of the World Bank in funding low carbon transport has been criticised, it argues that it responds to borrower country priorities, so it is up to developing countries to seek funds from these sources for more sustainable transport.

Special funds for low carbon transport: A range of funds have been set up to finance low carbon transport. There are multilateral ones like the Clean Development Facility,[13] the Global Environment Facility,[14] the Global Climate Change Challenge, the IDB Sustainable Energy and Climate Change Initiative, the ADB Climate Change Fund, the ADB Clean Energy Fund, the Hayotama Initiative and the International Climate Initiative. As well, there is the voluntary carbon market and some bilateral funds, such as the Japanese 'Cool Earth Partnership' and Germany's International Climate Initiative (ICI). An excellent guide on these funding sources, Accessing Climate Finance for Sustainable Transport: a practical overview (SUT Technical Document #5), has just been published and is highly recommended for those seeking funding or technical support.[15] For each of the funds the guide covers:

- an introduction to the fund
- key characteristics
- the level of support for transport projects (in the past, present and, if known, the future)
- criteria for accessing support
- the application procedure
- links and contact details to gain further information.

The guide indicates the types of support provided and the purposes to which this support can be put. Of 10 major sources of support, all 10 provide grants, 4 make loans and 7 give technical support. Six fund concepts and plans, 9 fund infrastructure, 5 operations and management, 9 technology transfer and 8 capacity building. Eight support road projects, 9 support rail, all 10 support urban public transport and 8 support non-motorised transport. The guide also addresses issues such as the need for interventions to be measurable, reportable and verifiable, and the role of consultants in obtaining climate finance..

Another source of information, *Environmental Finance For Pro-Poor Development:* Analysing the role of Carbon Finance, produced by WWF India and UNDP India, lists 18 different carbon financing facilities, provided by the World Bank, the Asian Development Bank and a range of other multilateral and bilateral institutions.[16]

The Clean Development Mechanism is one of the more important funding sources. The CDM was introduced under the Kyoto Protocol and enables developed country governments to invest in projects to reduce

emissions in developing countries as part of their emission reduction agreements (and thereby allows them to meet emissions targets at less cost). However, of the thousands of projects that have been through the process only a very small number concern transport, and only two transport projects are in operation, partly because of the difficulty calculating greenhouse gas emission reductions from such projects. At present the CDM is being reformed to make it simpler to apply for funding, for example, allowing countries to reduce the administrative load by applying for the funding of groups of projects together.

The Global Environment Facility is another important funding source. The GEF funds projects that contribute to the protection of the environment. With this fund a considerable proportion of co-funding is needed from national governments or donor agencies. It has so far funded 37 transport projects to the tune of US$201 million, and US$2.47 billion has come from co-financing. The GEF also provides technical and investment advice.

Commercial loans and consolidated revenue: Governments can of course fund transport developments through their own revenue generated by a range of taxes, or through normal commercial loans. If the services are well-run then there will be returns.

A mix of all of these: It is highly likely that transport developments will be funded from a mix of these sources of revenue and finance. Financing Sustainable Urban Transport has more information about them, and also refers readers to many sources of further information.

Several of the funding options mentioned involved raising taxes and charges. The public may resent additional charges for transport services or infrastructure unless it is clear they are getting something clearly of benefit to them. The following approaches may help:

- If charges are earmarked with services, for example, if the funds from an increased road tax are directed to the development of a bus service or a new train system, then this can increase public acceptance.
- If charges (for example for road use) are increased in line with the user-pays principle – so that the user is paying what the road costs, or at least more of it – then the justification for this can be clearly understood, and pricing distortions can also be avoided.
- If the payment is fair it will be better received, because perceptions of unfair treatment increase resistance.
- Gradual price increases over time will be better received that one dramatic increase.
- If measures are taken to compensate the poorest travellers then it will not only be fairer but will also be better accepted (at least by the poor). It may be preferable to raise normal fares higher and offer concessions for those on a pension or benefit. In Ghana, increased transport costs were offset for the poor by subsidised bus fares, school feeding programs and increased public housing.

The other side of adequately covering the costs of transport is being able to eliminate unnecessary costs. Perhaps the two most important ways of doing this have already been described: making mass transit as efficient as possible through a well designed and managed process of contracting out services; and ceasing to subsidise and encourage private vehicle transport. As efficient low carbon transit, walking and cycling increase their share of total transport, there will be a range of other savings for the public purse. In particular, there will be lower health costs and fewer work absences as a result of less pollution, fewer accidents, more exercise and reduced stress from noise and traffic congestion. Also, if there is a move towards denser urban areas with more mixed land use this will reduce the amount of transport required.

Finally, unnecessary spending can be curbed by careful management of transport finances. It is essential to distinguish between capital or development costs for transport on the one hand, and operational costs on the other, and to ensure that there are viable funding sources for each. Funding for transport developments or improvements can be raised on a project by project basis, but there need to be stable and predictable sources of funds for ongoing transport operations, and for the repayment of loans for development projects. Too often inefficient services simply continue to be subsidised, but there should be clear justifications for any subsidies, of which the following are some:

- if a service, after having been made as efficient as possible, still does not allow costs to be met by revenue, and that service offers wider social or environmental benefits
- if, in particular, a subsidy or cross-subsidy enables people to access transport who otherwise could not afford to do so
- if, through cross-subsidies, certain transport modes such as private vehicle transport, which have social and environmental costs, can be discouraged while more sustainable and socially beneficial modes are encouraged.

One way to assess whether a service is efficient enough and to see what level of subsidy is necessary is to examine how things operate in comparable countries of cities.

Capacity building

The successful planning, building and operation of new or improved transport infrastructure and services does not just depend on the availability of funds. It also requires the capacity to undertake all the tasks required: designing the systems; building the buildings, stations, tracks and routes; installing, operating and maintaining the technology, including mass transit vehicles and rolling stock, ticketing and information systems; as well as management and accounting. In the planning, design and construction stage bilateral and multilateral funding schemes usually provide technical assistance as well. This is common, for example, with bilateral aid programs, with World Bank and regional development bank projects and, as has just been noted, with the Global Environment Facility. Special arrangements to transfer capacity can also be made, such as the Swiss-Chinese arrangement mentioned in the Mass transit section of Chapter 4. As well, expertise can be provided by foreign consultants and firms hired for the purpose if local expertise is not available.

But foreign expertise only goes so far. There are lower level employees who must be trained, and later on, when transport systems are operational, as many as possible of the tasks from the top to the bottom should be undertaken by local people. This has big implications for secondary, technical and tertiary education systems, which need to be able to train local people in all the skills required, so education planners should be a part of the transport planning process from the early stages.

Periodic reviews of transport systems

No nation or city and no transport system is static: technology changes, populations grow and move, patterns of settlement and industry alter, economies grow, people become more affluent and educated… and sometimes some of these trends go into reverse. As these things change, transport needs to respond to them. The new change is the increasing impacts from climate change that are demanding global action, including the need to respond with low carbon transport solutions. Thus, transport has to be periodically reviewed, to ensure it adapts, grows and changes to meet the ongoing changes that characterise any dynamic society – especially one that can claim to be low carbon.

Endnotes

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5. Conclusion

Transport is primarily not an end in itself. Rather, it is a means to enable people to get to where they need and want to be in order to do things that are important and necessary for them: working, becoming educated, buying, selling, receiving health care, worshiping, visiting friends and family, or simply enjoying themselves. Transport must therefore be judged on its ability to do this in a way that people find acceptable, in a way that is affordable, safe, frequent, punctual, reasonably fast and direct, clean and comfortable, and that takes them where they want to go.

However, transport must also be judged on its impact on society as a whole. This can be positive or negative. It can make cities attractive and vital or dull and dysfunctional. It can increase or reduce greenhouse gases. It can increase or reduce local pollutants. It can deplete non-renewable resources or draw on renewable ones. Transport can cut communities in half or be a bridge between them. It can make life very unpleasant with its noise and congestion and dangers, or it can be a healthy part of life occurring in vibrant, safe, human-scale spaces.

As leaders within your nation, city or locality, you are not starting with a blank slate when it comes to developing a good transport system. You are starting with a mass of roads, paths, lanes, highways, waterways, rail tracks and bridges; with a myriad of cars, trucks, motorbikes, motor scooters, bicycles, carts, boats and pedestrians; with a broad range of transport habits, routines, likes, dislikes and levels of knowledge. This is the starting point; all change begins with this.

However, along with all the other people you can draw into the process – you can also start to imagine what might be. You can be like Mayor Jaime Lerner, who saw a radically different possibility for central Curitiba, and in the space of a weekend accomplished the first phase of the transformation. Or you can be like transport authorities in China, who are now starting to leapfrog twentieth century developed world transport solutions to get to efficient, sustainable twenty-first century solutions. You can have carless localities like Vauban in Germany, encourage the cycling rates of Amsterdam and Copenhagen, have transit systems inspired by Hong Kong and Singapore and Bogota. All of these places were quite different once, but they saw new possibilities.

This guidebook focuses on low carbon transport solutions, but the solutions advanced also provide many other benefits for travellers, residents and citizens. They mean faster, more frequent, safer and more pleasant transport to and from more places. They mean reduced transport costs to both the traveller and society, and reduced use of non-renewable resources. They mean a healthier, quieter, more attractive environment for all concerned. They mean a transport system for an efficient, twenty-first century economy. And they make this transport more accessible to all, so that all may participate more fully in economic and social life.

Of course it's not quite as simple as just envisaging these possibilities – though it rarely happens without some vision. Transport developments can require very large amounts of money, and they can require certain building densities and income levels to be viable. But there are many versions and variations of particular modes to suit different budgets. There are also many sources of funds and expertise, most notably, perhaps, in the private sector and in the multilateral funding facilities that are being created as part of international carbon pricing arrangements.

There are many things you will not want to change, or not want to change radically, because they are working well in some or many respects. Just as the Kampong Improvement Program in Surabaya retained the practical, multi-purpose, convivial, low-carbon character of kampong street life, and just made the changes that residents said they wanted, so the vision for other localities can be a blend of valued aspects of what is, and ideas about what can be.

And enabling people to be in a place where they can do what they want or need to do may not involve them moving at all, or not move as far as was previously thought necessary. There are many possibilities for reducing or eliminating the need for travel. Denser communities with mixed land use and a level of community self-sufficiency bring everything closer together. And if people are living in attractive neighbourhoods a pleasant walk that achieves several practical and social purposes may not seem like travel at all. Moreover, information and communication technologies enable people to communicate, cooperate, socialise and gain information and entertainment without moving from their home or workplace.

There is also a wealth of information to be mined. This guidebook provides a very small proportion of the ideas and information available, but in Appendix II it also suggests other information sources you can follow up, and these in turn offer other sources. As well, you can tap into your nation's research capacity in universities and institutes, into expertise within government departments, businesses, community groups, and private, government and multilateral aid agencies, and into the mass of information in print and online.

May your investigations, your plans and your actions bring about a transport system that is worthy of the people it is moving – and help show the world that low carbon options can really work.

Appendix I: Glossary

activity intensity: the population of residents and workers in a given area

auto-rickshaw: a motorised three-wheeled taxi, known by many other names around the world

behaviour change programs: programs that seek to change public behaviour on specific matters – in this case, discouraging private vehicle use and encouraging alternative transport modes and reduced travel, through information, persuasion and support

bilateral funding: funding of a project in one country through financial sources in one other country

bus rapid transit (BRT): bus services that usually feature dedicated road lanes, larger (often articulated) vehicles, off-vehicle ticket purchasing, real time information and other modern features

car-pooling: the practice of sharing regular car travel, for example, with co-workers

car-sharing: a commercial or cooperative membership scheme in which members book and pay for the use of a car for specified hours or days

congestion charge/tax: a levy on vehicles entering congested urban areas, to discourage this practice and to help fund alternative transport modes

DAT (development assisted transit): an arrangement whereby transit services are partly or wholly funded by property developers (private or government) when their developments are close to transit and hence are of greater value

demand management: reducing the demand for something that is deemed to have undesirable public costs, in this case, reducing the demand for private vehicle use by measures such as increasing its cost to the user, or restricting road or parking space for vehicles

developing and developed nations: non-industrialised and industrialised nations – see the note about this in the box in Chapter 1

drive train: the components in a motor vehicle that generate power and convert this into the vehicle's motion

Euro 1, 2 etc: European vehicle emissions standards – higher numbers represents later and more advanced standards

externalities: negative or positive effects on third parties from an activity or market exchange, for example, pollution generated by a vehicle

EV: electric vehicle

Gantry: also called a bridge crane or an overhead crane, the gantry's load is carried by a hoist that can move laterally on a rail or rails fitted under a horizontal beam

GJ (gigajoule): a unit of energy equal to 1 billion joules or 1000 megajoules

GPS (Global Positioning System): a global navigation satellite system providing reliable location and time information

Greenhouse gases (GHGs): Gases within the Earth's atmosphere, principally water vapour, carbon dioxide, methane, nitrous oxide and ozone, the increasing concentrations of which are raising the Earth's average temperature and causing a range of other adverse climate and weather effects

hybrid: in this case, vehicle engines generating power from two distinct technologies acting together, **particularly electric and internal combustion engines**

ICT (information and communications technology): computer, phone and video technology for communications and sharing information

integrated ticketing: the provision of tickets and smart cards that allow travel on multiple transit modes and routes

IPCC: Intergovernmental Panel on Climate Change, the principal international authority coordinating research and information dissemination on climate change.

Jevons effect: see rebound effect

light rail: a form of rail public transport that generally has a lower capacity and speed than trains and often travels along roads – sometimes the terms 'light rail' and 'tram' are used synonymously, and sometimes 'light rail' refers to vehicles of higher capacity and speed

logistics: in the freight context, the systematic organisation of the movement of vehicles and their cargo in a way that uses time and resources efficiently, often with the aid of computer technology

low carbon: technology, including transport, that emits minimal carbon dioxide into the atmosphere or, in the case of 'zero carbon', emits no carbon dioxide at all

Metro: Modern urban train systems that often run under- or above-ground

MJ (or megajoule): a unit of energy equal to 1 million joules

multilateral funding: funding of a project from an international source such as a UN agency, the World Bank, or a global funding facility set up to support sustainable development

multimodal transport: transport by two or more modes in the one trip, for example, a trip by bus, train and walking

park-and-ride: the provision of car-parking at suburban train and bus stations to discourage the driving of cars into inner city areas

peak oil: the point at which demand for oil exceeds the rate at which it can be extracted, after which its scarcity and price will progressively increase

public private partnerships (PPPs): arrangements between governments and private firms to build and/or operate new developments together, for example, private firms building or operating train services under government coordination

real time information: in this case, the provision of information, by electronic display screen or phone, on the time that transit services will actually arrive at stops or stations

rebound effect: in this case, the tendency for road improvements designed to achieve better flowing traffic to in fact have the opposite effect, encouraging more cars onto roads for longer trips and thus re-congesting the roads and increasing fuel use and greenhouse gas emissions (also known as the Jevons effect)

telematics: the integrated use of telecommunications and information technology, also known as ICT or information and communications technology – see ICT

traffic calming: measures to reduce motor vehicle speed and to make drivers more aware that they share travel space with users of other modes

transit: public transport (eg, trains, buses, light-rail)

transit leverage: the tendency for trips on public transit to reduce the overall amount of travel that a person does

Transit Oriented Development (TOD): urban development that both contributes to and benefits from the availability of transit services – see also DAT, and the introduction to the Transit Oriented Development section in Chapter 3

USEPA: The vehicle emissions standards of the US Environmental Protection Agency (USEPA)

value capture: a mechanism whereby the increased value of an urban development resulting from its proximity to transit services, parks, educational facilities etc. can be tapped in order to fund these facilities – see also DAT

zero carbon: see low carbon

Appendix II: Further Readings

General

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Chapter 3

The walkable locality

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Appendix III: Is My Area Walkable?

Some questions to help you assess the walkability of a locality and how it can be improved.

Anne Matan*

Use/Network

1. What is the volume of pedestrian traffic on this street? (pedestrian counts)
2. Who are the people using this street? Do they have special walking needs given their age or disability?
3. What is the pedestrian density of particular footpaths (numbers of pedestrians per metre width of footpath per minute)?
4. What are the main pedestrian routes in the area (day time and night time)?
5. What types of pedestrian facilities are in the area (dirt paths, paved footpaths/sidewalks, shared streets, pedestrian only streets, plazas, squares)?
6. What is the length and area of these pedestrian facilities?
7. What are the main arrival and exit points to the area? Are they connected via walkways?
8. How easy is it to walk through the area? (Do test walks to establish this.)
9. How adequate are footpaths/sidewalks in the area?(Some possible problems: no sidewalks, discontinuous, too narrow)
10. What proportion of streets have footpaths/sidewalks?
11. Are the footpaths/sidewalks complete on both sides of streets?
12. Is the footpath/sidewalk provision satisfactory in both major and smaller streets?
13. Are footpaths wide enough to cater for the number of people who walk on them?
14. What are the footpaths/sidewalks made from? (asphalt, concrete, paving bricks, flagstones, dirt, gravel, etc)
15. Are the sidewalks well maintained? (free from cracks, holes, rubbish, etc)
16. Are the block lengths short? (If they are long there may need to be walkways through the block.)
17. Does the pedestrian network connect major areas/destinations in the city?
18. Does the pedestrian network connect to primary destinations such as schools, hospitals, transit stations?
19. Is the pedestrian network itself well connected (with, for example, few pedestrian cul-de-sacs)?

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Barriers

1. Is the area accessible to those with disabilities? Are there ramps instead of steps where possible?
2. Are there obstacles on the footpaths (for example, street trade, shanty dwellings, piles of rubbish, parked cars, animals, road or building construction materials, or a large number of poles and signs)?
3. Are there buffers between the road and the footpath, such as fences, bollards, trees, hedges, parked cars and landscaping? (Buffers have advantages and disadvantages, but they can screen walkways from traffic and prevent parking on the walkways.)
4. Are there many small interruptions to the pedestrian networks (e.g., minor road crossings, parking lot crossings, driveway crossings)?
5. Are there other major barriers to walking in the area (major roads, train tracks, rivers, hills, gated land uses, etc)?
6. Does the slope of the area make it hard to walk?

Intersections

1. How convenient is it to cross the street? Where are the pedestrian crossings?
2. What type of traffic intersections are used?
3. Are pedestrians given priority at intersections?
4. What are the crossing aides used at traffic intersections (pavement markings, different road surface or paving, signs, traffic lights, median traffic islands, curb bulbouts, underpasses, overpasses, etc.)?
5. Is crossing made easier either by curb cuts or road raising?
6. How safe is it to cross the street (at designated pedestrian crossings)?
7. Do drivers obey road laws and traffic signals?
8. Are pedestrian crossings clearly marked?
9. Do traffic signals indicate how long you need to wait before crossing, and how much remaining time you have to complete the crossing?
10. Do you need to press a button for a pedestrian signal to permit you to cross?
11. Are there any mid-block crossings? Are these adequate?

Public Transport connection

1. Is the area connected to public transport? Where are the public transport nodes?
2. Are the public transport waiting areas of high quality (weather protection, information, signage, seating, waste receptacles. etc)?

Land use

1. What are the primary land uses of the area? (This will suggest the numbers of pedestrians at different times of the day.)

2. What are the primary destinations (industrial, commercial, governmental, recreational, community) in the area?
3. What is the population of residents and workers in the area?

Enjoyment

1. What are the main public areas (square, parks, plazas, etc)? Are they public (open to everyone) or private (limited access, controlled use)?
2. What is the quality of the public spaces (comfort, appearance, maintenance, possibilities for use)?
3. How many people are using these spaces? How are they using this space? (can be assessed through stationary activity counts or behavioural mapping)
4. Are there any spaces for children/elderly/youth within the city?
5. Does the area allow for physical activity, play, interaction and/or entertainment?
6. Are there any identifying features in the area (monuments, land marks, neighbourhood character)?
7. Is there any indication that one is entering a special district or area? (It's good to have the neighbourhood character indicated in some way along the walkway.)
8. Are the walking areas interesting?
9. Are there interesting views?
10. Are there temporary activities in the area (markets, festivals, buskers, street performers, etc)?
11. Does the area allow for resting, for meeting others, for social interaction?
12. Is there adequate greening in the area (plants, trees, etc)?
13. Is the area of a high visual quality (pavements, facades, art, etc)?

Streetscapes

1. Where buildings meet the street, is it clear what is private and what is public space?
2. Are the dimensions of the buildings lining the footpaths at human scale?
3. Are the facades of the buildings lining the street transparent/active (i.e., do the buildings having many doors and windows opening onto the street, 'soft edges', with many niches, detailed facades)?

Infrastructure

1. What is the amount of seating available?
2. Is the seating in the right place (with regard to views, comfort and protection from climatic conditions, located at the edge of spaces)? Does the seating maximise the natural advantages of the area?
3. Are the seating arrangements appropriate (can you talk to friends)?
4. What is the quality of the seating?
5. Are there places to stand? To lean against? Attractive edges?

6. Are waiting areas adequate, providing comfort and protection to pedestrians waiting for transit or to cross the street?
7. Are there enough rubbish bins?
8. Is there any public art?
9. Are there water fountains?
10. Are there wayfinding devices?
11. Are there public toilets?

Comfort

1. Is there adequate protection from the sun, rain and wind?
2. Is there adequate protection from negative aspects of vehicle traffic (pollution, noise etc)?
3. Are the ambient noise levels low and comfortable?
4. Do the sitelines allow you to see where you are going?
5. Is the area well maintained (footpaths, buildings lining the sidewalks, etc)?
6. Is the area clean (free from rubbish, broken glass, inappropriate graffiti)?

Safety

1. Is the area lively and active?
2. Is there street life?
3. Is there passive surveillance of the area? In other words, are there people around to watch out for each other? (This is especially important when it comes to night-time usage.)
4. Is the area safe? (both perceived and real)
5. Is the lighting from street lights and buildings adequate at night time?
6. Are there signs of other people at night time?
7. Are there night time uses of the area?
8. Is there a mix of land uses in the area?
9. Are there many small land uses?
10. Are the facades of buildings ‘closed’ at night?
11. Is there adequate visibility between modes of transport?
12. Is there protection from vehicle traffic?

Vehicle traffic

1. What is the traffic volume of the street? Does it make it hard/unpleasant for walking?
2. Is there street parking (on/off street)
3. What is the speed limit of the street? Does this make it hard/unpleasant for walking?

4. Are there any traffic calming or traffic control devices in the area?
5. How many lanes of traffic are there?
6. What are the traffic control devices used (traffic lights, stop signs, roundabouts, speed bumps, etc)?

Perception of the area

1. Is the area perceived as safe?
2. Is the area perceived as pleasant?

This guidebook covers a range of transport technologies and practices that can significantly reduce emissions of greenhouse gases and help achieve key development goals at the same time. All the options are dealt with in simple language, and approaches for implementing these technologies are also provided. This guidebook would be used by the national TNA teams which consist of stakeholders from government, non-government organisations and the private sector.

The publication is edited by Dr. Robert Salter, Dr. Subash Dhar and Professor Peter Newman with contributions from other experts in the transport sector. The contributing authors combine their expertise in the transport sector and climate change to provide a balanced description of technologies from a developmental and climate perspective.

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