# Sustainable Transport for APEC Megacities: Issues and Solutions

Vol. II Full Report





Asia-Pacific Economic Cooperation

APEC Industrial Science and Technology Working Group



The APEC Center for Technology Foresight

National Science and Technology Development Agency Bangkok, Thailand February 2000

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#### The APEC Center for Technology Foresight National Science and Technology Development Agency Bangkok, Thailand February 2000

This summary report was prepared for the APEC Center for Technology Foresight by *Mr. Ainsley Jolley*, Director, Emerging Technologies and Asian Growth Projects, Centre for Strategic Economic Studies, Victoria University of Technology and *Professor Greg Tegart*, formerly Director and now Executive Advisor, APEC Center for Technology Foresight Published for the APEC Secretariat by:The APEC Center for Technology ForesightNational Science and Technology Development Agency73/1 Rama VI Rd, Rajdhevee, Bangkok 10400, ThailandTel:(66-2) 644-8150-94 ext. 703, 706, 768Fax:(66-2) 644-8194E-mail:apectf@nstda.or.thWebsite:http://www.apectf.nstda.or.th

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The APEC Center for Technology Foresight was launched in Bangkok on 3 February 1998. The objectives of the Center are to:

- Promote the adoption of technology foresight across APEC member economies.
- Provide a means for comparison of technology foresight exercises and implementation in APEC member economies and across the world, with a view to stimulation of Best Practice in appropriate methodologies for Foresight in APEC economies.
- Conduct technology foresight exercise on an APEC-wide basis, and between relevant member economies.
- Improve the quality and effectiveness of technology-related planning and development and priority-setting for research, across APEC member economies.
- Develop a technology foresight research and application capability available to APEC member economies and International agencies.

#### The Center has adopted the following definition of Foresight:

"Foresight involves systematic attempts to look into the longer-term future of science, technology, the economy, the environment and society, with a view to identifying emerging generic technologies and the underpinning areas of strategic research likely to yield the greatest economic, social and environmental benefit."

The Center is currently tackling the issue of Sustainable Megacities in the APEC context. Urbanisation has been particularly pronounced in the Asian and Pacific region in the second half of the last century. By the year 2025, Asia will become predominantly urbanised with an urban population of 2.5 billion or 55% of the total population, and 20 of the world's megacities, with population exceeding 10 million, will be in Asia.

Megacities have both positive and negative values. They generate higherthan-average proportions of their economy's output of goods and services; are centers of innovation in science, the arts and lifestyles; contain many of the cultural assets of the economy and offer some of the better opportunities for people to lead full and satisfying lives. Yet they also offer potential shortages of water, environmental pollution, traffic congestion and a proliferation of slums, crime and social alienation.

The APEC Center covered issues of urban water supply and management in its first study "Water Supply and Management in the APEC Region," published at the end of 1998. The topic of "Sustainable Transport" was chosen for study in 1999 as another major component of the issue of Sustainable Megacities. The other one is "Healthy Futures for APEC Megacities." The aim was to involve as many APEC economies and their Experts as possible to produce an outcome relevant to all APEC economies. The approach was to have a Discussion Paper prepared in April 1999 by a Consultant and then together a group of Experts in Melbourne, Australia on 27-29 July 1999 to analyse the issues and develop scenarios. Based on these inputs and literature research, the Consultant produced two draft reports for comment in late 1999. After further interaction with experts and stakeholders, including discussions in Bangkok with Thai transport authorities, and the APEC Technology Foresight Center team, the Consultant produced the final volumes. The essential steps in the process and the outcomes are set out in Volume 1, which is essentially for policymakers and their advisers. The full report of the study is reported here, as Volume 2.

The Experts' Meeting drew together 16 experts from 7 economies and we are particularly grateful to them for giving their time and experience, and to their economies which supported them. The Consultant, Mr. Ainsley Jolley from the Centre for Strategic Economic Studies (CSES) of the Victoria University of Technology, Melbourne, Australia carried the bulk of the effort in producing material for the study and we thank him for his outstanding contribution. The staff of CSES supported him admirably and we wish to thank Professor Peter Sheehan for his encouragement and Ms Margarita Kumnick and Ms Gordana Volkanovska for their work in organising the Experts' Meeting and producing a Meeting summary for the participants. We are very grateful to Professor Ron Johnston for carrying the demanding role of facilitator at the Meeting.

The Australian Government, through the Department of Industry, Science and Resources made a generous financial contribution to assist attendance of APEC Experts and the cost of the Workshop. The study has been supported by funding from the APEC Central Fund and from the APEC Center budget which is provided by the Royal Thai Government. We are grateful to our colleagues from the APEC Center for their dedicated support.

> Greg Tegart Formerly Director, now Executive Advisor

Chatri Sripaipan Co-Director

# Introduction

The APEC Center for Technology Foresight, was established in February 1998 with the objective of serving and involving all APEC member economies in diffusing technology foresight expertise across the APEC region.<sup>1</sup> However, the aim is not just to assist member economies with their own foresight efforts, but also to conduct research at a multi-economy level. Technology foresight may be able to contribute to issues which cross national boundaries-from air pollution, to chicken virus, to electronic information distribution.

Prior to the selection of topics for multi-economy study, the Center developed a number of criteria which any foresight study should meet: the issue must be of concern to most economies, with at least four agreeing to participate in the study; the issue must transcend national boundaries, so that it can go beyond what might be achieved by a national or bi-lateral study; there must be potential for sharing the results with all APEC members; the issue should be of general, public concern or benefit and not one that is likely to be dealt with by the private sector; and finally, the issue will have important technological components but not necessarily 'hightech' ones.

<sup>&</sup>lt;sup>1</sup> More information can be found on the web site of the APEC Center for Technology Foresight http://www.apectf.nstda.or.th

The subject of Megacities as a topic for study emerged from discussions at a Technology Foresight Symposium held in Chiang Mai, Thailand in 1997 attended by over one hundred participants from sixteen different economies. It was agreed that issues of sustainability in Megacities would be increasingly important in the 21<sup>st</sup> century and that Foresight could assist policymakers and planners with resolution of problems. Its importance and relevance to the region cannot be disputed.

'Urban environmental conditions in the Asia-Pacific region are threatened by uncontrolled population growth, industrialisation and increasing vehicle densities. The economic impacts of pollution in Asian urban areas, in terms of productivity and health costs, have been estimated to range from 1 to 5 per cent of their GDP.' (Asian Development Bank 1998).

In early 1999 the APEC Center's International Advisory Board recommended that a study be commenced on the topic of Megacities and that in view of the social and economic issues associated with transport, it should be tackled first. The costs of traffic congestion in Asian cities are enormous:

'Estimated losses due to traffic jams, in terms of annual cost time delay, range from \$ 50 to 70 million in Manila, Jakarta and Kuala Lumpur to \$300 million in Singapore and Bangkok.' (Asian Development Bank 1998)

Based on a Discussion Paper prepared by a Consultant, an Experts Workshop in Melbourne in July 1999 identified sixteen issues in the future of sustainable transport as:

- Impact of post-industrial economy-change in characteristics of employment and leisure
- Impact of e-commerce and other 'non-transport' technologies
- Impact of environmental and energy supply considerations-greenhouse gas targets
- Balance between public and private transport
- Degree of continued reliance on motor vehicle
- Management of traffic demand
- Transparency and awareness of full cost of options
- Development of intelligent transport systems
- Funding (including subsidies) to transport
- Interaction between land use and transport planning
- Heterogeneity-different solutions for different countries
- Transport infrastructure provision
- Institutional reform
- Changes in professional praxis of transport planning
- New transport technologies
- Human and community dimensions-equity, social and environmental costs, safety concerns

These issues were then tackled using the scenario technique in which small groups of experts identified likely developments and key drivers over the next 20 years. They then speculated on possible, even improbable events, which could occur to change the pattern of development, e.g. major political changes, wars, natural disasters, scientific and technical breakthroughs, and created scenarios to cover a range of futures.

In this case, ten key drivers were identified;

- 1. Demographics
- 2. World economics
- 3. Environment
- 4. Changing social demands and values
- 5. International standards
- 6. Fossil fuel availability
- 7. Technology development
- 8. Changing patterns of land use
- 9. Power of multi-national corporations
- 10. Flows of people due to war or disasters.

Identification of 'Uncertainties' which can produce unexpected 'step-changes' is a crucial step in development of scenarios. Sixteen uncertainties were agreed to at the Meeting:

- 1. Social change against vehicles
- 2. Political crisis in Middle East disrupting oil supplies
- 3. Rise in economic protectionism and collapse of trade
- 4. Shift by motor vehicle manufacturers from product to services
- 5. Information technology techno-terrorism
- 6. Global warming and coastal flooding
- 7. Transport-saving technologies
- 8. New supply of cheap oil
- 9. Global nuclear pollution
- 10. Collapse of international borders
- 11. Civil war in Asia
- 12. Pandemic of disease-influenza
- 13. New mode of personal transport
- 14. New cheap energy source-hydrogen
- 15. Solar flare destroys computer memories
- 16. Epidemic of computer virus

Based on this material, three scenarios were created. In the first, 'Green Light Ahead,' increasing concerns about environmental problems provokes significant political actions which trigger a technological response. Thus breakthroughs occur in the use of hydrogen as a fuel in vehicles using fuel-cells, the establishment of driverless people movers using intelligent road systems, and in tele-commuting.

In the second, 'Take The Train,' instability in world markets leads to a recession and loss of purchasing power, while concerns over greenhouse gas emission prompt actions to curb private motor vehicles. This triggers a social change against private transport and a shift to public transport based on bus and train networks.

In the third, 'Back To Basics,' world-wide problems with computer systems lead to massive dislocations to vehicle production. Coupled with an oil crisis provoked by instability in several oil-producing countries, private transport becomes a difficult option and people move back to simpler modes of transport and change their travel patterns. New concepts of public transport are developed.

Such scenarios provide a basis for exploring options for policy development and highlight areas of technology that should be explored.

## The Concept of Sustainable Transportation

#### Definitions

#### Sustainable Development

The phrases "sustainable societies" and "sustainable development" had their origin in the mid-1970s, when concern over the environment and an expanding world population began to grow in many industrialised nations (Hitchcock 1991).

The originators of the term sustainable development had a particular definition of the word sustainable in mind: *capable of being continued*. Thus, sustainable development is development (activity) that is capable of being continued (OECD 1996b, pp. 10-11). An oft-cited definition of sustainable development is the following, adopted in 1987 by the United Nations World Commission on Environment and Development, the so-called Brundtland Commission (WCED 1987, p. 43): "A sustainable condition for this planet is one in which there is stability for both social and physical systems, achieved through meeting the needs of the present without compromising the ability of future generations to meet their own needs." The Brundtland Commission's definition was not only about sustainability in the various senses of the term but also about equity, equity among present inhabitants of the planet and equity among generations. David Throsby, chair of the Australian Government's Transport Working Group established to recommend policy measures consistent with the achievement of ecologically sustainable development, set out some principles for the attainment of sustainability in a paper entitled "Ecologically sustainable development and the transport sector" (Throsby, 1993). The six principles were:

- Advancement of material and non-material well-being;
- Inter-generational equity;
- Intra-generational equity;
- Protection of biodiversity and the maintenance of ecological processes and systems;
- Dealing cautiously with risk and uncertainty; and
- Recognition of global dimensions.

#### **Sustainable Cities**

Sustainability must also be considered in terms of its geographic scope. Activity may be globally unsustainable; for example, it may result in climate change or depletion of the stratospheric ozone layer. Activity may be regionally unsustainable, perhaps on account of the production and spread of tropospheric ozone or acidifying gases that kill vegetation and cause famine in one region but not in other parts of the world. Activity may be locally unsustainable (particularly in individual cities), perhaps because it results in hazardous ambient levels of carbon monoxide or because the noise it produces makes habitation impossible (OECD 1996b).

The city can be conceived of as an ecosystem. State of the Environment Report (1996) indicates that the attainment of a sustainable city can be defined as reducing both the resource inputs to the city (principally land, water, energy and building materials), and its waste outputs (solid, liquid and gaseous, including sewage, toxins, air pollutants and greenhouse gases), while simultaneously improving human livability in the city (income, employment, education, housing, leisure activities, accessibility, community and health).

#### Sustainable Transportation

The sustainable city implies sustainable city sub-systems such as transportation, water, and waste disposal.

Per Kågeson (OECD 1996b) says that the "objectives of sustainable transport must be to offer basic mobility to all citizens without damaging nature and the environment." Sustainability means that development can be accommodated environmentally, it is economically viable, and it results in a livable and equitable society. The same requirements can be placed on sustainable transport: finding ways of meeting transportation needs that are environmentally sound, socially equitable and economically viable (NRTEE (1997, OECD 1996b). The concept of sustainable transportation has been given prominence by international institutions like the World Bank and the Organisation for Economic Cooperation and Development (OECD). The World Bank definition of sustainable transportation integrates the concepts of economic efficiency, environmental sustainability and social sustainability.

The World Bank defines these concepts in the following way:

"Economic and financial sustainability requires that resources be used efficiently and that assets be maintained properly. Environmental and ecological sustainability requires that the external effects of transport be taken into account fully when public or private decisions are made that determine future development. Social sustainability requires that the benefits of improved transport reach all sections of the community." (World Bank, 1996, pp. 4-5)

#### **Economically Efficient Transportation**

The World Bank argues that "to be economically and financially sustainable, transport must be cost-effective and continuously responsive to changing demands" (World Bank, 1996, p.33). The Centre for Sustainable Transportation (1997) indicates that, with respect to economic considerations, transportation systems should provide cost-effective service and capacity, be financially affordable in each generation, and support a vibrant, sustainable economic activity.

In a broader sense, the economic viability of an urban center relates to its competitive abilities to generate trade, employment, and production while satisfying consumption and generating individual and community wealth. Transportation is a key aspect of this competitiveness, but cost-effective transportation is not easily secured because a) there are many externalities involved and b) market processes are flawed as a result of a lack of comprehensive pricing in the provision of access. A key question for transportation systems is: can we afford to continue doing this? Affordability in this sense embraces environmental and social considerations as well as economic costs.

In the United States, studies have shown that somewhere between 49% and 61% of the total social costs of motor vehicle use are paid for entirely by motor vehicle users (OTA, 1994). Examples of costs not taken into account when travel decisions are made by individuals are road construction and maintenance, environmental impacts (discussed in the next section), congestion travel time costs inflicted on others, and aspects of the costs of accidents.

Traffic congestion is a major problem in many cities of the world. Of course, traffic congestion is not wholly a bad thing - it can also be an indication that a growing economy has refrained from excess capitalisation in road infrastructure. But when congestion costs rise beyond a certain point, they are an indication that road prices are too low (Cervero, 1998). Congestion costs are an external cost to

the extent that drivers during congested periods impose costs on all other drivers sharing the road but do not account for these costs in their decisions to drive. Congestion costs not only reduce the economic efficiency of urban centers, but more importantly, they also add to environmental costs because stop-go driving both wastes fuel and generates more pollution per kilometre than free-flowing driving. They also generate particularly damaging local concentrations of pollution.

	Average Speeds of Travel by Mode (km/h)		
	Car	Train	Bus
Singapore	32.5	40.0	19.2
Hong Kong, China	25.7	40.2	18.4
Tokyo	24.4	39.6	12.0
Wealthy Asian Cities	27.5	39.9	16.5
Kuala Lumpur	29.4		16.3
Bangkok	13.1	34.0	9.0
Metro Manila	25.5	37.5	15.4
Jakarta	23.6	35.6	14.6
Developing Asian Cities	22.9	35.7	13.8
Portland	49.7	31.5	26.0
San Francisco	44.3	43.3	20.1
Los Angeles	45.0		19.9
San Diego	55.7	35.0	26.7
Houston	61.2		23.6
New York	38.3	39.0	18.8
US Cities	51.1	37.2	22.0
Vancouver	38.0	41.7	20.1
Toronto	35.0	30.9	20.3
Ottawa	40.0		24.0
Canadian Cities	39.8	33.3	21.1
Sydney	37.0	42.0	19.0
Melbourne	45.1	28.6	21.0
Brisbane	50.1	44.0	28.7
Adelaide	46.4	26.3	22.1
Perth	45.0	34.0	24.6
Australian Cities	45.5	35.0	25.0

#### Table 1. Average Speeds of Travel in Selected APEC Cities, 1990

Source: Newman and Kenworthy, 1999, pp. 82-83.

The net social costs of traffic congestion are high in most industrialised countries, generally being equivalent to between two and three per cent of GDP (OECD, 1997a).<sup>2</sup> Congestion costs are a lot higher in third world megacities, with relatively small land areas devoted to transport arteries, poor design of transportation systems and lack of maintenance (Cervero, 1998). Pendakur (1995) rates Bangkok with Mexico City and Lagos for having the world's worst levels of traffic congestion and air quality. In Mexico City , traffic crawls at an average speed of 9 km/h during peak hours (Cervero 1998). The situation is even worse on the most seriously congested roads in Bangkok. Khomnamool (1999) indicates that the direct annual economic costs of traffic congestion in the Bangkok Metropolitan Region before the onset of the Asian economic crisis was at least 163 billion baht in 1995 prices, which was equivalent to 3.7 per cent of the national GDP and in excess of 7.5 per cent of the regional GDP.

Table 1 (below) provides some data on average speeds of travel in a number of APEC cities.

The data in Table 1 indicate substantial regional variations in average speeds of travel by mode. In the three wealthy Asian cities of Singapore, Hong Kong and Tokyo, relatively low car speeds are compensated for by speedy travel on extensive rail networks. In the developing Asian cities, rail networks are comparatively unimportant and car and bus speeds are the lowest of the regions covered, with Bangkok suffering the worst congestion of the cities surveyed. In the United States, extensive road networks imply relatively high average car speeds, significantly faster than for train or bus services (the exceptions to this overall pattern being New York and San Francisco). In Canadian cities, average car speeds are lower than in the US but higher than in Asia, and transit services are more competitive with cars.

#### Socially Sustainable Transporttation

The Centre for Sustainable Transportation (1997) argues that socially sustainable transportation systems should:

- Meet basic human needs for health, comfort, and convenience in ways that do not stress the social fabric;
- Allow and support development at a human scale, and provide for a reasonable choice of transportation modes, types of housing and community, and living styles;
- Produce no more noise than is acceptable by communities; and
- Be safe for people and their property.

<sup>&</sup>lt;sup>2</sup> Note, however, the difficulties of estimating congestion costs. In arriving at an economically efficient solution, some degree of congestion needs to be traded off against gains in the utilisation of the fixed assets of transport infrastructure.

#### Access

Transportation is of vital importance to the poor because it provides the means of accessing employment, education and health services as well as a means of overcoming social isolation. Reducing the costs of access to these services through improved transportation contributes directly to the reduction of poverty (World Bank, 1996), as can increasing availability through the provision of wider mode choice. Public transport is of particular importance to the urban poor in terms of affordability and accessibility. Road or public transport systems that fall into disrepair because of funding bottlenecks or general inefficiency have socially damaging consequences.

As societies move towards increased dependence on the private automobile as the main method of transport, they become increasingly structured, physically and culturally, around the automobile, thereby marginalising a large minority that has little or no access to this method of transportation. This minority includes many elderly, young, poor, and handicapped people. Such marginalisation is a challenge in terms of addressing opportunities for the affected individuals and also in terms of the coherence and functioning of society. Lower-income citizens, faced with no alternative forms of transportation, need to own and operate personal vehicles to meet their transportation needs at great relative cost. Moreover, to the extent that they do have access to automobiles they tend to operate personal vehicles in poorer states of tune, increasing the amount of relatively high emitting traffic and perhaps prolonging the operating life of high-emitting vehicles (OECD 1996b). Inequities also arise in terms of location, with the less well-off often forced to live in suburbs without transit services, which thereby limits their access.

Examples of differential social access can be drawn from a range of countries. In the United States, the affluent and well -connected have moved to the outer suburbs or exurban areas, leaving the central cities with a concentration of lowerincome groups, higher unemployment, social deprivation and high crime rates. In Australia, inner-city and inner-suburban areas are being revitalised, while in some outer suburban areas there are growing concentrations of social deprivation and poor transport access for those without cars. To take one example, there is a marked contrast between the eastern parts of the Sydney metropolitan area, with comparatively good transport networks and higher-income residents, and the western parts, with poor transit and road networks and concentrations of social deprivation. In both Bangkok and Metro Manila, there were increasing concentrations of social problems in parts of these cities even prior to the financial crisis of 1997 (Kaothien, 1995, Ocampo, 1995).

#### Safety

A further social cost, injury and death caused by accidents, has, perhaps, the largest impact on individuals, although it is not strictly an external cost, since the costs are largely borne by those who choose to travel. In wealthy countries, most

citizens indemnify themselves against the risk of traffic accidents through insurance payments (which is frequently compulsory). While the costs associated with transport accidents are insurable to some extent and are in any case born directly or indirectly by the individuals at risk, there is little doubt that social welfare can be greatly increased by increased transport safety, and in most cases, communities are not being confronted with clear options that relate safety strategies to the cost of providing such strategies. In the developing world, where insurance is frequently a luxury, victims of traffic accidents can face a catastrophic situation.

Each day more than 2,500 people are killed and 50,000 injured globally as a result of traffic accidents (WHO, 1995). The economic losses amount to an estimated two to four per cent of GDP in the most wealthy countries (OECD, 1997a). The road traffic toll is expected by WHO to become the second-most important cause of death and disability in developing countries by the year 2020 (Cervero, 1998). Hence safety is a key issue for transport planning and management, future vehicle design and in the development of innovations in transport infrastructure.

Road traffic accidents are a major problem for roadways rather than transit. The European Conference of Ministers of Transport estimates the costs of accidents in Europe at 33/1000 ECU per person/km for car passengers/drivers, compared with 3/1000 ECU per person/km for rail passengers (ECMT 1998). Improved road infrastructure and safety features in vehicles, and increasingly stringent law enforcement have tended to reduce fatalities and injuries in some OECD countries, but overall growth in road traffic (with a trend to more powerful, faster cars and heavier trucks) is currently tending to increase the risk of accidents in several advanced economies.

Safety from criminal assaults is another important social issue connected with transportation. In many countries there is concern about safety in transit systems (usually concerning journeys in the evening, and related to perceptions about possible problems at transit stations as well as on transit vehicles). There are similar concerns about safety in parking stations.

#### Livability

Sustainable transport should help maintain or improve the quality of life in local communities. Making cities more amenable to live in is one of the traditional core values of urban planning. Newman and Kenworthy (1999) argue that community and neighbourhood interactions are lessened by the loss of "accidental" or casual interaction that occurs in cities with pedestrian and transit systems. They are also concerned that the vitality and culture of the city is reduced as public spaces are dominated by cars rather than people.

Livability is as subjective concept, and it is a function of values and culture (Brindle and Lansdell, 1999). These will vary from country to country (and even within countries) as well as over time. Planners need to be aware of these nuances, and processes need to be intact to ensure that the community is well-informed

about policy options that may impact on urban lifestyles, and that community views are obtained and taken into account in planning processes.

#### **Environmentally Sustainable Transportation**

The Centre for Sustainable Transportation (1997) argues that, with respect to the environment, transportation systems should:

- Make use of land in a way that has little or no impact on the integrity of ecosystems;
- Use energy sources that are essentially renewable or inexhaustible;
- Use other resources that are renewable or inexhaustible, achieved in part through the reuse of items and the recycling of materials used in vehicles and infrastructure; and
- Produce no more emissions and waste than can be accommodated by the planet's restorative ability.

The key principles of ecologically sustainable development<sup>3</sup> are:

- Precautionary or 'no regrets' (the threat of serious or irreversible environmental damage, rather than full scientific certainty, should provide the raison d'être for measures to prevent environmental degradation;
- Intergenerational equity (the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations)<sup>4</sup>;
- Resource conservation (the conservation of biological diversity and ecological integrity); and
- Resource pricing and environmental valuation (ensuring that the real costs of using environmental assets are fully taken into account in decisions about transportation or other aspects of economic development).

#### Local Issues

#### Air Pollution

Air pollution from motor vehicles comes from the exhaust pipe, fuel tank, canister and carburettor. Exhaust pipe emissions come from fuel combustion in the engine. Evaporative emissions occur while the vehicle is moving, standing or refuelling. The principal health-related pollutants include carbon monoxide (CO), nitrogen oxides (NO<sub>x</sub>), sulphur oxides, sulphurous and sulphuric acids, reduced

<sup>&</sup>lt;sup>3</sup> Commonwealth of Australia (1992).

<sup>&</sup>lt;sup>4</sup> The principle of intergenerational equity applied in the context of sustainable transportation implies meeting the needs for mobility, access and economic growth without compromising the ability of future generations to meet their goals, including those of economic development and environmental quality.

sulphur compounds, particulate matter, and volatile hydrocarbons (VHC) such as benzene, toluene, ethyl benzene, the xylenes and the trimethylbenzenes. Lead is a pollutant when it is added to fuel to improve engine performance. Ozone is a secondary air pollutant created in the atmosphere through a photochemical process that involves  $NO_x$ , reactive non-methane hydrocarbons and volatile emissions (Schwela and Zali, 1999).

Motor vehicle exhaust is a complex mixture, the composition of which depends on the fuel used as well as the type and operating condition of the engine and whether it uses any emission control device. Pollutants and their metabolites can cause adverse health effects by interacting with, and impairing, molecules crucial to the biochemical or physiological processes of the human body. Three factors govern the risk of toxic injury from these substances: their chemical and physical properties, the dose of the material that reaches critical tissue sites, and the responsiveness of these sites to the substance. Pollution effects may also vary across population groups; in particular, the young and the elderly may be especially susceptible to deleterious effects (Schwela and Zali, 1999).

Table 2, shown below, indicates the level of emissions on a per capita basis for selected regions within APEC. Emissions from transportation are positively correlated with motor vehicle usage. As a consequence, the cities of North America and Australia have high per capita emissions as a result of high incomes and car dependency. Low car dependency in the wealthy Asian cities means low emissions per capita. In the developing Asian cities, per capita emissions are held down by lower incomes, but are boosted by an emerging car dependency. Bangkok has high per capita emissions of VHC and the highest emissions in the world of suspended particulate matter. The large number of motorcycles contributes to the later situation (Newman and Kenworthy, 1999).

Among the different vehicles classes, automobiles are currently responsible for the greatest amount of polluting emissions, particularly CO, CO2

	CO2 Emissions from All Transportation, kg/person	Emissions of NO <sub>x</sub> , SO <sub>2</sub> , VHC and SPM, kg/person
Wealthy Asian Cities	1158	30
Developing Asian Cities	837	89
US Cities	4536	252
Toronto	2434	216
Australian Cities	2789	233

#### Table 2. Data on Emissions for Selected APEC Regions, 1990

Source: Newman and Kenworthy, 1999, p. 121. The wealthy Asian cities are Hong Kong, China; Singapore and Tokyo. The developing Asian cities are Bangkok, Jakarta, Kuala Lumpur, Metro Manila, Seoul, and Surabaya. and VHCs. On the other hand, heavy-duty trucks and buses are responsible for half the world's emissions of motor-related NOx, in spite of a comparatively small share (around 5 per cent) of the vehicle population. They are also the source of a large share of fine particulate matter emitted by diesel engines. This reflects not only the high fuel consumption and large amount of travel logged by heavy duty-vehicles, but it is also indicative of comparatively poor standards and emission controls on this vehicle class (OECD 1997c).

#### Specific Air Pollutants

Lead (Pb) additives in motor fuels account for an estimated 80-90 per cent of Pb in ambient air. The degree of pollution from this source varies from country to country, depending on motor vehicle density and the efficiency of efforts to reduce the Pb content of petrol. Infants and young children less than five years old are particularly sensitive to Pb exposure because of its potential effect on neurological development. Anaemia, encephalopathy, and the impairment of learning ability, behaviour, intelligence and fine motor coordination can result (Schwela and Zali, 1999). Phased reductions in lead from petrol have been effective in leading to dramatic reductions in Pb exposure in North America and Western Europe, but leaded petrol is still widely available through a large number of developing economies and in some advanced economies.

Carbon monoxide (CO) decreases the oxygen transport to the tissues. Organs that are dependent on a large oxygen supply are the most at risk, particularly the heart and central nervous system, as well as the foetus. Subjects with previous cardiovascular disease seem to be the group most sensitive to CO exposure. Lowlevel exposures to CO result in headaches and dizziness, with cardiovascular symptoms and malaise occurring at higher levels. It is suspected that exposure of expectant mothers to CO concentrations can result in low birth weight. The invehicle exposure to CO in traffic has tended to decline in the United States between 1965 and 1992. Emission controls are thought to be the main explanation for this trend which has occurred despite substantial growth in the motor vehicle population and total miles travelled (Schwela and Zali, 1999).

Studies of short -term exposure to high levels of nitrogen dioxide  $(NO_x)$  suggest it has the potential to increase the intensity and severity of respiratory infections, and worsen the clinical status of persons with asthma, chronic obstructive pulmonary disease or other chronic respiratory conditions. Nitrogen oxides react with other pollutants in the atmosphere to produce a form of ozone. Exposure to ozone impacts primarily on the lung. Ozone exposure produces cellular and structural changes, the overall effect of which is a decrease in the ability of the lung to perform normal functions. Exposure to an increase in total oxidants results in eye, nose and throat irritation, coughing, throat dryness, thoracic pain, increased mucous production, rales, chest tightness, subternal pain, lassitude, malaise and nausea (Schwela and Zali, 1999).

The major source of atmospheric benzene is emissions from motor vehicles and evaporation losses during handling, distribution and storage of petrol. The toxic effects of benzene in humans following inhalation exposure include haematotoxicity, immunotoxicity, neurotoxicity and carcinogenicity. Polycyclic aromatic hydrocarbons (PAHs) are a group of chemicals formed during the incomplete combustion of wood and fuel. Exhaust from diesel engines has significant concentrations of PAHs. Many of these PAHs are mutagenic and carcinogenic. Studies indicate an increased risk of developing cancer (Schwela and Zali, 1999).

Sulphur dioxide  $(SO_2)$  and suspended particulate matter (SPM) are the primary products of fossil fuel combustion processes. Secondary particles, including acid aerosols, are formed by atmospheric chemical reactions. Vehicular traffic is becoming an increasingly important source of  $SO_2$  and SPM, taking over from the use of coal for domestic heating and industrial purposes. Inhaled  $SO_2$  irritates the upper airways, and high concentrations can cause laryngotracheal and pulmonary oedema. It can have acute effects on asthmatics. High concentrations of  $SO_2$  and SPM are correlated with increased respiratory mortality and cardiovascular mortality, those with chronic obstructive lung diseases and pneumonia being particularly at risk. Short-term peak concentrations of  $SO_2$  and SPM may also increase morbidity for those with asthma and chronic bronchitis (Schwela and Zali, 1999).

The Harvard Six Cities epidemiological study, published in 1993, found a clear association between mortality and fine particulate matter in the atmosphere. The American Cancer Society's records of over half a million people and data on fine particulates from 50 cities, showed the same clear relationship. Most recently, results were released of a study by the Institute of Environmental Medicine in Stockholm on the effect of fumes on 3500 men living in areas with the heaviest traffic. It found there was a 40 per cent higher chance of contracting lung cancer for 30-year residents and a 20 per cent higher chance for 10-year residents (Fisher, 1999).

#### **Exposure to Air Pollution**

The commercial districts and public facilities of urban areas attract and generate large volumes of traffic that typically circulate at low speeds with frequent stops and starts. This traffic pattern produces relatively high emissions. If emissions occur in open areas, they may be dispersed by wind and concentrations diminish with greater distance downwind if the source. If emissions occur in street canyons, high concentrations of pollutants may result at street level. The potential for human exposure is great because commercial districts and public facilities attract large numbers of people. Emissions can increase dramatically whenever petrol driven vehicles stop and idle at street intersections or otherwise form a queue. The severity of exposure partly depends on how much traffic is handled by the intersection and the distance of an individual from it (Schwela and Zali, 1999).

Human exposure to an air pollutant occurs wherever a person or population makes contact physically with a pollutant at a particular instant in time. An individual's dosage of an air pollutant is affected by the amount of the pollutant that enters the body, either through inhalation, ingestion or dermal absorption. Concentrations of pollutants from motor vehicles in such locations as congested roadways, parking garages, service stations, street canyons and the passenger cabins of motor vehicles in traffic cause particular problems. Commuters using motor vehicles had exposures nearly twice that of transit users (note Schwela and Zali, 1999).

In some places, people serve themselves with fuel at service stations. This practice potentially puts these people at risk of exposure to evaporative emissions during refuelling and other motor vehicle pollutants. Studies have shown very high concentrations of CO and other pollutants in poorly ventilated, confined spaces used by motor vehicles. These include parking garages, tunnels and underpasses (Schwela and Zali, 1999).

Most air quality reporting is of background or ambient levels. There are big differences in roadside readings which can vary according to the traffic level, its composition, atmospherics and season, recording height, canyon features and lining vegetation (if any) as well as distance from traffic stream. The first metre up from the kerbside, for instance, has been found to be especially high in finer SPM and thus young children may be more seriously at risk than adults. Further, the average city resident moves from locality to locality. Diurnal exposure is therefore the product of an individual's lifestyle and may well outstrip background levels in many cases (Fisher, 1999).

Occupational and commuter exposures to air pollutants from motor vehicles in some large cities of developing countries are severe. Examples cited are for Metro Manila jeepney drivers and commuters in Mexico City. Numbers of roadside exposures are large because many people are forced to spend large parts of the day in roadside situations (eg street-sellers) and pedestrians have to share road space with traffic, compared with high-income urban centers that have separated pedestrian ways and shopping malls from road traffic. This adds to problems emanating from low or non-existent emissions standards and traffic congestion (Schwela and Zali, 1999).

Epidemiological studies are increasingly finding correlations of higher morbidity and mortality rates with long-term low exposures of particulate matter, well below the concentrations prescribed by EPA air quality standards. Further research is needed along with an improved understanding of the effects of particulate matter on human physiology and health (TRB, 1997).

A British government paper on air quality standards noted that recent studies had found effects on health at pollutant levels which would not have been considered a problem 10 years ago. Moreover, analytical tests for the toxicity of air contaminants assume that people are exposed to chemicals one at a time. This is obviously wrong and synergistic effects most likely exist but remain unexplored (Fisher, 1999).

#### The Cost of Air Pollution

The air pollution cost estimates surveyed by the European Conference of Ministers of Transport show a broad range. This reflects in part the complexity of the valuation of damage costs, which must link emissions to impacts through models of dispersion, ambient concentration and dose-response relations; in addition, financial valuations must be attached to impacts. Utility valuation techniques (stated or revealed preference) are of limited use for assessing air pollution. Pollution is too dispersed to be reflected in property values and few people sufficiently understand the chemistry and dose-response relations involved to make informed statements of preference.

In the damage cost estimates reviewed, the authors cautioned that they were unable to cover all the effects relevant to the costs of air pollution. The damage cost estimates reviewed place the cost of air pollution at 0.25 to 1.1 per cent of GDP (one study lay outside this range at 0.03 to 1.1 per cent). Studies of prevention costs (i.e. the costs of meeting predetermined emissions targets) yield estimates in a similar range. The few examples of utility valuations examined provide estimates from the upper end of the range of damage cost estimates, up to three per cent of GDP (ECMT, 1998).

The costs of air pollution associated with transportation in the major cities of the developing world are likely to be well above the estimates for European cities. Based on a review of available air quality data, it has been estimated that roadside emissions of SPM and CO must be reduced by 85 per cent and 47 per cent respectively, if acceptable air quality is to be achieved in Bangkok.<sup>5</sup> Recent data indicate that ozone concentrations downwind from the city may also be approaching unhealthy levels. It would therefore be appropriate to adopt measures that reduce VHC and NO<sub>x</sub> emissions. (Schwela and Zali, 1999). Emissions are well above the WHO guidelines in Metro Manila, Beijing, and Kuala Lumpur. Mexico City has had huge problems in the past as a result of an aged stock of polluting vehicles, stagnant meteorological conditions throughout the winter season, and its physical location (lying in a bowl surrounded by mountains). However, air quality has improved for a number of pollutants over recent years (particularly Pb, CO and SO<sub>2</sub>) even though serious problems remain for ozone and SPM.

#### Noise

Transportation has been identified as the main cause of environmental noise. In OECD countries, 16 per cent of the population is exposed to noise levels

<sup>&</sup>lt;sup>5</sup> SPM emissions in Bangkok result from the large number of motor cycles, diesel trucks, and dust form traffic movements and construction sites. Old vehicles that are without catalytic converters contribute to CO emissions.

from transportation capable of severely disturbing sleep and communication, and thereby contributing to disease; and additional 50 per cent is exposed to "unsatisfactory" noise levels from transportation (Barde and Button, 1996).

Excessive noise is known to cause hearing loss and may contribute to stress-related health problems including raised blood pressure and minor psychiatric illness. Noise can interfere with sleep and thus may contribute to accident proneness and reduced immunity to disease. Foetal growth may be inhibited and birth weights reduced as a result of exposure to high noise levels. In animals, exposure to noise has caused still births, birth defects, and reduced birth weights (RCEP, 1994).

What may not be available is clear evidence that ordinary loud noise from road traffic is harmful in any of these ways, as opposed to merely being irritating. The World Health Organisation has recognised noise as a health hazard and has suggested day-time outdoor noise levels should be less than 55dB (57dB for aircraft noise) and that they should not exceed 65dB. A report for the German government has suggested that night-time noise levels of 40dB can lead to disturbed sleep, inability to concentrate, and an increase in noise-related illnesses such as cardiovascular disease (WIK 1995). Ordinary loud noise from road traffic on busy roads results in nearby sound level meter readings of some 65dB (Barde and Button, 1990).

Estimates of the external costs of road noise range from 0.06 to 0.75 per cent of GDP, with a mean value of 0.3 per cent of GDP. Most of these estimates are based on the revealed preference approach, measuring the reduction in market value of housing exposed to noise compared with similar housing in quieter areas. Other studies, based on stated social preferences, yield estimates generally towards the upper end of the range. Studies of prevention costs, based on expenditure on programs to reduce noise impact, generally yield estimates at the lower end of the range. The Frauenhofer Institute in Karlsruhe estimates that total transport noise nuisance costs might represent close to 0.5 per cent of GDP, with road traffic accounting for 64 per cent of total transport noise, rail traffic 10 per cent and air traffic 26 per cent (ECMT, 1998).

#### The Consumption of Land

Transport is a major consumer of land. For example, five per cent of the land area of the former West Germany is estimated to be used for transport routes; a further, unstated proportion is devoted to off-route transport purposes such as parking, manufacturing, and maintenance facilities. Some 25 to 35 per cent of the land is devoted to streets in modern cities, compared with less than 10 per cent in cities designed before motorised transport (Litman, 1995 and Hodge, 1989). Land used for parking would raise the total still further. An adverse environmental impact of such paving is the typically increased flushing of pollutants into water courses, rather than their slow disposal into natural drainage basins (OECD 1996b).

#### Impact of Transportation Infrastructure

Transportation systems have many enduring effects on water systems that have proved difficult to address. Highway construction can affect local hydrology profoundly. For instance, exposed soils, cut road banks, and uncontained construction debris and building materials are susceptible to mudslides, wind erosion, and movement in surface runoff. Many of these materials find their way to local streams, causing sedimentation that can alter the hydrology of an area and reduce water quality, thereby adversely affecting aquatic and terrestrial communities. During the past 30 years, strategies have been developed to contain erosion and minimise contaminated runoff and hydrological disturbances from the building of transportation facilities. These measures include temporary fences, sodding, groundcover vegetation and plantings, diversion beams, artificial wetlands, and alternative deicing and maintenance materials.

Once built and in operation, highways and other transportation facilities (including structures, terminals and yards) can have enduring effects on the quality of nearby waters and local hydrology. They remain a chronic source of sediments and contaminants in nearby receiving waters as a result of runoff of materials deposited on the road surface by traffic and road maintenance crews and by erosion of side slopes and degraded construction materials. Storm water runoff from roads and airport surfaces, as well as paved surfaces in ports and other transportation facilities, can include oils and greases and heavy metals such as zinc, lead, copper, and cadmium deposited by tyres, vehicle leaks, worn coatings, and metal components of structures. Surface drainage can also carry chemicals and materials used in maintenance operations, including pesticides and herbicides, coatings, sand, and deicing agents (especially chlorides; TRB, 1997).

Roads and other transport facilities occupy land that would otherwise serve as habitat area. In the US roads and adjacent rights-of-way occupy one per cent of the total surface area of the contiguous United States, or an area equivalent to the land contained in the state of South Carolina. More than three-quarters of roadway mileage is in rural locations, ranging from forest to agricultural settings. Habitats are lost directly as a result of the physical imprint of a road and the changes of terrain and other natural features that accompany it.

Perhaps the most noticeable effect of roads that traverse habitat areas is the dead birds, mammals, and other animals found along the roadside. In most cases, these road deaths have little effect on animal populations, but this is not the case with rare and endangered species.

Roads and the traffic moving along them are also the source of invasive species that can transform the habitats they enter. Roadside plantings are a source of invasive grasses, shrubs, weeds, and other vegetation that may spread into nearby pasturelands, forests, and nature preserves. The cleared corridors, underpasses, overpasses, and drainage ways of highways, railroads, and other transportation facilities can serve as avenues for the long-distance movement of invading species. Vehicular traffic also serves as a transport mechanism for non-native animals, plants, insects, and seeds.

The disturbances created by traffic noise, vibrations, and light can be disruptive to essential animal behaviours as feeding and reproduction. Depending on the species and habitat type, the effects may extend for hundreds of metres form the roadway. Roads cutting through wilderness areas create edge habitats usually inhabited by different flora and fauna than those found previously.

By subdividing the landscape into small pieces, roads also fragment habitats and interrupt essential wildlife movements. This is particularly the case in areas where road networks are dense, since the patches between the roads become very small, incapable of providing the resources needed to maintain viable and resilient populations. Landscape and habitat fragmentation can inhibit the exchange of breeders (impeding gene flows and encouraging inbreeding), and inhibit the spread and exchange of plant species (TRB, 1997).

#### **Regional Effects**

The most pervasive air pollution problem in areas with temperate climates is tropospheric ozone, which results from the reaction of nitrogen oxides and volatile organic compounds in the presence of sunlight. Numerous studies have demonstrated that photochemical pollutants inflict damage on forest ecosystems and seriously impact the growth of many crops, causing annual losses of several billion US dollars.

Emissions of sulphur and nitrogen compounds, their chemical transformation, atmospheric transport, and deposition are the causes of acid deposition.  $NO_x$  emissions play a major role in the formation of acids and in acid deposition. Motor vehicle emissions are responsible for about 25 per cent of total acid deposition in Western Europe. Furthermore, photochemical oxidants may play a key role in the conversion of sulphur and nitrogen oxides into acids; thus motor-vehicle hydrocarbon and  $NO_x$  emissions also contribute to the acidification problem.  $NO_x$  emissions contribute approximately one third of the acidity in rainfall, and even higher shares in the cases of acid fog and snowfall. Increased nitrogen depositions due to the release of large amounts of  $NO_x$  into the atmosphere have been found to disrupt the nutrient balance in ecosystems, and are thus significant contributors to forest dieback in Europe (OECD 1996b).

#### **Global Issues**

Transport also damages the global environment. Pollution from motor vehicles produces about one-fifth of the incremental carbon dioxide in the atmosphere arising from human activity (which potentially contributes to global warming), one-third of the chlorofluorocarbons (which contribute to the depletion of the ozone layer), and half of the nitrogen oxides <sup>6</sup> (World Bank, 1996).

<sup>&</sup>lt;sup>6</sup> Nitrogen oxides contribute to continental scale acidification and ecological damage.

#### **Global Warming**

Most emissions of  $CO_2$  - the most abundant of the greenhouse gases that are building in the atmosphere - result from the burning of carbon-rich fossil fuels, with petroleum, the predominant fuel used in transportation, being especially prominent. Transportation's use of petroleum accounts for about 30 per cent of the  $CO_2$  emitted in the United States. Although market prices regulate the near- and long-term supplies of petroleum, they do not reflect the many environmental costs of its use, including the long-range risks associated with  $CO_2$  emissions (TRB, 1997).

The increase in greenhouse gases has the long-term effect of raising global temperatures (IPCC 1996). Human-induced changes in climate associated with emissions of greenhouse gases will be superimposed on a background of natural climatic variations that occur over different space and time scales. Natural climatic variability can occur as a result of changes in the radiative forcing of the climate system, for example as a result of aerosols emitted from volcanic eruptions (which can have a short term cooling effect). Climate variations can also occur without a change in radiative forcing as a result of complex interactions between components of the climate system, such as the atmosphere and the ocean (TRB 1997).

The greatest potential impact on global climate associated with the concentration of greenhouse gases is believed to arise from the atmospheric accumulation of carbon dioxide, a gas that in the atmosphere traps the sun's heat causing an increase in the planet's surface temperature. The effects of continued rises in mean surface temperatures will include raised sea levels, expansion of deserts, spread of vector-born diseases, and widespread destruction of plants, animals, and ecosystems unable to adapt to changes in temperature and other aspects of climate. Developing countries are particularly at risk. There may be beneficial effects in some parts of the world, including expanded food production (OECD 1996b).

Most estimates of the damage done by greenhouse emissions have been of the US economy and involve a benchmark of a doubling of pre-industrial-era atmospheric  $CO_2$  concentrations. The results mostly suggest damage amounting to around one to two per cent of GDP. Assuming that on average in OECD countries transport is currently responsible for 30 per cent of  $CO_2$  emissions from fossil fuel combustion, transport emissions might imply damage of around 0.3 to 0.6 per cent of GDP (ECMT, 1998).

Aggregate estimates of damage for the world economy lie close to the estimates for the US due to the weight of GDP in the developed economies in comparison with the economic output of other countries. Obvious ethical concerns arise because many poorer countries stand to suffer heavily, with estimates of up to eight to nine per cent of GDP in parts of South Asia and Africa. The precautionary principle would favour using an approach that poses a risk of abating too much rather than too little.

Table 3 indicates that the transportation sector is becoming increasingly important as a source of carbon dioxide emissions from the OECD economies.

	Total emissions, % change since 1980	Transport emissions, % change since 1980	Road transport as % of total emissions 1980	Road transport as % of total emissions mid 1990s
North America	10	21	22	24
OECD Europe	-5	48	14	22
OECD	6	31	18	22
G7	3	28	18	23

#### Table 3. Contribution of the transport sector to CO<sub>2</sub> emissions

Source: OECD 1997a p. 16.

Table 4 provides statistics on transportation energy use, and annual travel by private car and by transit. Energy use is positively correlated with the use of private cars, and transit usage lessens the need for car travel.

#### Persistent Pollutants

Motor vehicles also contribute to the atmospheric accumulation of persistent pollutants. Unlike emissions of conventional pollutants -which, although emitted in very large quantities, have a comparatively brief stay in the atmosphere persistent pollutants are not reduced or removed from the atmosphere through chemical reactions or other means; they can remain in the atmosphere for several hundred years or more. Because of this durability, even persistent pollutants emitted in very small annual amounts can reach harmful ambient levels across several years. Such pollutants can be widely dispersed, affecting the environment on a global scale (OECD 1996).

Ozone is beneficial when concentrated naturally in the higher altitudes of the stratosphere. It forms naturally in the stratosphere when energy from sunlight splits oxygen molecules causing some atoms to combine with molecular oxygen atoms to form ozone. Because of its molecular structure, stratospheric ozone absorbs and prevents penetration to the earth's surface of short-wave ultraviolet light, high exposure to which is associated with skin cancer in humans and harmful effects for many plants, aquatic species, and other organisms. More penetration of ultraviolet light may also lead to increased surface warming (TRB, 1997).

Man-made CFCs are chemically stable and can rise to the higher altitudes of the stratosphere, where they are eventually broken down by ultraviolet radiation. Once liberated, the chlorine atoms are free to react with and destroy thousands of stratospheric ozone molecules. Among the principal transportation sources of CFCs are vehicle air-conditioning systems, many of which contain the refrigerant CFC-12. Substitute refrigerants for air-conditioning systems have been developed, and

	Total Transportation Energy (MJ per capita)	Annual Travel in Private Cars (passenger km per capita)	Annual Travel in Public Transport (passenger km per capita)
Singapore	18079	3169	2775
Hong Kong, China	9612	813	3784
Токуо	18243	3175	5501
Wealthy Asian Citi	es 15311	2386	4020
Kuala Lumpur	20017	6299	1577
Bangkok	18176	4634	2313
Metro Manila	7335	1281	2568
Jakarta	9072	1546	1323
Developing Asian (	Cities 13650	3440	1945
Portland	70698	14665	286
San Francisco	65890	16229	899
Los Angeles	62167	16686	352
San Diego	67248	18757	259
Houston	71624	19004	215
New York	51626	11062	1334
US Cities	64351	16045	474
Vancouver	37211	12541	871
Toronto	33613	7027	2173
Ottawa	33562	8236	850
Canadian Cities	39173	9290	998
Sydney	35074	9417	1769
Melbourne	38890	9782	844
Brisbane	39277	11188	900
Adelaide	37103	11173	572
Perth	41395	12029	544
Australian Cities	39456	10797	882

#### Table 4. Indicators of Transportation in Selected APEC Cities, 1990

Source: Newman and Kenworthy, 1999, pages 70-71 and 84.

their introduction into the fleet of new vehicles has been accelerated by international treaties and domestic legislation phasing out production and use of CFCs. In addition, disposal and replacement procedures for refrigerants from automobile air-

conditioning systems are now subject to federal requirements. Favourable results from these policies are now evident, with the growth in CFC concentrates in the atmosphere having stopped (TRB, 1997)

Vehicle air conditioning systems produced before 1993 continue to use substantial amounts of CFC-12. The cost of CFC-12 has increased by a factor of about ten during the last few years on account of taxes and shortages (by international agreement, CFCs are no longer produced in OECD countries). The cost increase, together with regulations concerning the handling of CFCs, have reduced the amounts of CFCs vented into the atmosphere. Non-OECD countries are exempt from the production ban until 2006. A black market in CFCs based on illegal imports has already emerged, weakening the impact of the ban in OECD countries and causing legislators in the United States to question its value (OECD, 1996b).

#### **Oil Depletion**

Worldwide, the transport sector accounts for more than 60 per cent of the consumption of oil products, which constitute about 98 per cent of transport energy use, up from 92 per cent in 1960. In OECD countries, road vehicles are responsible for more than 80 per cent of oil use for transportation. Most of the remainder is used by air transport. Railways and shipping consume no more than five per cent (OECD, 1996). While non-transport use of oil has been declining, the rate of transport-related use is increasing significantly, particularly in the emerging economies (IEA, 1993).

After falling in the early 1980s, world oil use is rising again, largely on account of industrialisation in non-OECD countries and transport uses everywhere. In OECD countries, non-transport use of oil is declining but use for transport is increasing at a rate of about two per cent a year, resulting in an overall increase in the demand for oil of just under one per cent a year. In non-OECD countries, oil use is increasing overall at three times the rate in OECD countries (IPCC, 1996).

Authoritative sources suggest that there are proved reserves of oil sufficient to last 35-50 years at present rates of extraction. This does not necessarily mean that available oil will be exhausted in that time. Since 1960 the identification of proven reserves has generally kept pace with extraction, meaning the time horizon of available oil has been within the range of 35-50 years for several decades (World Energy Council, 1995). Moreover, should what are now regarded as recoverable reserves become exhausted, other reserves will be made available, albeit at a higher cost of extraction. One can also argue that as the resource becomes more scarce, prices should increase, thus encouraging more cautious use of the resource and development of new technologies.

Notwithstanding the past tendency for the supply of oil to continue expanding, resource depletion is a significant aspect of the unsustainability of transporta-tion. An intrinsically non-renewable resource is being depleted more quickly than renewable substitutes are being developed and there is a possibility in the next two decades that supply problems will inflict oil crises on the world economy. There is also a security issue for those countries whose transportation systems rely almost entirely on a resource that for the most part has to be imported from elsewhere, often from places characterised by a high degree of political volatility; about two-thirds of the world's proved oil reserves are in the Persian Gulf area (OECD, 1996b).

#### Sustainable Transportation as an Integrated Concept

A sustainable transportation system is one that:

- allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, and with equity within and between generations;
- is affordable, operates efficiently, offers choice of transport mode, and supports a vibrant economy; and
- limits emissions and waste within the planet's ability to absorb them, minimises consumption of non-renewable resources, reuses and recycles its components, and minimises the use of land and the production of noise (CST,1997).

The transport sector is characterised consistently in the literature as an important example of market failure to internalise the high social and environmental externalities. Transport markets in many OECD countries fail to make users pay the full cost of transport services. While some safety, health and environmental costs may partly be internalised through regulation, transport prices generally do not reflect the full social costs of noise and air pollution, increased risk of accidents or traffic congestion. The European Conference of Ministers of Transport (ECMT) has recently estimated these to be the equivalent of 5% of GDP in ECMT countries (although this figure underestimates certain substantial costs, such as climate change, and ignores others, such as separation effects on ecosystems and human communities and damage to landscapes).

Knowledge of transport sector social costs is gradually improving as more and better research is done. The uncertainties that remain have many causes, most of these being related to the difficulty of calculating monetary values in the absence of markets, and to imperfect understanding of the harmful effects of transport in certain fields, such as noise or pollution. Internalisation should only seek to account for currently uncovered costs but it should also attempt to structure prices more efficiently so as to create incentives for adopting less environmentally harmful behaviour (e.g. shifting the balance from fixed to variable costs, eliminating distortion-causing subsidies, etc.). Internalising the social costs of transport has been and remains a major theme of work by the ECMT and OECD (OECD, 1997c).

Economic, environmental and social sustainability are often mutually reinforcing. Road or public transport systems that fall into disrepair reduce economic efficiency and hinder access for the poor. Measures to improve asset maintenance,
the technical efficiency of supply, and safety can produce substantial economic, environmental and social benefits. Because, in third world countries, the poor are most affected by inner city concentrations of exhaust emissions from automobiles, while the rich benefit from vehicle use, there are social benefits from addressing environmental goals. However, the simultaneous achievement of these three goals is not always easy, and difficult tradeoffs may be required. A sustainable transportation strategy is one that both identifies and implements the win-win policy instruments and explicitly confronts the tradeoffs in order to achieve deliberately chosen outcomes (World Bank, 1996).

The sustainable transportation system needs to meet a number of criteria, relating to environmental, social and economic issues. The principal environmental criteria, based on the goals of achieving environmental quality, health, and sustainability, comprise  $CO_2$  emission targets;  $NO_x$  emission targets; volatile organic compound emission reduction; reduction of harmful particulates; globally effective phase-out in the use of CFCs, leaded petrol and CO emissions; noise minimisation; and the more careful use of land areas so far as transportation infrastructure is concerned. The main social criteria relate to accessibility for all groups in the community; livability (which will differ from country to country and city to city, reflecting local preferences with respect to lifestyle and culture, as well as the nature of local communities); and safety (minimising the risk of traffic accidents and reducing the threats posed by urban crime to mobility). With respect to economic issues, the key criteria are cost-efficiency of transportation and quality improvements in transportation to meet such development needs as changes in the level and structure of employment, income generation, and enterprise creation and growth.

# The Drivers of Change

The threat of increasingly unsustainable transportation systems in APEC mega-cities comes from the interaction between growing demand for transportation services and the environmental impact of transportation. Demand tends to grow at a geometric rate, while the environmental capacity at given technologies to handle such growth is fixed. Technology offers enormous possibilities for change in the longer run, but unless harnessed to the goal of overall sustainability, may aggravate some problems while in the process of fixing others.

# The Demand for Transportation and Social Factors

The demand for transportation is one of the three principal drivers of change in future transport systems. Consideration needs to be given to the responsiveness of demand to changing incomes, to prices, the phenomenon of induced traffic, and the changing structure of travel demand.

# The Responsiveness of Transport Demand to Rising Incomes

In the advanced economies there has been a strong correlation between overall GDP growth and the expansion of the transport sector - growth of GDP has been

accompanied by a roughly similar growth in transport for passengers and goods, and by much faster growth in transport by road. More recently, growth of the transport sector, and of road transport in particular, has exceeded that of GDP in many countries. Whether ongoing structural adjustment, improved logistics and the changing nature of economic activity can ultimately reduce the 'transport intensity' of OECD economies remains to be seen (OECD 1997c).

Analysis of data for the period 1960 to 1990 shows that people devote a roughly predictable fraction of their expenditures to transportation. This fraction is typically 3 to 5 per cent in developing countries, where people rely predominantly on non-motorised and public transportation. The fraction rises with automobile ownership, stabilising at 10 to 15 per cent. Nearly all members of the OECD have completed this "automobile transition". Even during the two oil-shocks of the 1970s, this fraction remained nearly constant. Travellers compensated for higher operating costs by demanding less expensive (and more fuel-efficient) vehicles (Schafer and Victor, 1997). For the advanced economies, the relationship implies an income elasticity of demand for transport stabilising at unity. This means that, even where the aggregate population of a metropolitan area stabilises, traffic growth will still be rising at a significant rate, stimulated by rising per capita incomes. For developing economies, traffic growth in metropolitan areas gains an additional impetus from such influences as faster overall population growth, increasing urbanisation rates, more rapidly rising per capita incomes (in particular, for a range of large developing economies, including China, the economies of South East Asia and Mexico), and an income elasticity of demand for transport services well in excess of unity. Bangkok, for example, wass experiencing an annual rate of growth of two per cent in its human population, 12 per cent growth in the car population and 18 per cent growth in the motor cycle population prior to the economic crisis of 1997 (Pendakur 1995). Vehicle registrations in Metro Manila are increasing at 10 per cent per annum (Abanes, 1999), over 20 per cent per annum in Kuala Lumpur, and in Beijing they are growing by 19 per cent per annum.

Rising incomes lead to increasing demand for transportation services. This long-term growth in demand implies increasing inputs into the city's ecological system that will create a variety of waste outcomes. Geometric growth in inputs and outputs comes into conflict with a fixed capacity to deal with the harmful outputs. There are immense challenges here for transportation management, urban planning and technological innovation. The economic and social constraints operate through the time period it takes to change transportation infrastructure, and constraints on the speed with which the urban form can be changed, and physical constraints on the way in which this form can be altered. Congestion and isolation can become a phenomenon of rapidly increasing proportions as a result of fixed infrastructure in the face of geometric growth in transportation demand.

# The Responsiveness of Transport Demand to Price Changes

That a variety of fuel-saving responses are triggered by higher fuel prices is less controversial than the specific timing and magnitude of the responses. Various studies have sought to determine the price elasticity of demand for motor vehicle fuel. Short-term price elasticities are low because motorists can primarily only respond to higher prices by reducing discretionary travel. Estimates range from - 0.05 to above -0.5 (TRB, 1997).

Over the longer term, increased demand for fuel-efficient vehicles becomes more important as a source of reduced fuel consumption in the face of higher oil prices. Other longer-term adjustments include moving to locations closer to work and other needs, and finding alternative means of transportation. Estimates of longer-term price elasticities range from -0.2 to above -1.0, with an average of -0.53 (TRB, 1997).

Constraining factors that limit the price elasticity of demand for kilometres of travel include:

- the low responsiveness of company-financed executive cars (executives often do not directly pay recurrent motoring costs) and the provision of free corporate parking to employees;
- the limited options for transport that individual motorists might face, with residential location fixed in the short term and inflexible working conditions;
- the availability of roads, rail beds, airports and other essential transport infrastructure further constrains transport choices - because transport infrastructure is expensive and long-lived, it takes considerable time to change its characteristics, implying transport choices for a considerable period of time will be limited by earlier investments; and
- the inflexibility of public transport service provision.

Current research undertaken in Sydney has attempted to assess the crosselasticity of car travel with public transport usage. A one per cent increase in the cost of a journey by car is estimated to lead to only a 0.024 per cent increase in public transport usage (AATSE, 1997). That result may be indicative of a broad range of car-dependent cities in North America and Australia. Cross-elasticities are likely to be higher in cities with more comprehensive transit services. A strategy of customising public transport, both in terms of service provision and in terms of the framework for spending on capital equipment and infrastructure is needed if the substitutability of public for private transport is to be increased.

There is significant system inertia affecting transportation in most urban areas. This reduces the sensitivity of traffic movements to changes in relative prices. Inertia reflects the limited substitutability between different transport modes as a consequence of different performance and quality requirements, relative economics, accessibility to infrastructure, and consumer preferences. Policies aimed at influencing particular modes of transport are likely to encounter strong "system opposition". There is a need for policy to focus on increasing modal substitutability by narrowing gaps in terms of performance, quality, economics, and accessibility, as well as increasing choices within particular transport modes.

How closely past patterns of price responses are likely to correspond to future trends over even longer term time horizons (on the order of decades) is uncertain. Most measurements of long-term price elasticities have been computed over relatively brief time horizons, encompassing several years rather than many decades. Moreover, during the 1970s and 1980s (when many of the elasticities were estimated), motorist responses to higher gasoline prices were aided by the relatively simple and inexpensive improvements that could be made in vehicle fuel economy, especially reductions in vehicle weight (through changes such as front-wheel drive). Further advances in vehicle fuel efficiency might prove more difficult and costly. On the other hand, continued advances in motor vehicle and fuel technology, as well as travel substitutes such as telecommunications may greatly expand response options, causing fuel demand to become even more responsive to changes in fuel price (TRB, 1997).

#### **Time Savings and Travel Demand**

The law of the constant travel time budget is enjoying increasing popularity. It says time savings made possible by an enhanced transport system (including improved infrastructure) will be fully reinvested (through new or longer trips) in the enhanced transport system; there is therefore no real saving of travel time.

The demand for travel is, in the simplest form a function of incomes (with a positive income elasticity of demand), the costs of transport (with a negative price elasticity) and travel time (with a negative time elasticity). The law of the constant travel time budget implies that all the elasticities and cross elasticities of the above equation except for the direct and cross time elasticities would have to be exactly zero. The total transport demand would depend exclusively on travel times. Income and costs would have no impact on demand. In the case where there is only one mode of transport, the time elasticity of demand would have to take precisely the value of -1. It is most improbable that these conditions are fulfilled in reality (ECMT, 1996). Improved transport infrastructure that results in time savings will result in increased travel, but the trend in other influences on travel demand (such as incomes and prices) needs to be taken into account before overall predictions about travel demand are made.

Reasonably well-established research on petrol price and on values of time suggests an overall average short-term elasticity of traffic with respect to travel time of about -0.5 and a longer-term elasticity of the order of -1.0 (ECMT 1996).

#### Induced Traffic

A further aspect of transport demand that policy analysis needs to take into account is the phenomenon of 'induced traffic'. Induced traffic occurs when changes

impacting on one part of the traffic system increase traffic demand in another part of the system. One example, already referred to, is that increases in the fuel efficiency of vehicles tend to encourage motorists who purchase such vehicles to drive greater distances and share a car less frequently. In this case, the reduced cost of travel leads to substitution effects in consumer budgets. In the absence of additional policy initiatives, there is therefore a danger that improvements in vehicle technologies with respect to emissions that result in tangible benefits to drivers of those vehicles could result in an increase in road traffic movements.

A second aspect of induced demand is associated with partial approaches to road pricing. Increased charges on specific tollways will, in part, lead to the diversion of traffic onto alternative routes. Even a more comprehensive approach to road pricing affecting all traffic within a designated area can lead to traffic substitution. The city of Vienna has succeeded in reducing traffic congestion within the city center, but the peripheral motorway has experienced much heavier traffic. The city of Toronto has put into effect much-admired improvements in transport management within the city, but new urban developments both within and without city limits has resulted in new sources of road traffic demand developing. Urban land use can therefore have an important impact offsetting the impact of specific transport management initiatives (The Economist, 1998b).

New road construction may lead to more traffic being encouraged - and induced demand. This additional traffic demand may bring benefits in terms of previously suppressed opportunities, but it will also generate additional environmental costs. Investigations in the United Kingdom have shown that induced traffic was likely to be of greatest importance where:

- (1) a network was operating close to capacity, or
- (2) the elasticity of demand with respect to travel cost was high, or
- (3) the implementation of a given scheme would lead to large changes in travel cost. If one of these conditions were met, induced traffic was likely to be of significance (SACTRA, 1994).

### The Nature of Travel Demand

Rising incomes and car ownership, coupled with the spread of cities, has sharply increased motorised travel throughout much of the world. Besides being more frequent in number, motorised trips are also occurring increasingly over longer distances and in single-occupant cars. Longer journeys are contributing more to traffic growth in Europe than the rising number of trips. Exclusionary zoning that keeps apartments and affordable housing out of many areas experiencing rapid job growth is one factor influencing these trends. Others are residential location choices based on being in a good school district (important in the US) and the trend toward two-earner households (Cervero, 1998).

It is apparent that improved economic welfare and greater leisure time are shifting car travel away from commuter trips and increasingly towards social, leisure and shopping activities. Research by the ECMT points to a number of social factors tending to increase demand for car travel: the growing population of the elderly in the population (now motorised to a high degree and with a strong propensity to continue driving as long as possible); greater access of women to cars as new drivers; growth in numbers of two-worker households; expectations of young people to drive earlier and more; and declines in household size leading to increases in car ownership (OECD 1997c). Despite these trends, the journey to work remains an important factor in traffic congestion for most major cities.

## Travel to Work

In North America and Australia, jobs have gradually dispersed from the central business district of major urban centers to sub-centers. An exodus of households from central cities has accompanied job dispersal (although this trend is beginning to change in Australian cities). Shopping plazas, restaurants and other consumer services have followed. These trends do not square well with the physical configurations of most transportation networks, designed to serve radial trips.

The shift from goods producing and handling to information processing in the newly emerging knowledge economies has brought about both concentration and decentralisation. Some Information Age jobs are clustering in cities, some are ending up in sub-centers, and many are settling in far-flung places. Today's global economy requires central places to serve as command and control posts for multinational corporations. Financial and business services that rely on face-toface contact and easy access to specialised skills often congregate in large CBDs. Where high-end businesses go, five-star hotels, up-scale retailers, and major cultural activities soon follow (Cervero, 1998).

Another profound change has been the trend towards flexibly specialised modes of production, such as in the high-technology sector (where highly networked small and medium-sized enterprises are mutually dependent on one another's presence and proximity for innovation). Flexible specialisation favours spatial agglomeration, though not in central cities but rather in outlying clusters and corridors. Factors such as proximity to major international airports and leading universities govern where many high-technology firms locate. Businesses that cater mostly to regional and sub-national markets, such as engineering and consulting firms, often concentrate in suburban mega-centers. Outer suburban or exurban locations are possible with the utilisation of appropriate information technologies for routine, low-skilled information processing functions (such as billing and collection services), and also wholesaling, construction and consumer services (Cervero, 1998).

#### Social Influences

Kemp (1999) notes that social trends in advanced economies have contributed to the misfit between urban form and post-industrial employment growth:

- Lack of employment in middle and outer suburbs have developed since the 1970s;
- Concentration of social disadvantage;
- Concentration of disempowerment by lack of access, particularly low income and low skilled women and young people;
- Lack of choice in opportunities; and
- Conventional transport solutions find it difficult to address these problems in a cost-effective manner.

A further issue is the changing characteristics of leisure. Some transportsaving in home-based entertainment, accentuated by new technologies. Against this, a more diverse range of interests in sport, culture, entertainment, education and training related activities has created more complex patterns of movement. Leisure-related activities are a high-growth source of demand for travel. They further add to demand for crosstown travel, increasing the dominance of the car as opposed to transit.

Growing prosperity and the more diverse patterns of behaviour facilitated by rising incomes have not only spawned more vehicle use for passenger travel, they have also fostered growth in the trucking industry. Rising incomes have encouraged more consumption and the accompanying producer goods, leading to higher freight demand. The creation of a national network of freeways and more liberalised truck size and weight allowances led in the US to rapid growth in truck movements starting in the 1950s. Between 1965 and 1980, total truck travel per year grew nearly twice as fast as passenger car travel (TRB, 1997).

# Demography

In the advanced economies, baby boomers have averaged more travel, not only because of higher incomes and more cars, but also because they are more active - they go out more often, have more expansive social networks, and chauffeur children. As they are replaced by the baby bust generation, travel rates may be constrained. Ageing populations will have different transport requirements. However, in other parts of the world, places with bottom-heavy population pyramids, each succeeding generation will continue to be much larger than the preceding one, and demand for transport will grow rapidly (Cervero, 1998).

The changing role of women in the workplace has also impacted on travel worldwide. To the extent that participation rates have yet to reach their peak, the entry and re-entry of women into the workforce has led to a faster growth in the workforce than for the population as a whole. Since many women must balance their roles as wage earners and homemakers, their travel patterns tend to be more complex than men's. Many women are forced to drive to chain trips between work, child-care centers, shopping and home (Dunphy, 1997). A secondary factor contributing to increased trip chaining has been the growth of Americans (and Australians) working two jobs (Cervero, 1998).

The demographic trend that might favour transit in the future is the maturing of populations, especially in the Western world. While the elderly are generally more transit-dependent than other age groups, in car-dominant societies like the US, seniors still make at least three of four trips in a private vehicle, either as a driver or as a passenger. Winning more seniors over to transit will hinge on elevating the quality and safety of services, in addition to more effectively integrating urban development and transit provisions.

#### Current and Future Influences on Demand for Transportation

In the advanced economies, there is evidence that some of these trends have stabilised over the past several years and that growth in the motor vehicle fleet may be less correlated with growth in GDP. Since 1980, the vehicle fleet, which had previously kept pace with GDP, has grown only two-thirds as fast as GDP. However, the slowdown in fleet expansion has not translated into a comparable slowdown in travel by motor vehicles, with more kilometres being travelled by the average vehicle. In the developing economies, travel-intensity per unit of GDP is still rising.

In the advanced economies, several of the key demographic and social factors contributing to the dynamic growth in motor vehicle travel in past decades appear to be subsiding (participation rates in driving for women have now reached a maximum level, and the influx of baby boomers into the workforce has come to an end), Against this, the market factors (such as petroleum prices) that stirred public interest in motor fuel economy during the 1970s and 1980s have all but disappeared from public consciousness (TRB, 1997).<sup>7</sup> In all economies, the dominance of the motor vehicle for passenger and freight movements has increased.

In the US, between 1980 and 1993 the retail price of petrol, already cheap by the standards of Europe, fell by 7 per cent in real-dollar terms, while fleet-averaged fuel efficiency increased by 40 per cent and inflation-adjusted transit fares rose by 47 per cent. Differences in price trends have similarly favoured motoring in much of Europe, contributing to a loss of transit's share in urban transportation. In the US, free parking - which motorists enjoy 99 per cent of the time they make a trip has long been a strong inducement to drive. In addition, motorists receiving free petrol for their daily work trips adds to the worth of free parking and the inducement to drive (Shoup, 1997). Motoring subsidies are higher in the US than in Europe where roadway taxes are higher and fuel taxes much higher. Deteriorating service levels have undermined transit in many cities. Declining ridership often triggers service cuts, which in turn drive even more customers away, forcing even further service cuts. Only through an infusion of government subsidies has it been possible to sustain transit service levels in most wealthy countries. Nevertheless, changing political priorities, tight budgets, and government's retrenchment from the public transit arena have in many cases cut into subsidy transfers, particularly in the United States (Cervero, 1998).

<sup>&</sup>lt;sup>7</sup> Perhaps the recent rise in oil prices, which may well be sustained over the next few years, will change the general climate of opinion.

Projections for the increase in kilometres travelled by all vehicles between 1990-2030 are 79% within the OECD, 312% outside the OECD, and 144% in total, of which 137% is for light vehicles and 192% for heavy vehicles. In terms of weight of fuel used, the projections are 18%, 206%, 73%, 25% and 181% (OECD 1996). These projections highlight two major structural features in the demand for transportation - the rapid potential growth in developing economies compared with advanced economies, and the magnitude in growth of heavy vehicle traffic.

# **Environmental Influences**

The growth in urban traffic generates increasing waste outputs, assuming given technologies, which give rise to a range of environmental problems, local, regional and global. The following analysis indicates the nature of changes that could be expected under such assumptions, as well as indicating the possible reductions in waste associated with the adoption of newly developing technologies.

# **Air Pollution**

Local conditions with respect to air quality have improved in many advanced economies over recent years. The catalytic converters installed in newer cars remove most of the carbon monoxide previously emitted into the atmosphere<sup>8</sup>, and the introduction of lead-free petrol has had significant benefits. However, further technological improvements will be required to avert a resurgence of difficulties next century. Projections indicate that the increased volume of traffic will lead to major environmental problems in the larger cities of the industrialised economies in the absence of new initiatives. Of significant concern are rising levels of fine particulate emissions, especially related to the use of diesel fuels. The situation in many third world countries continues to deteriorate in the absence of the strict measures adopted in high-income localities. Bangkok reputedly has the highest concentrates of volatile hydrocarbons and particulates in the world as a result of too many inefficient, poorly maintained vehicles and two-stroke motorcycles idling in traffic jams for hours (Cervero, 1998). These air pollution problems affect not only the major metropolitan centers but also broad regional areas downwind from the polluted cities.

# Nitrogen Oxides

Notwithstanding the potential for removing NO<sub>x</sub>, emissions of NO<sub>x</sub> from vehicles are expected to increase during the early part of the century and be more than 40 per cent higher worldwide in 2030 than in 1990, largely on account of increases in non-OECD countries. However, even in OECD countries, transport-related NO<sub>x</sub> emissions are expected to fall during the same period by only 20 per

<sup>&</sup>lt;sup>8</sup> Although there are latent problems as the limits of the useful lifetime of catalytic converters is approached.

cent. This is far short of the 90 per cent reduction in ambient  $NO_x$  levels claimed necessary for Europe by Kågeson (1994).

Current emissions controls in the OECD economies result in emissions of NOx from light-duty road vehicles of 0.62 grams per kilometre. Advanced emission control technologies have become available that will move that level to 0.12 g/km, a reduction of just over 80 per cent, while advanced control technology can reduce emissions from heavy-duty road vehicles by about 70 per cent (OECD, 1995). Thus, a reduction by 90 per cent from transport over the next 35 years may well be possible, although the overall reduction might comprise a greater contribution form lightduty than from heavy duty vehicles. To sustain a 90 per cent reduction in ambient NOx levels resulting from transport in spite of traffic growth, the average reduction per vehicle-kilometre would have to be greater than 90 per cent (OECD, 1996).

#### Volatile Organic Compounds

Emissions of volatile organic compounds (VOCs) mainly result from the operation of light-duty petrol engines. Technically, by improvements to engine design, fuels, fuel systems, and exhaust systems, it should be possible to virtually eliminate emissions of VOCs due to transportation (OECD, 1995). There is considered to be no safe level for airborne 1-3-butadiene, benzene, and carcinogenic polynuclear aromatic hydrocarbons (PAHs) as they present a cancer risk for humans. Stringent VOC controls are also justified to prevent photochemical smog formation (OECD, 1996). There are concerns that lags in the adoption of new technologies could see a major growth in problems in developing economies associated with emissions of VOCs.

#### Ozone

In temperate climates, high ambient levels of ozone (smog) comprise the most pervasive air pollution problem associated with transportation. Smog episodes can result in the immediate hospitalisation of vulnerable people. Ozone is known to be formed by the action of sunlight on vehicle emissions, notably NOx and VOCs. A considerable challenge is that ambient levels for ozone appear to have increased in some OECD economies in spite of impressive improvements in the ability of pollution control technology to reduce unit emissions of NOx and VOCs.

Part of the response to this challenge may be that the relationship between ozone formation and  $NO_x$  levels in particular is complex, and that high  $NO_x$  levels can be associated with low levels of ozone production. This may happen because of scavenging of ozone during the production of  $NO_x$  from the nitric oxide created during combustion. Catalytic converters that remove  $NO_x$  may thus, under certain circumstances, contribute to increased ozone levels. Other emissions that scavenge ozone may also be removed by pollution control systems (RCEP, 1994). The relation between ozone formation and levels of VOCs is also complex. The most effective control strategy to reduce peak ozone levels involves reducing emissions of both  $NO_x$  and VOCs. As long as the internationally accepted air quality guideline for ozone (70 parts per billion, one-hour average) is exceeded by a factor of two to four in many OECD countries, considerable reductions in emissions of precursors will be necessary to meet currently acceptable ozone levels. If critical levels of ozone as defined by Unite Nations experts as necessary to protect agricultural crops and trees (40 parts per billion, accumulated exposure) are to be attained, reduction in precursor emissions of 70-80 per cent or more will be needed. This will be a difficult task in the advanced economies, yet alone in developing economies.

# Suspended Particulate Matter

Diesel engines are the major source of suspended particulate matter (SPM). The growth in freight traffic based on the use of diesel engines has led to a significant increase in SPM emissions. Technological solutions to this problem are not simple, although reduction in emissions of particulates from diesel vehicles can be achieved through use of trap-oxidisers, cleaner fuels, low sulphur fuels and also by running engines at higher temperatures (however, this can raise emissions of particulates from 1993 levels are anticipated in actual and proposed EU emission limits (RCEP, 1994). Because potential carcinogens are involved, more stringent conditions may be required. This will present a significant challenge in all economies.

# **Global Warming**

The close link between fossil fuel use and  $CO_2$  emissions means that worldwide success in improving the energy efficiency of industrial and other operations during the last few decades might have reduced accumulated  $CO_2$ emissions. The conspicuous exception is the transport sector, where increases in vehicle-kilometres travelled have mostly offset improvements in efficiency. Between 1973 and 1988,  $CO_2$  emissions from transportation increased by 30 per cent worldwide to 773 million tonnes,  $CO_2$  emissions from other human activities fell overall by about two per cent to 1969 million tonnes (Nijkamp, 1994). In OECD countries the differences are even more stark, the proportion of total  $CO_2$  emissions contributed by transportation increased from 13 to 24 per cent during the same period (Hart, 1994).

# The Availability of Fossil Fuels

Motorisation has a big impact on the demand for energy. Overall, the transportation sector accounts for at least one-quarter of primary energy use (IIEC, 1996) and current trends suggest that transport energy consumption may well double in the next twenty to thirty years (IPCC, 1996). However, the supply of fossil fuels is finite, and further growth in demand could lead to significant problems (Campbell

and Laherrére, 1995). Because of the heavy reliance of major world powers on imported oil, especially from the Middle East, major interruptions in supplies can not only throw the global economy into a tailspin ( the result of sharp spikes in the price of crude oil and interruptions in supplies) but can also spark political tensions and military confrontations (Cervero 1998).

# The Impact of Technological Change

#### **Technological Change and Transportation**

Technological change impacting upon transportation can take many forms. It can change the design and operational characteristics of transport vehicles (cars in particular, but also paratransit vehicles). It can impact on how vehicles are used and maintained (for example, advanced traveller information, automated vehicle control and on-board diagnostics), and it can offer new possibilities for traffic management (such as electronic road pricing and the utilisation of traffic simulation models in traffic management).

Increasing demand for travel and fixed environmental limits to the capacity to sustain such travel movements, create a potentially huge market for technologies addressing the harmful environmental side-effects of travel. However, because the environmental costs of travel are externalities, and not borne directly by those undertaking travel, policy intervention is required to transform a potential market into an actual market. Moreover, the impact of new technologies on the social sustainability of transportation is difficult to assess. Some of the innovations may increase access for the community as a whole (in particular, innovations that broaden the range of, and reduce the price of transit services). However, because there are important aspects of the social impact of transportation that are externalities, policy interventions may be required to ensure socially optimal outcomes form technological change. Finally, the impact of technological change on the livability of cities is difficult to predict, with some social scientists arguing that there is a risk that technology may merely perpetuate present problems (note Newman and Kenworthy, 1999).

It is estimated that existing vehicle design and engine technologies are rapidly becoming capable of securing significant improvements in vehicle fuel efficiency of the order of 20 per cent. If lower performance were accepted (reduced engine power, reductions in weight), improvements of 50 to 60 per cent or more could be achieved with limited technological development implications. Combinations of advanced emission control technologies already exist that could allow light-duty vehicles to meet tailpipe emission standards 50 to 80 per cent tighter than the most stringent values currently in effect in any OECD country. Similarly, available control techniques can reduce evaporative emissions by 75 to 90 per cent (OECD 1997c).

## Virtual Technologies

Technology may contribute to the extent to which non-transport alternatives

can meet accessibility objectives. Examples of such alternatives include home entertainment systems, telecommuting for work, delivering services through the Internet, lean manufacturing and distribution systems that minimise transport movements, utilising transport logistics to the full, and improved urban design that minimises the need for environmentally damaging transport movements. Using advanced information technologies, a large range of travel movements could, perhaps, be displaced:

- Journeys to work could be reduced by managerial and technological changes that greatly increase working from home;
- Business travel (local and international) could be displaced by increased use of conferencing and other information technologies for communications;
- Social and entertainment needs could be displaced to a significant extent by virtual reality, especially for the young; and
- On-line and distance education could displace journey-to-school or campus.

# Teleworking, Telecommuting, and Working from Home.

Current telecommunications and IT technologies enable an increasing number of employees to be home-based using personal computers, the Internet, telephone and fax machines to carry out their business. Occupations such as software developers, graphic artists, financial advisers and insurance brokers are taking to this mode of work. The list of occupations is likely to extend to a much wider variety of white collar jobs.

While homeworking will undoubtedly reduce the number of journeys to work, it will not necessarily eliminate all journeys to a workplace as some home workers may visit a work-site periodically for training, mentoring, supervision, and so on. It seems that there is a strong human need to bond with fellow workers and to benefit from the social interaction that the traditional work environment provides. In addition, while home workers will substantially reduce the number of journeys to a central work place they may well relocate their homes to more remote locations away from the major commercial centers in towns and cities. This could lead to a net increase in total vehicle-kilometres of travel when home delivery vehicle travel is also taken into account. Also, while work travel is substantially reduced, additional trips may be generated. Examples include parents taking their children to school by car instead of letting them use school buses, or using increased leisure time to travel to the gym (Brogan *et al.*, 1999).

For the most part, research to date sides with the proposition that telecommunications substitutes for, rather than stimulates, trip making. A study of a pilot telecommuting program of 200 employees in Sacramento (California, USA) found no increases in non-work trips and, indeed, out-of-home trips became more efficient (Mohktarian, 1991). This study found that vehicle kilometres travelled

went down to just 20 per cent of the distance they normally commuted on commuting days, and on the one or two days a week they drove to their offices, they tended to make efficient chained trips.

Even greater reductions in travel were found several months into a telecommuting demonstration program in Rijswijk, the Netherlands (Travers Morgan, 1995). A recent study of telework centers, which are neighbourhood-based shared workplaces equipped with advanced communications facilities, in the Seattle Metropolitan Area found vehicle-kilometres travelled was cut by more than half (Henderson and Mohktarian, 1996).

Yet telecommunication has not proved to be the panacea some people had hoped for, in large part because most occupational roles are not suited for home working, at least not on a regular basis. Management fears of losing oversight controls over teleworkers have also thwarted past initiatives. Another concern is that home workers will feel cut off from office social life and promotion opportunities. It is for this reason that part-time telecommuting - say, working at home one or two days a week and in the office the remaining workweek - has gained popularity (Cervero, 1998).

#### Telephone and Internet Shopping.

The use of communications technology for shopping involves the purchase of retail goods and services (banking, and travel, for example) via the tone dial telephone and the internet. There have been delays in the adoption of e-commerce, driven by concerns over the security of credit card and bank account information. However, there are now signs that these concerns are being overcome and that this mode of purchasing goods and services will explode in the next decade, even though it is unlikely to completely displace physical shopping.

The impact of e-commerce on the demand for transportation is difficult to predict. On the one hand it will reduce the need for people to travel to retail service outlets but it will increase the demand for home delivery transport services, many of them requiring truck or courier type one-off deliveries rather than consolidated delivery. It is thought that supermarket shopping, video rentals, takeaway meals and wine will be delivered on a just in time basis whereas purchased CD's, videos and books could be delivered by mail (Brogan *et al.*, 1999).

#### Tele-education.

There is an increasing capability for institutions to provide education via the Internet. Distance education via the radio and, more recently, mail and TV, has had a long history in Australia and in East Asia. The potential for Internet education appears greatest for tertiary education and least for primary school education (Brogan *et al.*, 1999).

#### Tele/Video Conferencing.

Futurologists in the 1960s and 1970s were predicting that telecom-

munications would substitute for the need to travel. The evidence is to the contrary. The rapid increase in availability and quality of telecommunications over the last 30 to 40 years and the very significant reduction in their real cost has not led to any decrease in travel (note the high rate of growth in long distance air travel). There appears to be no substitute for face-to-face interaction. This is particularly so where there are complex issues to be worked through or there are detailed negotiations which require frequent time out periods. Again, the all too human need for bonding or really getting to know the other party, makes it seem unlikely that the electronic alternative to real meetings will substitute for them (Brogan *et al.*, 1999)

# Recreation and Leisure Activities via Telecommunications.

The introduction of the valve-based radio early in the twentieth century revolutionised how people spent their recreation and leisure time. In turn, the introduction of television after the Second World War had a similar revolutionary effect. The development and rolling out of the new broadband telecommunications systems such as cable and satellite TV, digital and terrestrial TV, Internet, digital radio, and interactive services is going to further revolutionise recreation and leisure activities. This will probably lead to even more home-based recreation and leisure activities. However, the effects on transport demand are difficult to predict and given peoples' need to enjoy live entertainment (theatre, music and sport, for example) it is possible that this will not have a significant effect on transport demand (Brogan *et al.*, 1999).

# Accelerating Change in the Motor Vehicle Industry

The surge in oil prices that occurred during the 1970s combined with increasing concern about the environment led to a wave of innovations impacting on the design of the motor vehicle. New materials (lightweight alloys, plastics, composites and ceramics); aerodynamic styling; and improved braking, suspension, and transmission systems have been adopted. Electronics has become an essential feature of vehicles and plays a key role in improving engine efficiency and overall performance. Computer-aided design and engineering is reducing the lag between new concepts and their introduction into production. Product reliability has been significantly increased as a result of improvements in manufacturing systems.

The subsequent reduction of oil prices during the 1980s and 1990s has led to some reduction in consumer interest in fuel-saving technologies for transport, but longer-term concerns about oil and about the environment are beginning to shape both policies and the research agenda. The process of technological change can be expected to accelerate over the coming decades.

Major improvements in the energy efficiency of motor vehicles could be achieved through a radical shift in technology and design (OTA, 1994). The basic features of an advanced automobile incorporating radical new technologies, some of which are already at an advanced stage of development, include:

- new body materials (most probably carbon-fibre or other composite materials, but also lighter metal alloys) which increase energy efficiency by reducing mass, and also aim for a lower energy cost in production;
- enhanced streamlining, using sophisticated body design and reduced frontal areas, aimed at reducing the vehicle's drag coefficient from the current state-of-the art 0.3 to 0.2 or lower;
- high-pressure, low-rolling resistance tyres similar to those used in General Motor's Impact electric vehicle;
- an advanced engine;
- extensive use of aluminium and other light-weight materials in suspension and other components (such as brake fittings, sway bars, and wheels);
- major redesign of seats, bumpers and other components to reduce weight; and
- advanced transmissions (probably continuously variable automatic).

# **Alternative Fuels**

Throughout much of the industrialised world, unleaded fuel has been the norm for more than a decade. The potential for reformulating petrol to reduce other pollutant emissions has attracted considerable research over the past decade. The most significant potential emission reductions that can be achieved by reformulation are reducing volatility (to diminish evaporative emissions), reducing sulphur (to improve catalyst efficiency), and adding oxygenated blend stocks (thereby reducing the need for hydrocarbons).

Diesel fuel generally contains much higher levels of sulphur than petrol. Many advanced economies have decided to take steps to lower the sulphur levels as a strategy to reduce diesel particulate emissions. This has the added benefit of increasing the potential for catalytic control of diesel particulate and organic HC emissions. Attention is now being turned to the possibilities for modifying diesel fuel composition as a quick and cost effective means of reducing emissions from existing vehicles. The two modifications which show the most promise are a reduction in sulphur content, and a reduction in the fraction of aromatic hydrocarbons in the fuel. The possibility of substituting cleaner burning, alternative fuels for diesel fuel for buses has attracted increasing attention over the last decade. The main alternative fuel under consideration at present is methanol made from natural gas.

The use of alternative, non-petroleum-based fuels in vehicles offers opportunities to reduce overall energy use and greenhouse emissions. Methanol and natural gas have higher octane ratings than gasoline, allowing engines to use higher compression ratios, thereby raising thermal efficiency. Differences in the carbon content and general chemical make-up of alternative fuels yield different fuel cycle emissions of greenhouse gases. Heavy trucks, buses and commercial vehicles have been demonstrating financial, as well as environmental, savings through the use of natural gas as a fuel for several years.

Alternative fuels can be used in internal combustion engines for light-duty vehicles, the primary fuels under consideration being natural gas, liquefied petroleum gas (LPG), ethanol, methanol, and hydrogen. LPG is widely used for taxis. Shenzhen in China has launched a large project on LPG-powered transportation. Millions of cars in the United States and Brazil run on an ethanol-blended fuel made from ethanol derived from sugar cane and petroleum. A number of European countries have the beginnings of an ethanol-fuel infrastructure as well.

Methanol can be produced from just about anything containing carbon including natural gas, coal or biomass. Methanol is widely used as the fuel for racing cars. In the United States, blended petrol/methanol mixes are increasingly being offered at many new refuelling facilities for use in passenger and light-duty vehicles. There has also been increasing interest in biogas as an alternative fuel, with Sweden leading the way. In the future, ethanol, methanol and biogas have increased prospects for use in cars and trucks designed and built to be operable on different types of fuel.

The production of ethanol and methanol from advanced processes using cellulosic biomass (wood, grasses and wastes) is also being examined. These alcohol fuels offer potential for use in ICEs in pure form, in mixtures with other fuels, in hybrid vehicles, or as a chemical fuel in fuel cell vehicles. The advantage of these fuels is that production of their feedstock is not as carbon-or land-intensive as grain crops. Because wood and grass resources are renewable and store vast amounts of carbon, most of the  $CO_2$  emitted during the use of cellulosic biofuel could be offset by the additional  $CO_2$  removed from the atmosphere by the renewable wood and grass used as feedstock. An important consideration in the development of biofuels is the environmental and agricultural effect of feedstock production (TRB, 1997).

In the future, ethanol, methanol and biogas have increased prospects for use in cars and trucks designed and built to be operable with different types of fuel. Piston engines in conventional motor vehicles can be adjusted to run on alternative fuels (such as ethanol and methanol) which reduce nitrogen-oxide emissions. Motorists are wary of using alternative fuels in case they are unable to replenish supplies, and filling stations are reluctant to move unless assured of a reasonable demand. A new technology known as the flexible-fuel vehicle is being developed (Volkswagen is a leader) which will detect which type of fuel its tank has been filled with and automatically adjust the engine; this would increase the flexibility of the vehicle for operational purposes.

Hydrogen is potentially an important source of energy for road vehicles. It can best be used in fuel cells, and methanol and natural gas can act as hydrogencarriers for fuel cells.

Key policy issues for the future effective utilisation of alternative fuels are:

• improved distribution networks for alternative fuels;

- conversions of engines to dual fuel use; and
- improving information networks about efficient vehicle use.

#### **The Internal Combustion Engine**

Among the new types of internal combustion engines likely to appear in the next decade or so is an advanced two-stroke engine accompanied by new electronically controlled fuel-injection techniques designed to both raise the efficiency of the combustion process and reduce emissions of unburnt fuel. General Motors, Ford and Toyota are all testing prototypes of two-stroke cars. Western Australian company Orbital has a 2-stroke direct in-cylinder engine design that has been licensed to General Motors, Ford and Mercury Marine in the United States, Fiat and Piaggio in Italy, Bombardier in Canada, Tohatsu in Japan and Bajaj in India. The Orbital engine prevents unburned fuel from being exhausted and hence offers significant emissions reductions and fuel economy.

Many of the two-wheeled vehicles which are prevalent in many developing countries are powered by two stroke engines. Two stroke motorcycles are a major source of white smoke and emissions of aromatic hydrocarbons and suspended particulate matter. Technological solutions to the smoke and unburned aromatic hydrocarbons associated with two stroke engines have now become available or are under development. They include catalytic exhaust conversion, direct cylinder electronic fuel injection and electronic computer control. In addition, as indicated above, modern two stroke engines are emerging which are starting to demonstrate very low emissions, excellent fuel economy and low cost (Schwela and Zali, 1999).

Mitsubishi Motors has developed a new gasoline direct injection engine (the GDI) used in models introduced in Japan in late August 1996, and to be introduced across the whole Mitsubishi range from 1999. Direct injection into the cylinder has long been used in diesel engines, but Mitsubishi has made it work with petrol engines. Mitsubishi claims that the motor uses 35 per cent less fuel, produces 35 per cent less carbon emissions, and 95 per cent less nitrogen oxides in its exhaust and still turns out 10 per cent more power than the conventional injection system used in existing petrol engines (The Economist, 1996c). Although Mitsubishi's claims on the extent of fuel-savings have been disputed (they vary across the whole model range), at least 22 per cent fuel savings are being delivered (Boyd 1997). Toyota is launching a car using a similar power plant, and Nissan, Honda, and several companies in Europe and America are working on their own direct injection designs.

A further new development in engine technology is the MDI-EV3 engine being tested by the Luxembourg engineering company ADMP. This engine has separate compression and expansion cylinders, a technology which is theoretically 50 per cent more efficient than the conventional two-stroke engine. It can also work on cold compressed air, thereby producing zero emissions, or in a hybrid compressed air/fuel injection form (The Economist, 1996d).

A second type of combustion engine with potential is the gas turbine. To be

efficient, the gas turbine has to work at a very high temperature, high enough to melt iron and aluminium, the traditional engine block materials. New and more tractable ceramic materials, together with electronic combustion controls, would make a small powerful gas turbine engine possible for automobiles. Such an engine would emit negligible pollution and could run on a variety of fuels.

Diesel engines are typically more efficient than petrol engines because they burn less fuel, and hence produce less carbon dioxide. However, they can be noisy, smelly and they produce nitrogen oxides and particulates, the result of incomplete combustion. To overcome this latter problem, a new kind of turbo-charged direct injection engine has been developed, and is being used, or is becoming available, in cars produced by Volkswagen, Toyota, BMW, Mercedes, Alfa Romeo, Rover, Peugeot and Citro?n. A further refinement, exhaust-gas recirculation, is being adopted as a way of cutting the amount of nitrogen oxide produced by diesel engines (The Economist, 1998c).

# **Electric and Hybrid Vehicles**

Instead of an advanced internal combustion engine, a radically redesigned automobile might use electric motors powered by batteries or fuel cells. Alternatively, it might use a hybrid combination including batteries and a motor/generator (or one of a variety of other combinations of power sources, including flywheels). Recent significant technical advances have placed such vehicles closer to reality, with a few examples of vehicles that have actually become available for sale. The key hurdles remaining to be overcome before full competitiveness with conventional vehicles is attained include improving the manufacturing capability and reducing the cost of advanced materials, designing adequate safety systems for small vehicles, and achieving significant further improvements in fuel cell and battery technology.

# **Electric Vehicles**

Electric vehicles (EVs) use either batteries, fuel cells, or a combustion engine-generator combination to provide electricity to power electric drive motors. An advanced EV would use small variable speed alternating-current (AC) motors mounted at the wheels rather than the larger, heavier direct-current (DC) motors used on current EV designs. Recent advances in electronics have greatly reduced the size and weight of equipment to convert the DC power provided by fuel cells and batteries into AC power for motors. AC motors can attain very high drivetrain efficiencies and no transmission is required. The main constraint on EVs is the difficulty of storing enough energy on-board; the energy density of battery storage is a small fraction of that of gasoline; and also hydrogen, needed for fuel cells, is lacking in energy density (OTA, 1994). Currently, General Motors' electric vehicle (the EVI) can travel only 110 kilometres between charges, and its batteries take several hours to recharge from a household power outlet, though they can be charged faster with special (but expensive) equipment.

Electric battery vehicles are at the most advanced stage of development. If recharged with electricity from low-emission sources (nuclear, solar, hydroelectric), they can be very efficient with respect to limiting  $CO_2$  emissions, depending on the source of the electricity used. Their high price and restricted driving range limit their market penetration currently. They are most suitable for local or neighbourhood-oriented vehicles - urban cars in multicar households (TRB, 1997). One and two-person powered vehicles offer mobility independence for people with mobility disabilities, and could find much wider application. Electric motor scooters are now filling an important niche in the transportation system of Taipei.

## Battery Technology

The crucial element for successful mass commercialisation of a battery electric vehicle is the development of a battery that combines high energy density for range, high power density to allow competitive acceleration performance, a long life-time under relatively adverse conditions, and moderate cost. A variety of battery types are under development, including lithium-aluminium-iron disulfide, several different types of other lithium-based batteries (including lithium polymer and nickel-metal hydride), and new variants of the traditional lead-acid battery (which seek higher energy density and longer life through design alterations and use of new materials). Lithium polymer or lithium ion batteries appear to hold important advantages over the lead-acid batteries currently used in the General Motors EVI electric car. Flow batteries, in which the electrolyte is pumped through the battery cells from tanks external to the battery cells, offer an alternative approach in new battery technology. The two most commercially viable contenders are both the result of Australian innovation. They are the Perth-based ZBB Technologies' zinc bromide battery and the Melbourne-based Pinnacle VRB's Vanadium Redox Battery (VRB).

# Hybrid Electric Vehicles

Hybrid electric vehicles combine two power sources with at least one powering an electric motor. The range of alternative power sources includes batteries, flywheels, ultracapacitors, and heat engines. Hybrid systems come in a variety of configurations. One would use a small, constant speed internal combustion engine as a generator to power high-efficiency electric motors at the wheels, with a highpower-density battery or ultracapacitor used to provide a current boost to the motors for acceleration or hill climbing. The internal combustion engine in this case could be small, efficient and clean because it runs at one design speed. Alternative systems could rely exclusively on batteries for most trips, with the engine-generator for extended range only, or they could use both electric motors and a small internal combustion engine to drive the wheels, perhaps with the electric motors providing high power only when necessary (OTA, 1994). The electric hybrid vehicle overcomes the performance disadvantages of pure battery-powered vehicles, but are more complex and expensive, while still offering bonuses in terms of emissions (TRB, 1997).

# Fuel Cells

A fuel-cell-powered vehicle is essentially an electric car with the fuel cell and storage tank (for hydrogen or for a hydrogen-carrying substance such as methanol) substituting the battery. If the fuel is a hydrogen carrier (methanol or natural gas; hydrogen itself is volatile and awkward), an on-board reformer is required to release the hydrogen from the carrier fuel. Fuel cells work by taking hydrogen and oxygen and putting them through a chemical reaction to produce electricity and water. Excess electricity from the fuel cell, as well as electricity obtained from regenerative braking,<sup>9</sup> can be shunted to battery storage. The vehicle can then use a high-power-density battery (or other storage devices such as an ultracapacitor or flywheel) to provide the necessary power boost for acceleration, so that the fuel cell does not have to be sized for the vehicle's maximum power needs.

Fuel cells are particularly efficient energy converters, they generate no harmful emissions,<sup>10</sup> and they can be refuelled quickly, so that range constraints are less of a problem than with battery electric vehicles once sufficient refuelling infrastructure is put into place. Three types of fuel cells may be suitable for light-duty vehicles: proton-exchange membrane (PEM) fuel cells, alkaline fuel cells, and solid-oxide fuel cells. Of the three, the PEM fuel cells are closest to commercialisation; the patenting of a method to achieve an 80-fold reduction in the amount of platinum needed in the cell has greatly enhanced the commercial possibilities (OTA, 1994). However, technological uncertainty remains higher than for battery electric vehicles.

PEM cells go back to the late 1950s. Until recently they required large quantities of expensive platinum as a catalyst to make the reaction happen - \$US30,000 worth for a car fuel cell. The Canadian company Ballard Power Systems started working on PEM fuel cells in the 1980s, and teamed up with a British specialty chemicals and metals company, Johnson Matthey, in 1993 to find ways of cutting back the platinum. They worked out how to adapt Matthey's catalyst technology (developed for catalytic exhaust converters) for use in PEMs. Having found a suitable method, Ballard then teamed up with Daimler-Benz to commercialise the use of the technology for motor vehicles (The Economist, 1997b). Ballard has now shrunk the size of fuel cells to the point where they can fit into the sub-compact Mercedes-Benz A-Class. On December 15, 1997, officials from Daimler-Benz and Ford agreed to form a new partnership with Ballard. A combined investment of \$US1 billion is planned, and the new consortium hopes to produce an initial 10,000-50,000 cars a

<sup>&</sup>lt;sup>9</sup> Regenerative brakes use the motors as generators to provide braking force and storing the electricity thus generated in the batteries.

<sup>&</sup>lt;sup>10</sup> Although the total system will generate emissions if the vehicle fuel is a hydrogen carrier such as methanol and must be converted into hydrogen on board.

year powered by fuel cells, starting commercially in 2004 (The Economist 1997d). The first prototype vehicle was driven in April 1999.

Ballard is now working out how to mass-produce fuel cells. A target of cost reductions of 90 per cent has been set for the year 2003 to make fuel cells competitive in vehicles. It is developing two fuel-cell systems for vehicles (one for cars, another for buses and trucks), but it is also developing systems for large and small power generators and for portable applications. Ballard does not have the field to itself - about 30 companies are actively developing fuel cells (part of the United Technologies Group) in the United States, De Nora in Italy, and Siemens in Germany. Among the vehicle manufacturers, General Motors and Toyota are also developing fuel cells (The Economist 1998d).

Hydrogen used in an ICE or to generate electricity in fuel cells would offer dramatic reductions in  $CO_2$  emissions, and the latter would also produce virtually no conventional pollutants. The extent to which these vehicles can reduce net greenhouse gas emissions will depend largely on the source of the hydrogen (natural gas, coal, or biomass; one day it may be possible to produce hydrogen by electrolytically splitting water using solar power). Safety in delivering and utilising hydrogen must be improved. Processing hydrogen on-board using a reformer may be safer, but reduces the environmental efficiency (TRB, 1997).

#### **Current Progress in Commercialisation**

Major initiatives to encourage electric and alternative-fuel vehicles are occurring in several states in America, as well as in Japan, France, and several countries in northern Europe. General Motors in 1996 commenced production of a battery-powered car, the two-seater EVI whose price has been reduced by more than a quarter through various subsidies. It is being marketed in a number of locations in southern California and Arizona, but it is not regarded as being suitable for the colder conditions experienced in the northern parts of the United States. It has a range of between 70 and 90 miles in normal conditions, and recharging can take up to ten hours. Available only on lease, and at the same price as a Cadillac, it had miniscule sales of under 300 in it its first year (The Economist, 1997a). In April 1999, General Motors and Toyota signed an agreement to produce a range of alternative vehicles, including battery-powered cars, hybrid vehicles and vehicles powered by fuel cells (The Economist, 1999, April). Ford has introduced a new electric utility the Ranger EV. However, there is considerable market scepticism in the United States about green cars, with petrol prices historically low and consumers apathetic (Fries, 1998).

Honda, initially the leading Japanese company in electric vehicles, announced a purpose-built electric car in April 1996. Toyota, in September 1997, unveiled a standard car (the RAV4) fitted with electric motors powered by fuel cells. It retails at twice the cost of its conventional alternative. Toyota then moved to developing a hybrid car using petrol on the open road and batteries in town. The new hybrid system achieves twice the fuel efficiency of a conventional petrol engine and cuts emissions to about one-tenth of the amounts set by current pollution regulations. This new Toyota model, the Prius, has acceleration comparable or better than a conventional vehicle and recharges itself on the road. However, it will be years before the hybrid system will be available across the Toyota range (Boyd, 1997). The Prius was launched at the Tokyo Motor Show in October 1997. As of mid-1999 it had sold 25,000 models in Japan, and a global launch was planned for 2000. The car is still about \$US3,000 more expensive than a similar petrol-engine model, so tax incentives are being sought (Bickers, 1999). Toyota's Prius is being followed by hybrids from Honda and Nissan (Fries, 1998).

Daimler-Benz has built a concept car powered by fuel cells which, in turn, have been developed by Ballard Power Systems of Vancouver.<sup>11</sup> This vehicle uses methanol as a feedstock, converted on-board into hydrogen. It has also introduced an electric van powered by a fuel cell. A commercial fuel-cell bus was launched in 1998, and a car should follow by 2003. Renault has developed a number of experimental hybrid vehicles. They include the Hymne series, parallel hybrids built on three different platforms, which have an electric and petrol engine driving the front wheels. These vehicles can be zero emission vehicles in town and reduced emission on the open road. Renault has also been working on series hybrids. In town, the electric motor (or motors) run off batteries. On the road, an alternator driven by a petrol engine keeps the batteries charged or provides current for the electric motor. Renault has experimented with two series hybrids: one with a turbine driving the alternator, and the other with a fuel cell. Renault hopes to have a hybrid vehicle on the market by 2003-04. Peugeot Citroën have provided six all-electric vehicles for self-service availability in the port of La Rochelle. Peugeot will bring out a purpose-built electric vehicle in less than three years, but it will be heavily subsidised

# **Materials Technology**

The materials used in an average vehicle - glass, steel, aluminium and plastics are highly energy-intensive. Moreover, traditional materials technology in vehicles are well short of optimal for recurrent vehicle energy consumption. Reconciling safety with environmental sustainability offers a considerable challenge to materials technology. Light composite structures can be even stronger than steel, although the assessment of the robustness of composites to accidental impacts is more difficult than for traditional metals. The manufacturing technology for strong, lightweight composite materials is still accomplished largely by hand and costs are prohibitive.

Much research needs to be done on the feasibility of automated manufacturing processes for new materials. Nevertheless, materials technology and its application

<sup>&</sup>lt;sup>11</sup> Daimler-Benz acquired a 25% stake in Ballard Power Systems in 1997.

to transportation in terms of motor body construction and for components is a key area for research in both the United States and Japan. Automobile manufacturers in these countries are working with materials such as carbon fibre to decrease weight and increase safety. Ford's new prototype P2000 has a curb weight of about 900kg, which makes it more than 500 kg lighter and 30 per cent more energy efficient than its conventional equivalent, the Ford Taurus (Fries, 1998).

#### **Electronics**

Electronics embedded in motor vehicles is a growth area. Most of the new engine technologies imply an enhanced role for electronics, as do innovations with respect to steering, braking and throttle control. Already, substantial technological change is occurring. The Mercedes-Benz S-Class car has a radar-assisted cruise control system that represents an important stage towards a self-running automobile. It also has systems to help with planning routes, avoiding traffic jams, and parking in tight spaces. Jaguar is to fit a similar cruise control system in its luxury cars, and Nissan is set to follow suit.

Cars have had on-board computers for years, but most have been limited to regulating engine performance or controlling braking and suspension. Now, however, the blending of car and computer technologies is being harnessed in new and promised innovations that will help drivers find their way in unfamiliar territory, pay road tolls without stopping, avoid traffic jams, access emergency help and repair, and utilise the kind of information and entertainment features currently available only at home or in the office. General Motors is planning to introduce in the next Cadillac line a night-vision system using an infra-red sensor. Some of the new systems in development are complex for users, and attention is being given to improving the interface with drivers. Jaguar's new S-Type saloon will allow a motorist to operate everything - from the sound system to the air-conditioning to the navigation computer - by voice. A further innovation is the reconfigurable display. Ford has a prototype on-board PC which can provide both the information currently conveyed by instrument panels and text displays, such as a newly-arrived email message. The Clarion AutoPC offers a choice of screen display or speech synthesiser for messages.

The potential blending of car and computer technology has strong support from the information sector. Netscape, Sun and IBM have formed a consortium to develop in-car computer systems. Microsoft has joined the competition with an automotive adaptation of its light-weight Windows CE operating system. While still pricey, in-car technology is getting cheaper. The motor vehicle industry recognises that it can push costs down further by standardising its technology. Ford, GM, Toyota, DaimlerChrysler and Renault recently joined together as partners in the Automotive Multimedia Interface Consortium, and most of the world's other car makers are expected to sign up shortly. Within the next few years, the consortium will issue standards for both hardware and software (The Economist, 1998e). A further application of electronic technologies relates specifically to air pollution minimisation strategies. Surveys indicate that a large part of the air pollution attributable to motor vehicles is caused by older vehicles that have been poorly maintained. Environmentalists in Germany have suggested installing a smart card in the electronic engine-management system that would record the pollution emitted by a vehicle. It would be read during periodic inspections and the information passed on to the tax authorities. Another method is being tried in Sacramento County in California. The program involves running an infrared beam across the tail-pipes of passing cars. Excessive levels of smoke or pollutants will distort the beam and trigger a camera to take a picture of the offender's licence plate. The provision of on-board diagnostics indicating the effectiveness of emission control systems will also be important.

# Vehicle Maintenance

New technologies have an important role to play in enabling improvements in the maintenance of road vehicles. On-board diagnostic systems monitor all the emission controls on a vehicle and warn the driver, through instrument panel displays, of any faults that may occur. These systems have become mandatory for new passenger motor vehicles in the United States. Even greater opportunities for detecting malfunctioning vehicles is provided by the use of transponders to allow roadside units to monitor the condition of vehicles as they drive by. Within 20 years, these systems could be installed in sufficient numbers to render inspection and maintenance programs unnecessary.

While diesel exhaust emissions pose considerable health threats, programs to identify and rectify high polluting diesel-powered vehicles are still constrained by the lack of a simple, low cost test to identify these vehicles. There is intense interest in the United States, Australia and parts of Asia in developing appropriate testing technologies (AATSE, 1997).

# **Trucks and Buses**

Improving energy efficiency in the freight sector rests largely on measures related to trucks: the introduction of new, more energy-efficient trucks, retrofit technology for the existing truck fleet, changes in operations to reduce waste, increased linkages with other transport modes, and shifting to other transport modes. There is considerable potential for improved truck energy efficiency from using commercially available and new technologies: incentives may be needed to encourage purchase of the most efficient vehicles and to reduce the age of the average truck fleet. Regulatory or fiscal policies will need to be established to encourage energy efficiency in commercial and road transport because of the great variety of truck types and cargo (OTA, 1994). Opportunities exist for the introduction of improved transmissions, and increased aerodynamic efficiency associated with lighter structures and better power/load ratios through the increased use of B-double and B-triple

combinations, although there are ultimate mass limits to the extent these designs can be taken, as well as impacts on road wear and tear to be taken into account. Improvements in tyre technology and truck maintenance offer further possibilities.

It should be noted that currently available technology does not allow automakers to improve light-truck fuel economy to the same extent that they improve passenger vehicles. Load carrying requirements impose structural and power needs that are more of a function of the payload weight than the body weight of the truck, yielding fewer flowthrough benefits from weight reductions. Open cargo beds for pickups and large ground clearance limit potential for aerodynamic improvements. Additional safety and emission requirements would create penalties for fuel economy.

The original focus of program for heavy-duty trucks, buses and other diesel vehicles was smoke control because smoke was clearly visible and considered to be a nuisance. As the evidence for serious health and environmental risks associated with diesel exhausts has grown in recent years, more attention has focused on control of the particles themselves, particularly for health reasons. Although smoke standards lower visible smoke, they are not as effective at lowering particulate emissions as standards for particulates (Schwela and Zali, 1999).

But tampering with the fuel characteristics alone will not do the trick. There needs to be a re-configuring of the powertrain into a more environmentally friendly technology. Many European engines can, through improved engine design, now meet Euro 2 emission standards (which unlike Euro 1 include stipulations on particulates) by burning low sulphur fuels. In the US truck engines have also increasingly measuring up to similar standards. But the next rung up, Euro 3 standards, can only be met by CNG engines, although some believe that diesel technology is advancing towards that end, especially if used in combination with ethanol-diesolene blends. (Fisher, 1999).

With respect to urban buses, similar possibilities for improved efficiency in design exist as for other larger vehicles. Transport Energy Systems in Brisbane is developing a low emissions-discharge, hi-tech hybrid bus suitable for public transport. Retrofitting urban buses offers possibilities in many countries.

# **Transit Vehicles**

Investment in passenger rail services is growing around the world as urban congestion worsens and car traffic is restrained. The deregulation of railways is increasing their flexibility, and the financial performance of rail services is improving in many countries. A combination of road and air traffic congestion, deregulation and innovation has transformed the prospects for passenger rail. For journeys between 100 and 400 miles, rail is now usually quicker than either air or road from city center to city center if access times are taken into account, and it is undoubtedly more energy-efficient and safer (The Economist, 1998a).

Japan's *shinkansen* railway, which operates between Tokyo and Osaka, a distance of 312 miles, is usually cited as the model for contemporary high-speed

rail services. The service has been continuously upgraded to the point where the journey takes 2.5 hours, and 368,000 passengers a day are carried, and holds 84 per cent of the Tokyo-Osaka traffic market. Advanced train design, transmission-based signalling, and an army of 3,000 workers who carry out essential maintenance after rail operations close down at night ensure both excellent service and an exemplary safety record (The Economist, 1998a).

High-speed trains using conventional steel wheels on steel rail are now widely used for inter-city passenger traffic in Europe (particularly in France, Germany, Spain and Italy), with plans for their utilisation in the United States, Korea and Taiwan. Japanese and French engineers are now working on new ultra-fast train designs that could raise speeds from the 120-130 miles per hour applying for European very-fast-trains and the 170 miles per hour of the *shinkansen* to a cruising speed of 225 miles per hour. However, high-speed conventional trains face problems as they push speeds higher and higher. The impact of the *shinkansen* travelling at high speed is so intense that sonic booms are triggered off as they enter tunnels. As a result, cowls have had to be fitted at tunnel entrances in an effort to limit the disturbance. In addition, *shinkansen* trains have to be expensively pressurised to prevent damage to passengers' eardrums.

The huge cost of building new high-speed railways, and environmental concerns, have encouraged alternative technological approaches to reducing rail journey times. Tilt technology is the most noteworthy of these alternatives. Tilt technology allows trains to run up to a third faster on old track by using suspension systems that lean into bends. The *Pendolino* tilting train built by Fiat Ferroviaria now operates in Germany, Finland, Switzerland, Spain, Portugal and the Czech Republic, and will soon be introduced in Britain. Other types of tilting train are in operation in Sweden, and will become operational in the United States. Tilt technology requires only modest track upgrading, and the trains are only a third higher in cost than a conventional train.

Another alternative to high-speed conventional trains is the magnetically levitated train (maglev). The maglev has the advantage over the high-speed trains of being much quieter while being even faster. Both the Japanese and the German governments are investing huge sums in magnetic levitation. The technology involves the use of high-powered magnets and linear-induction motors to lift, guide and propel trains along a cushion of air along a concrete track. The construction of a 250 mph maglev link between Hamburg and Berlin, that will cost \$US5.4 billion but will cut the time of a journey to under an hour, is due to begin in 1999. Commercial operations are expected to start in 2005. The Japanese government is also contemplating construction of a maglev track between Tokyo and Osaka (The Economist, 1998a).

Rail has become an increasing focus of attention for intra-city transport. Current investment in mass transit and light rail systems in a number of Asian cities, notably Taipei, Seoul, Bangkok and Singapore, is huge. Technological innovations in such areas have tended to be incremental. The application of information technologies enable driverless people movers to operate on light rail systems. In Singapore, the introduction of sophisticated signalling equipment has enabled the headway of trains in the Mass Transit System to be reduced from 3 minutes to 1.5 minutes in peak periods.

While inter-city trains have been the main focus of new technological development over the past thirty years, urban people-mover systems may also benefit from new designs. Guideway-based (driverless) systems are a form of "Advanced People Mover" which has been under active development since the 1950s. These systems can be categorised into either "Personal" (taxi-sized vehicles not shared with strangers), "Group" (shared vehicles of varying size), or "Freight".

The term "Personal Rapid Transit" (PRT) describes small (typically three to six seat) automated vehicles that usually operate on demand at any time on a guideway network. The vehicles, once boarded, go non-stop to the passenger's destination. They thus provide the required key service elements currently offered only by private cars and taxis. "Dual mode" PRT systems accept vehicles which can operate on surface streets as well as under system control on the guideway. "Group Rapid Transit" (GRT) describes shared vehicles, up to the size of a railway carriage but usually smaller, that operate on a fixed schedule and with scheduled stops.

These systems utilise various combinations of computer, communications and control systems technology. The basic technology of their operational systems has been available for more than 20 years, and some systems in actual operation were developed in the 1970s. Vehicles may be "supported" (run on guideways) or "suspended" (hung from guideways). Support for the guideways may be via conventional wheels (rubber or steel) or magnetic suspension ("maglev"). The Australian Austrans vehicle now in development uses a new type of wheel technology that enables vehicles to turn around tight corners, thereby enabling cheaper guideways to be built around winding streets (Roberts, 1998).

#### **Aviation**

From a social perspective, safety is the key issue associated with aviation services. From an environmental point of view, noise and emissions are the major considerations. Aviation emissions impact on air quality when they occur at ground level or low altitudes. Emissions above a certain level will be dispersed and are unlikely to contribute to ground level pollution. As a rough guide, it is the last 20 kilometres before landing and the first five kilometres from take-off that are most important with respect to environmentally significant emissions (AATSE, 1997).

Since the 1970s there have been ongoing sources of improvement in the sustainability of air transport from continuous technological progress in the design of civil aircraft. As a result, the following effects have occurred:

improved fuel efficiency;

- reduced emission factors for all pollutants except NOx and N2O (for which they have increased);
- reduced noise; and
- improvements in safety (except for general aviation, which will undoubtedly benefit from a major research program now under way in the United States).

Further improvements can be expected over the coming decades.

When considering the environmental impacts of aircraft it is especially important to consider emissions of nitrogen oxides, which have a powerful indirect greenhouse effect when injected into the troposphere at the heights at which commercial jet aircraft fly, which also happens to be the height where they have the most impact on global warming. The study (Martin and Michaelis, 1992) finds that the contribution to global warming of air travel is some 4.3 times greater per passenger-kilometre than that of travel in a new-model, gasoline-powered automobile, and more than 10 times greater than that of travel by bus or train. The impact of air freight is approximately 20 times greater per tonne-kilometre than for a medium-sized truck and more than 240 times greater than for slow rail (OECD 1996).

A special report prepared by the Intergovernmental Panel on Climate Change (IPCC) quantifies the effects of aircraft operations on the atmosphere for the first time and suggests that contrail-formation, not ozone-depletion, could have the most detrimental effect. Contrails produced by aircraft when water vapour condenses at high altitudes had previously been considered relatively benign in terms of climate change. However, researchers have discovered evidence that persistent linear contrails evolve and create clouds that would not have formed in the same way if an aircraft had not passed through. While difficult to quantify at this stage, the contribution of contrails has a big potential impact on radiative forcing and hence climate change. The results could provide encouragement to the introduction of more stringent engine-emission regulations, environmental levies, emissions trading, and a transition from air to rail and other forms of ground transportation, particularly in densely populated regions such as Europe (Scott, 1999).

# **Travel Demand and Traffic Management**

Cars on congested roads are the most serious source of central city air pollution. Reducing the demand for travel and facilitating smoother traffic flows are key elements in achieving environmentally sustainable cities. Travel demand management (TDM) is an important technique for dealing with this problem. TDM is intervention, other than the provision of new infrastructure, to modify travel decisions so that improved economic, social and environmental outcomes can be secured and the adverse impacts of travel can be reduced. TDM can assist the realisation of social objectives by improving accessibility, safety and security for all groups in the population. It can further environmental objectives by promoting the use of more ecologically sustainable transport modes, and it can increase economic efficiency through the more efficient utilisation of existing infrastructure.

Newly emerging measures are expected to contribute significantly to the improved efficiency of the management of traffic and travel demand. They are largely based on the use of advanced information technologies to provide information which greatly increases the scope for efficient traffic management, makes road pricing more feasible and provides advanced traveler information and driver assistance.

# **Electronic Road Pricing**

Electronic road pricing had its origins as a means of implementing toll charges on major motorway projects. However, its application to time-sensitive roadway charges that discourage congestion is now attracting attention. By 1997 some \$US3 billion of electronic charging systems had been installed worldwide (The Economist, 1997c). The latest automated tolling equipment, which deducts charges from electronically tagged vehicles, travelling at speeds of up to 100 miles per hour, is being installed in more than 20 countries around the world.

Singapore has been the pioneer in road pricing. It began with a system of area-access charges based on paper licences, in 1975. In 1989, licences were introduced for driving into the central area during the peak traffic periods. Direct congestion charges are now implemented by a cordon of toll points around the inner city area in Singapore. Vehicles are electronically tagged, and charges vary by time and day (The Economist, 1998b).

The European Commission has developed a program known as Eurotoll. It has the objective of ascertaining how high charges need to be pushed in order to change drivers' behaviour. Earlier research conducted in the city of Stuttgart has shown that different tariffs for peak and non-peak hours and for alternative routes did affect the flow of traffic, but charges were less effective in persuading drivers to give up their cars in favour of other means of transport, although demand for parkand-ride facilities was increased (The Economist, 1996a).

Road-pricing schemes based on peak-hour charges have been successfully operating for more than six years in the Norwegian cities of Trondheim, Bergen and Oslo. The Netherlands plans to introduce road pricing by the year 2001 over the densely populated Randstad area (which is centerd on the cities of Amsterdam, Rotterdam, Utrecht and the Hague). Tolls will vary according to the time of day, and it will be impossible to enter the center without passing a toll point. In France, the motorway company that runs the A1 north of Paris towards Lille introduced variable pricing with the effect of speeding journeys and reducing jams during hightoll periods.

In California, electronic road pricing is being used to encourage ride-sharing. Drivers carrying more than three people pay nothing. Route 407 in Toronto is a totally-electronic toll road that has charges varying on an hourly basis. Current technologies used in the latest tolling equipment can electronically charge vehicles on multi-lane motorways, even if they switch lanes at high speed. Pre-paid smart cards purchased by drivers to pay tolls can be slotted into the in-vehicle unit that links to the toll gantries, thereby preserving privacy. Recording of licence plates on camera is required only for vehicles that fail to carry a valid card. Vehicles diverting away from tolled routes on minor roads are a more difficult problem. This is where American plans, taking the technology a stage further, will become really useful. By using global positioning satellites, combined with in-car receivers and digital maps, vehicles can be charged wherever they are within a specific geographic area and at rates that vary according to the time of day and degree of congestion (The Economist, 1997c).

Perhaps the most important policy issue associated with electronic road pricing is the persuasion of motorists that road pricing is good for them. The use to which revenues are put is crucial in convincing voters that road pricing is desirable. Borrowing against future revenues allows spending on better public transport or other transport infrastructure to be brought forward so as to coincide with the introduction of road pricing. This has been the key to the success of Norway's road pricing initiatives.

#### Intelligent Vehicle-Highway Systems

Intelligent vehicle-highway systems (IVHS) encompass several different technologies that can provide services ranging from timely information about congestion and alternative routes to fully automated control of vehicles on limited access roads. Drivers can obtain real-time information about road and traffic conditions, directions to unfamiliar or distant sites, identification of alternative routes, and determinations of optimal and safe driving speeds and automobile spacing on roads. These technologies have the capacity to increase road capacity by 10 to 20 per cent by encouraging the optimal use of road space, improving the flow of traffic, and reducing congestion (OTA, 1994).

IVHS technologies include advanced traffic sensing and signal control technologies to improve traffic flow, as well as on-board systems to help drivers interpret highway system data to reduce travel time and improve safety. IVHS comprise three major groups of technologies: advanced traffic management (ATM), advanced traveller information (ATI), and automated vehicle control (AVC).

ATM technologies are designed to monitor traffic by using radar and other remote traffic systems to analyse data derived from these monitoring systems, to alter traffic flows electronically by adjusting signal timing and freeway ramp controls, and by providing information on roadside bulletin boards. ATM bypasses direct participation and interaction with the driver. The Tomei Expressway, Japan's busiest motorway, has been using ATM technologies for some years on a 250 kilometre stretch leading out of Tokyo (The Economist, 1992b). In Seattle (Washington State, USA) transportation authorities provide a website with an up-to-date map of motorway hotspots, and the site is viewed some 300,000 times a day on the Internet (it will soon become available on cable TV). The Seattle system also allows traffic signals to be adjusted to traffic flows. Turin in Italy is testing a system that turns traffic lights green for heavily loaded buses, but not for empty ones. On Toronto's Highway 401 (Canada), sensors buried in the roadway detect when traffic is slowing, and video cameras let controllers see the problem. Among other things, this system has cut the average time required to clear minor accidents from 45 minutes a decade ago to just 20 minutes today (The Economist, 1998b).

ATI technologies are on-board systems that impart information about traffic conditions and alternative routes and may include electronic maps and navigational tools. ATI information may be tailored to an individual driver's travel plans. They are particularly useful for drivers with multiple route options. Such systems could also pre-book parking spaces and even hotels. For some European countries, BMW now offers a built-in electronic road map with information on the state of motorway traffic,<sup>12</sup> and a similar system is available in some Avis rental cars in the United States.<sup>13</sup> There are at least fourteen different navigation systems available in Japan. Oztrak, a start-up firm partly owned by the University of Ballarat in Australia, has developed a Telematic Starter Kit now licensed to ADAC, the huge German automotive club, that is installed in a car and uses a keypad hooked to a standard mobile telephone. Drivers can use it to request such services as roadside help, travel information, and accident assistance.

AVC technologies are on-board technologies geared towards traffic safety. They can assist drivers with such facilities as adaptive cruise control, obstacle detection, and infrared sensing to improve safety for night driving. Other AVC technologies are designed to intervene directly in driving. They include automatic braking and manoeuvring. The rationale behind these technologies is to maintain optimal, but safe, distances between vehicles to improve driving and traffic flow. The most ambitious AVC technologies under development involve automated driving, where human drivers essentially become passengers until reaching their destinations. They may have their first practical applications on motorways. Already, some Greyhound buses in America carry microwave radar to monitor their distance from other vehicles and their closing speeds, and many American school buses use another version of this system to alert the driver to children behind or beside the bus where they cannot be seen in mirrors. Systems currently operational include speed monitors that warn drivers who go too fast, or alert drivers who stray out of lane or show signs of sleepiness, and which brake or steer automatically in certain circumstances (The Economist, 1995).

<sup>&</sup>lt;sup>12</sup> A network of sensors equipped with radio beacons to collect and transmit traffic information from along the motorways and major trunk roads in Britain (the so-called Trafficmaster system), and in several other European countries, is now available.

<sup>&</sup>lt;sup>13</sup> Delco, the components arm of General Motors, is developing a sophisticated new navigation system for America, and the European Union is supporting similar research in conjunction with Mercedes-Benz, BMW, Fiat, Renault, Ford and GM Europe.

In August 1997, the middle two lanes of an eight-mile stretch of highway near San Diego, California, was taken over for an experiment with AVC technologies. Squads of 10-12 vehicles equipped with sensors, radar scanners and dedicated onboard computers communicated with each other and a control center and were operated on automatic control, travelling a distance of two metres apart at motorway speed. The experiment was designed to ascertain the degree of automation that works best. The American Government has spent around \$US1 billion on AVC technologies so far, working with a consortium of companies that includes General Motors, Lockheed Martin and Bechtel. The Americans believe that they will have a fully-tested prototype intelligent highway system up and running by December 2001 (The Economist, 1996b).

The Japanese Government, in collaboration with public agencies and the private sector, has initiated a program known as Japan's Intelligent Transport System (ITS). The first phase of the program began in 1997 and involves the promotion of car-navigation systems, for which an annual market of 800,000 systems has been identified. Traffic information is being distributed through a Vehicle Information Communication System. Covering a number of key locations at present, it will eventually span the whole of Japan's highway network. Electronic toll collection on the roads is to spread during this phase of the program. In the second phase, intended to be in place by 2005, drivers will receive optimised route planning, which will include not only the fastest and least-congested way to drive, but also all the public-transport options for the same journey and the times they take. The information will be distributed by the ITS, picked up by car antennae and accessed via computer screens in cars. The system will also give drivers warnings of accidents ahead and suggest different routes to avoid them.

The third phase of Japan's ITS, which is due to be in place by 2010, involves the development of an AVC system. The plan is for the government and the private sector to collaborate on the installation of a system of "magnetic nails" or electronic markers under expressways at 50- or 100-metre intervals. Time taken between nails, which will communicate with receivers in the cars, will determine the speed of each vehicle and regulate the space between it and the car in front. Lines of these nails will also enable each vehicle to stay in its own lane. The cars will be controlled by a microwave or fibre-optic system that is already installed nation wide (Firth, 1997).

Members of the European Union have agreed to develop trans-European networks that would encompass energy, telecommunications and transport technology. The European Telematics Applications Program, which ran from 1994 to 1998, encompassed vehicle safety, navigation and transport efficiency. The advanced vehicle-safety systems in development included multi-directional collision avoidance, preventing impacts with objects in front, behind or to either side. They also covered restraint systems which sense impending accidents and activate passenger-safety devices before impact, and vision enhancement for crash avoidance (Firth, 1997).

Jaguar is developing a large range of safety systems for its cars, including collision-avoidance and collision-warning systems, an intelligent cruise control system that detects the speed of the vehicle in front and maintains a safe distance from it, plus screens displaying traffic information beamed in from roadside beacons. Jaguar's cruise control is modified from defence technology, and uses laser and infrared laser systems. Adapting defence technologies to the use of the civilian vehicle industry is not easy because many defence technologies are prohibitively expensive or conflict with safety criteria. Jaguar cooperated with Texas Instruments of the US, Pilkington Optronics and Cranfield University in Britain in the Prometheus program over the years 1986 to 1994. This program examined ways in which aspects of military technology could be adapted for automotive applications. Among other innovations, it resulted in the development of a night-vision for cars reminiscent of the systems used by helicopter pilots in the Gulf War.

As with electronic road pricing, IVHS technologies will work best through broad applications across traffic systems and the vehicle fleet rather than through incremental investments. Moreover, many on-board technologies require driver interaction and attention which may reduce safety by distracting drivers. Finally, concerns about legal liability in cases where AVC technologies fail and cause accidents may limit industry interest in these tools. Nevertheless, the development of IVHS technologies in the United states has been considerable, and the use of technologies to improve the timing of traffic lights has indicated the substantial gains that can be made through the application of newer technologies (OTA, 1994).

ITS America, a government-backed pressure group, suggests that the introduction of "intelligent vehicles" and "intelligent highways" could cut expected congestion by 20 per cent and accidents by 8 per cent by the year 2011. Their introduction could also create new options for car design, including lighter car bodies and propulsion systems requiring less power (The Economist, 1995). Finally, the developments occurring in Seattle have shown that intelligent transport technologies can be applied to encouraging public transport. By attaching global positioning devices to buses, information can be made available, both at busy pickup points and on websites that allow commuters to see exactly where their bus is currently located.

#### **Transport Logistics**

Logistics is the management of the flow and storage of raw materials, goodsin-progress and final goods from point of origin to point of final consumption; it includes the recovery and disposal of waste products. Cost, quality of service and timeliness are the key parameters of the economic efficiency of logistics, while sustainable logistics also takes into account social factors (accessibility and safety) and environmental considerations. Globalisation and technological change have increased the importance of logistics. Globalisation has increased competitive pressures and therefore the priority accorded to cost reduction and early delivery to market. Technological change has reduced product life, further increasing the importance of early delivery to market. The greater use of outsourcing in manufacturing has added to the complexity of logistics. Finally, increases in the value-weight ratio of traded goods and a decline in the real cost of transport has made higher speed transport an affordable alternative.

Technological change has also offered new solutions to logistical problems. Improvements in information technology are one example of this trend, but the standardisation of container sizes and the development of groupage services is another.

The benefits of logistics management include savings in transport costs; reduced stock levels (facilitating savings in working capital); increased flexibility in the manufacturing process; the ability to customise the product close to the market; a reduction in the need for product tracking; and the smoother introduction, and phasing out, of product lines. In addition to these economic benefits, logistics management offers advantages with respect to the environmental and social aspects of transportation with its implications for the minimisation of transport movements and the potential for greater accessibility.

Logistics is only effective when there is an adequate supply of information about what is happening at each point in the supply chain, and when available alternatives are well known and understood. The improvements in information technology therefore make increasingly sophisticated logistics management possible. There is much debate about whether the availability of increased information is lengthening or shortening supply chains, acting as a substitute for transport, or enabling transport to be performed more efficiently.

The speed with which logistics management techniques have been brought into common use varies considerably both between industry sectors and between countries. The initiative appears now to be with customer companies, rather than their suppliers or freight forwarders. Companies experienced in the use of new technology and modern management techniques have become most active in logistics management, and geographic or functional clusters of such companies are the drivers of change (Euro-CASE, 1996).

The effectiveness of logistics can be enhanced if attention is given to removing certain obstacles and increasing awareness of the benefits among non-users. Among the obstacles identified in many areas are the absence of a bar-coding system suitable for tracking goods, a lack of policies on electronic commerce, and regulations against, or resistance to, night-time collection and delivery systems. With respect to raising awareness, support systems for electronic data interchange (EDI) have been identified as being important. Singapore; Hong Kong, China; and Malaysia are leaders in this respect (Euro-CASE, 1996). High quality electronic logistics systems are increasingly being used by road freight operations in the advanced economies, as are rail freight operators.
The Internet is now beginning to be used to increase the efficiency of the road haulage industry. National Transportation Exchange (NTE) uses the Internet to connect shippers who have loads they want to move cheaply with fleet managers who have space to fill. NTE helps to create a spot market by setting daily prices based on information from several hundred fleet managers about the destinations of their vehicles and the amount of space available. It then works out the best deals. The whole process takes only a few minutes. NTE collects commission based on the value of each deal, the fleet manager gets extra revenue that he would otherwise have missed out on, and the shipper gets a bargain price, at the cost of some loss of flexibility.

When NTE was first set up four years ago, it used a proprietary network, which was expensive and limited the number of buyers and sellers who could connect through it. By moving to the web, NTE has been able to extend its reach down to the level of individual truck drivers and provide a much wider range of services. Before long, drivers will be able to connect to the NTE website on the move, using wireless Internet access devices (The Economist, 1999b).

#### **The Freight Sector**

Three approaches can be taken to securing more sustainable freight transportation: improvements in the engine technology and other aspects of truck design such as aerodynamics (dealt with above); utilising options such as load aggregation and electronic commerce to shift road freight to rail and sea; adaptations in land use planning; and improved transport logistics.<sup>14</sup> The locations of major freight generating activities, such as transport terminals, distribution centers, factories and shopping centers, will have a major effect on the pattern of urban freight transport and its impact on the urban environment, particularly through reducing the number and length of freight trips.

Improved transport logistics can lead to improved environmental outcomes. Examples include:

- selecting the best mode of transport for the task;
- improved coordination of pickups and deliveries;
- using the most appropriate vehicle for the task;
- improved driver behaviour (impacting on fuel consumption and vehicle wear and maintenance);
- increases in vehicle capacity; and
- improved traffic management and reduced stop-start driving.

Unladen trucks produce emissions without any freight transport output. Greater coordination of pickups and deliveries can improve vehicle utilisation.

<sup>&</sup>lt;sup>14</sup> Note also the advantages associated with allowing larger truck configuration such as B-doubles and road trains, which reduce total kilometres of freight transport (although their impact on road maintenance needs to be taken into account and an overall costbenefit assessment undertaken).

Improved routing and scheduling of trucks, increased back-loading, driver communications and information systems and extended operating hours can all improve efficiency. The utilisation of advanced technologies for vehicle location monitoring, computer aided routing and dispatch, and data and voice communications can all yield benefits to freight efficiency. Extended warehouse operating hours enables trucks to make pickups and deliveries at times of low road congestion.

Transport logistics has the potential to have a huge impact on freight movements. Supply chains can be completely restructured to fit in with transport schedules and optimise transport-storage relationships. The restructuring can go as far as the redesigning of products. Suppliers of intermediate products can be encouraged to co-locate to form clusters of related activities.

A number of new technologies for inner city urban freight systems are under development, including:

- AGV Navigation System a prototype from Israel that uses automated guideway vehicles for moving cargo at seaports;
- Combi-Road, a new concept from the Netherlands for the surface transport of containers;
- Subtrans an American freight system that utilises underground tubes;
- HighRail an American system currently under development that uses a monobeam for two-way travel on one narrow guideway; and
- The Japanese Automated freight System which proposes to use dualmode trucks for inner-city and intercity freight movement.

# Uncertainties about Future Influences on Urban Transportation

There are many uncertainties about the future influences on urban transportation. Some of them relate to factors that will shape the economic, environmental and technological framework within which transport systems will develop. Other uncertainties relate to the way in which both households and business react to changing circumstances.

# **Economic Trends**

Many projections about the future demand for transportation are based on the assumption of a continuation of past economic trends into the future. However, alternative and vastly different economic scenarios for the future are also plausible.

One scenario would be based on the assumption of wider sharing of technological information which leads to an acceleration in the contribution of technology to world economic growth. In this scenario, world growth rates accelerate, along with the growth in personal incomes, leading to a strengthening in government finances. In these circumstances, transport demand pressures intensify, but the resources are present to increase innovation in transport policy and transport technology. In such circumstances, environmental problems associated with transportation may be more speedily resolved, but social problems may not if rapid economic growth is accompanied by an intensification of structural change in employment leaving some groups in the community worse off.

A second, and more pessimistic, scenario about the world economy is based on increased global financial instability. The trends in financial markets of the past decade or so intensify. There are marked swings in the allocation of financial funds between economies and between financial instruments leading to intensifying swings in stock prices and the spread of yields on financial securities. These trends are accompanied by growing instability in the banking systems in many countries as banks encounter major difficulties in managing the much greater risks involved. In different countries at different times, financial instability results in severe economic recessions. The general pattern emerging would be one of increasing fluctuations in world economic growth around a reduced long-term trend. In these circumstances, while the demand for travel will grow much more slowly than in the past, the financial capability to adopt improved policies or new technologies will be much reduced, leading to the possibility of declining environmental sustainability of urban transportation. Social stresses would increase as unemployment rises, accentuating difficulties of access.

#### **Technological Discontinuities**

The optimistic economic scenario identified above may coincide with unexpectedly rapid breakthroughs in transport technologies or in energy economics. In the first instance, possibilities include accelerating change leading to hydrogenfuelled, almost completely emission-and -energy efficient personal cars, through to new modes of personalised transit that are highly energy-efficient. On the latter possibility, solar energy and/or fuel-cell technology might rapidly displace conventional fossil-fuel technology as a means of generating electricity. New technologies would enable reduced waste outputs from transportation, although issues such as the harmful impact of transport infrastructure on the local ecology and social isolation may not necessarily be addressed.

An alternative scenario is one of a slowing of technological change as information flows reduce as a result of business concerns about the possible flows of benefits form in-house research and development to competitors and increased international barriers to technology flows. The slowing of technological change would put enormous strain on the other mechanisms for changing transportation in a more sustainable direction.

#### **Oil Crises**

A combination of declining non-OPEC oil production and rising demand for crude oil, would greatly increase the leverage of OPEC (particularly a small number of Gulf) producers. In these circumstances, political conflict in the Middle East or an internal political crisis in Saudi Arabia could trigger savage price rises and physical shortages of petroleum products, leading to accelerated energy-saving policies and technologies. The development of hydrogen-powered fuel cell motors and fuel cell technology in power generation would be greatly encouraged.

An alternative scenario is based on the assumptions of improved recovery technologies which boost crude oil production over the coming decade or so combined with decisions, under political pressure, to cut fuel taxes. Reduced real oil prices would greatly diminish the incentive to adopt more energy-efficient transport solutions, thereby exacerbating a range of environmental problems associated with increased transport demand.

### Greenhouse Concern and Policy

Global warming trends could be offset for a substantial period by mediumterm global cooling associated with complex, and little-understood, ocean circulations (as in the period after World War II), or the wider distribution of pollutants reducing exposure to the warming effects of solar radiation in heavilypopulated regions. This could encourage complacency and backtracking on global commitments on greenhouse emissions policies. Eventually, as the medium-term influence moves from cooling to warming, it interacts with long-term global warming associated with greenhouse emissions, leading to a marked increase in global temperatures, for which the world would then be ill-prepared.

The above challenge may come sooner if medium-term influences reinforce the long term influence on global average temperatures. Inundation of low-lying areas would be the most dramatic side-effect, impacting on highly populated areas in Bangladesh, China and Java, for example. Agricultural production would be affected, with falling yields in some places and rising yields in others, and there would be significant incentives for the genetic modification of the principal crops. The consequence would be pressure to enforce the existing Kyoto protocols and to develop a new and stricter set of protocols. This, in turn, would act as a major spur for local changes in policies and for global technological change. Against this, sudden disasters might be politically disruptive with pressures emanating from international population movements.

### **Social Factors**

Perhaps the greatest uncertainty in the social arena is the lack of detailed knowledge of how households, and to a lesser extent businesses, will react to changing circumstances in transportation markets. Reactions to change are not only difficult to predict at a general level, since key variables determining transport behaviour will be moving outside the range of past experience, but they will be even more difficult to predict at the level of the individual metropolitan area, since insufficient work has been done to assess the importance of local reactions to changes in the environment shaping transport demand.

Other social factors are difficult to forecast. For example, it is possible that the motor vehicle becomes an even bigger status symbol than it has in the past, particularly in developing economies. This would lead to stiffening resistance to many sustainable transportation initiatives.

The optimistic scenario would be a radical shift in community preferences and values that downgrade the status of the car and the social acceptability of driving. Indeed, if green awareness and green values become strong social drivers in the community, conventional motor cars may take on the outcast social status of smoking, for example. This would clear the way for major changes in sustainable transportation policies.

# Policies for Sustainability

# **Traditional Policy Approaches**

Traditional transportation policy approaches focus on optimisation of the transport vehicle fleet (standards which new vehicles are expected to meet, vehicle maintenance, and fuel standards), and the development of transportation systems (involving both transport logistics and urban design).

### **Optimisation of Vehicle Fleets**

Ambient air quality standards, first established in the United States in 1970, are designed to achieve a desirable level of air quality and protect society and the environment from the harmful effects of air pollutants. They provide an essential reference base for other standards, such as emission standards and fuel quality standards. In order to determine compliance with ambient air quality standards, systems of ambient air quality monitoring have been developed. They involve sampling pollutants, analysing the samples, data collection, and data transmission and control.

Emission standards for new motor vehicles have been a key means of addressing the environmental sustainability of transport. Regulations set by the United Nations Commission for Europe are the only true international standards applying to motor vehicles, and they have been substantially upgraded in recent years. They are on a par with those applying in the United States, which, in turn, influence the standards applying in Latin America. The objective of emission standards is to limit discharge of air pollutants from new motor vehicles. The establishment of vehicle emission standards has provided a major impetus for research and development of engine designs and pollution control technologies (World Bank, 1997). To be fully effective, emission standards for new vehicles need to be accompanied by:

- certification that vehicles actually manufactured comply with the standards;
- the performance of assembly line testing to ensure compliance;
- the recall of vehicles where noncompliance is identified; and
- consumer warranties for defective design or workmanship of vehicles' emissions control equipment.

Regulations targeted at improving the performance of automobiles have generally been far more successful, politically speaking, than those that seek to modify travel behaviour. The United States has made more headway in legislating the design of fuel-efficient, low-emission cars than any other nation. New cars now emit 90 per cent less pollutants than a typical 1970 model, although this has been at the cost of a slight loss in fuel efficiency and at the expense of more carbon dioxide emitted into the air. Today, with the stepped-up use of oxygenated fuels and the retiring of older vehicles, carbon monoxide is no longer a serious outdoor pollution problem in most American cities. Fewer inroads have been made in eliminating the serious health threats posed by fine airborne particles, with diesel engines being a significant source of particulate emissions (Cervero 1998).

To fully realise the benefits of tightening new vehicle standards, there is a need to ensure that emission control systems remain effective throughout each vehicle's operating life. Research conducted in Australia by the Federal Office of Road Safety (1996) has shown that deterioration, abuse and tampering over the life of a vehicle can result in emissions from individual vehicles being up to 100 times higher than typical new vehicles. There is an average tenfold increase in emissions by the time a vehicle reaches the median age (10-11 years) of the fleet. Developments in vehicle emission testing technologies have greatly reduced the cost of routine testing of in-service vehicles to identify high polluters. The reported average cost of repairing identified high polluters is \$A240 (\$US160). It usually involves quite simple maintenance tasks, such as the replacement of plugs, points and filters.

Inspection and maintenance programs need to be adopted to ensure compliance with standards; roadside inspection programs are an alternative sometimes used where periodic inspection and maintenance programs are not implemented. The retrofitting of older vehicles, involving engine work, installing pollution control components, or changing fuel systems to burn cleaner fuels, is another policy option. Finally, vehicle replacement programs designed to eliminate the most polluting vehicles are a further option. These programs produce financial incentives to scrap or replace such vehicles. They have been used in Hungary, the United States and France (World Bank, 1997).

Fuel standards play an important role in strategies designed to reduce emissions. Regulations have encouraged the introduction of unleaded petrol across most of the advanced economies. The widespread adoption of unleaded petrol is a major health priority for the emerging economies. Attention is now focussed on the reformulation of petrol, the aims being to reduce evaporative emissions through reduced volatility, improving the efficiency of catalysts through reducing sulphur, and adding oxygenated blend stocks (with a corresponding reduction in the highoctane aromatic hydrocarbons which might otherwise be required). A number of countries regulate the benzene and aromatic hydrocarbon content of petrol in order to reduce the toxic properties of emissions.

Current regulatory attention is being given to the tightening of diesel fuel standards with particular reference to reducing sulphur levels, but a reduction in the fraction of aromatic hydrocarbons in the fuel is also being sought. Europe is leading the way on this issue. Detergent additives in diesel fuel reduce smoke levels, and this may be helpful in reducing SPM emissions although this has yet to be firmly established. Another related issue is the use of additives in diesel fuel to help reduce the build-up of gums, varnishes and carbon deposits on engine components. Such deposits can result in degradation of the combustion process and increased emissions. Alternative fuels for buses under consideration are natural gas methanol made from natural gas and, in limited applications, LPG.

In developing economies, emission standards, vehicle inspection and maintenance programs, and fuel standards have traditionally lagged well behind that of the advanced economies. However, progress in raising standards is being made in a number of countries.

In Thailand, unleaded petrol, introduced only in 1991, has now completely displaced leaded petrol. Standards for diesel fuel have been raised, taxis and tuktuks have been converted to operate on LPG and buses are being converted to CNG. Motorcycles now have to meet European standards. All new vehicles are now inspected to ensure compliance with noise and emission regulations, and inspection requirements have been established for all in-use vehicles (Schwela and Zali, 1999 and Chaimankong, 1999).

In the Philippines, progress is being made towards achieving:

- The establishment of a motor vehicle inspection system;
- The introduction of a clean air fee as part of the vehicle registration process (this is seen as discouraging the import of second-hand cars that are high emitters of pollutants); and
- The phase-out of leaded petrol, improving the quality of diesel fuel sold,

and hastening the use of alternative fuels, such as CNG and LPG (Abanes, 1999).

In Mexico City, emission standards for new cars have been raised, attempts have been made to improve the inspection and maintenance system, and there has been a significant improvement in the quality of fuels used. Nevertheless, emissions standards still lag those in the United States, standards do not apply to motorcycles and heavy-duty petrol engines, and further improvements are required in the inspection and maintenance system (Schwela and Zali, 1999).

#### **Transport Management**

Transport management measures have been an important aspect of strategies to achieve sustainable urban transportation in many advanced economies. Vehicle bans have been used in a number of urban centers. These are usually based on vehicle type, day of the week, time of the day, and location. Restrictions on the movement of trucks in certain areas have also been applied. A further method of restriction used is to reduce on-street parking and stop vehicles loading and unloading passengers and goods. Traffic priority measures for buses increase the attractiveness of bus services by reducing transit time and increasing the reliability of the service. Encouragement can be given to ride sharing through the introduction of highoccupancy lanes in an urban area, and through the review of regulations relating to insurance and liability. Staggered work hours have been used in Singapore and in some European cities to relieve congestion.

The management of the roadway system can impact on the overall efficiency of urban transportation to a significant degree. Roadway management includes roadway maintenance, signal control, and incident management. Traffic bottlenecks and delays can be reduced by properly scheduled maintenance, coordinated traffic signal control, incident management that minimises interruptions associated with accidents and stalled vehicles.

#### **Restraints on Automobile Use**

An important measure to restrain automobile use in major urban areas is traffic calming, which involves reducing speeds and accessibility for cars in local neighbourhoods and thereby improving the quality of those neighbourhoods. Areawide schemes provide a more efficient framework for removing traffic from residential streets and onto commercial streets. Banning automobile traffic altogether in city cores is a policy adopted by a number of cities in Europe and the United States. Cars are banned for particular days of the week in Mexico City and Manila, and other cities, such as Santiago in Chile, use episodic controls aimed at reducing car use when atmospheric conditions are most conducive to smog formation. In Bangkok and Jakarta, trucks and heavy vehicles are banned from central-city streets during the busiest hours of the day.

#### **Improving Public Transport**

Measures to improve the efficiency of urban public transport are a key aspect of sustainable transportation strategies. Among the strategies being pursued are investment in facilities (including the construction of mass transit systems) and increased linkages between transport modes by improving transfer facilities (including the development of park-and-ride interchanges) and integrating fare systems.

#### Promoting Non-Motorised Transport

The promotion of non-motorised transport - specifically walking and cycling is a strategy designed to limit the costs associated with vehicular traffic. Walking can be encouraged by providing sidewalks, improving the quality of the walking environment, and making city centers more friendly to pedestrians. The use of bicycles can be enhanced by constructing bikeways. In addition, in a number of urban environments, non-motorised traffic can be encouraged by improving security in the inner city.

#### **Other Measures**

Intermodal integration in freight transportation, involving rail, road and shipping, can lead to important gains in transport efficiency. These gains relate in large part to the reduction in road transportation movements. Gains can also be achieved from intermodal integration in passenger traffic.

# **Analytical Issues**

Conventional improvements to automobile efficiency have the potential to stabilise carbon dioxide emissions for a decade or two in the United States. To outreach rising travel demand and achieve reductions in emissions in the industrialised countries, and to keep up with the rapid growth in travel demand and overcome deteriorating air quality in many Asian cities will require more radical changes. The alternatives are using some combination of taxes or incentives to reduce travel demand (which should produce positive returns in the advanced economies, but is likely to be less effective in rapidly growing third world urban centers), the major redesign of urban areas (which would take many decades to have significant impacts, although reshaping transport infrastructure and promoting transit services could yield earlier returns), or radical changes in the design of transport vehicles (which will also take time). It is important to use a combination of all these policy instruments in order to achieve the benefits of mutually positive interactions.

The benchmarking of transportation outcomes against policy goals is recommended. The ECMT and OECD are leading the way in developing quantifiable goals for environmental outcomes (OECD 1996b) and social indicators have been suggested by CST (1997). The ECMT and OECD and the US Department of Transport have developed analyses of the likely impacts of policy instruments which could be utilised in modelling the outcomes of actual policy initiatives (OECD 1997c, ECMT 1998, TRB 1997).

#### Potential Conflicts and Reducing Policy Inconsistencies

The underlying goals for transport sustainability relate to social, environmental and economic issues. A key challenge for policy is dealing with the conflicts that can exist between these goals. For example, environmental and social objectives may conflict when policies pursued for environmental purposes (such as the scrapping or retrofitting of leaded-petrol-consuming cars) lead to reduced accessibility for the poor (such as those without access to public transport that are reliant on older vehicles for transport). The pursuit of environmental goals may also conflict with narrowly-specified economic goals (for example, the costs of transport may need to be generally increased to deal with emission volumes). To some extent, these conflicts boil down to political problems associated with the fact that there are frequently gainers and losers when policies are changed. If a broad view is taken of economic development needing to be on a socially and environmentally sustainable basis, some of the apparent goal conflicts can be seen to be insubstantial on deeper analysis (for example, while environmental sustainability may appear to be in conflict with economic efficiency in the short run, it is a precondition for long-run economic efficiency).

That still leaves the equity issues associated with gainers and losers from policy change. Compensation mechanisms are important to maintain accessibility for disadvantaged groups. Broader notions of compensation on a wider basis are possible if transport reforms are pursued in a wide enough context. Examples of particular political problems associated with transport reforms include unwillingness to pay in a situation where external costs are priced, and the clash that often exists between individual and community interests (important with respect to urban land use, infrastructure development and, to some extent, safety).

The experience of recent decades shows that traffic demand has high income elasticities and low price elasticities, and the cross elasticity between public and private transport is very low. Under these circumstances, efficiency pricing would result in large price rises for particular transport movements and relatively small reductions in actual transport movements because of the low price elasticities of demand. A key objective for policy should be to influence technology and transport service development such that greater choice is available for consumers. This greater choice would be represented by increased alternatives within a given mode of transport, enhanced possibilities for intermodal substitution, and the development of non-transport means of enhancing accessibility requirements. In turn, such a strategy would facilitate greater responsiveness in traffic demand to changing prices, or to advanced traffic management systems that simulate market-type solutions to accessibility requirements. The overall price elasticity of demand for high-emission transport movements, and the cross elasticity between public and private transport, could be significantly increased by increasing intermodal transport substitutability. Technological changes that increase the flexibility of urban transit services and system innovations that allow for increased customisation of such services are needed as would developments such as park-ride schemes which focus primarily on intermodality.

The growth in information technology, computing power and analytical techniques means that transport planners have increasing capabilities through the application of modelling and decision support technology. Modelling also provides a number of benefits, allowing transport planners and decision makers to:

- Evaluate trade-offs in a structured and efficient way;
- Identify better solutions to transport problems;
- Undertake sophisticated what-if analysis;
- Involve independent analysis, leading to more defensible decisions;
- Facilitate the creative and strategic thinking needed to address the complexity of transport planning; and
- Enable the introduction of advanced traffic management systems based on the use of simulation models to direct traffic and manage potential congestion problems.<sup>15</sup>

Government has an important role to play in securing sustainable transportation outcomes. Reforms are required in the following areas:

- The examination of the current provision of capital by all tiers of government for transport infrastructure that cannot be met by the market, and the coordination of activities at different levels of government in both capital provision as well as looking at the scale and impact of their taxes and charges on transport provision and the achievement of environmental goals;
- The acquisition of more information on the nature of the environmental impacts of transportation in particular urban centers and assessing the social costs of these impacts and developing risk management strategies; and
- The development and utilisation of standards of management and reporting for public agencies and government that encompass sustainability goals as well as financial ones.

More work needs to be done on the identification and removal of barriers to securing progress towards sustainable transportation, including societal attitudes and trends, government and corporate practices, and the prospect of economic adversity. Work is required also on how the economic benefits associated with moves towards sustainable transportation might be enhanced.

<sup>&</sup>lt;sup>15</sup> Note Spinks (1999).

# The Desirable Principles for Transport Policy

The policy process for sustainable transportation should incorporate:

- Consultative measures involving all stakeholders;
- The use of technology foresight methodologies to explore future possibilities;
- Goals that are clearly articulated and, where possible, quantified;
- An estimate of how actual developments will impact on such goals, including an assessment of the impact of particular policy initiatives; and
- The periodic assessment of overall progress in attaining goals including the evaluation of specific policy initiatives.

Policies aimed at improving transport efficiency so that it fulfils the conditions for sustainability need to adhere to the following principles:

- implementation of short-run marginal cost pricing to generate maximum net benefits for society (efficiency pricing that takes into account external social and environmental costs);
- investment in infrastructure whenever the additional benefits exceed the resource costs of doing so (economic viability, but allowing again for environmental and social costs and benefits);
- investment in transport resources when social returns exceed social costs (economic viability in the broadest sense);
- maintenance of 'fairness' among beneficiaries where possible (equity); and
- use of technologies and corporatisation strategies to improve the efficiency of public transport, particularly customer focus.

The conclusions of the 1996 Vancouver Conference on Sustainable Transportation (OECD 1997) provide a summary of a range of views on the principles and realities of sustainable transport.

- Sustainable transportation is achieved when needs for access to people, services, and goods are met without producing permanent harm to the global environment, damage to local environments, and social inequity. This implies rates of use of non-renewable resources that do not exceed the rates at which renewable substitutes are developed, and rates of emission and of concentration of substances that do not exceed the assimilative capacity of the environment.
- 2. The systems of transportation used in the OECD and some other countries are unsustainable. Substantial improvements in technology have been made, but their impact has been more than offset by growth in individual mobility and in the movement of freight, In most countries, current trends point away from sustainability.
- 3. Achievement of sustainable transportation will likely involve improvements in vehicles, fuels, and infrastructure, on the one hand, and

reductions in personal mobility and in the movement of goods, on the other hand. It is possible that some improvements may be counterproductive, and even that things may have to get worse before they get better; environmental catastrophe may be the only sufficiently strong motivator for change in transport policies.

- 4. Present thinking focuses on measures concerning the use of vehicles as opposed to ownership - designed to secure progress towards sustainable transportation. However, a focus on ownership may also be required, notwithstanding the political difficulties inherent in limiting ownership. Successful restrictions on use or ownership will require the development of satisfactory alternatives.
- 5. Moves towards life-cycle analysis, full-cost accounting, and full-cost pricing are desirable components of strategies for achieving sustainable transportation. However, full-cost pricing may not be enough to secure sustainability, even higher prices may have to be imposed, or other measures.
- 6. Other key components of strategies for moving towards sustainable transportation are measures to increase urban and suburban densities of land use and the setting and enforcing of targets that represent required changes in environmental and other indicators concerning transportation.
- 7. More work needs to be done on the identification and removal of barriers to securing progress towards sustainable transportation, including societal attitudes and trends, government and corporate practices, and the prospect of economic adversity. Work is required also on how the economic benefits associated with moves towards sustainable transportation might be enhanced.
- 8. Two other areas requiring further work with respect to the attainment of sustainable transportation are aviation generally and the inter-city movement of people and freight and aviation generally.

# **Priority Strategies Recommended**

The Experts Meeting on Sustainable Transport of July 1999 identified a number of priorities for sustainable transport policies over the next two decades. It ranked five main policy weapons in the following way.

- The reprioritisation of transport infrastructure towards public transport (35 per cent).
- 2. Land use planning linked to transport planning to move away from low density sprawl (29 per cent).
- 3. Alternative growth centers (13 per cent).
- 4. Robust transport management systems, protocols and standards (9 per cent).

5. R&D, both technological and social (5 per cent).

The meeting also identified the following initiatives as being worthwhile:

- The application of communication technologies to create communityfocussed meeting and work-spaces and thereby reduce work journeys;
- The introduction of intelligent transport systems;
- A graduated increase in car registration fees; and
- Increased taxes on conventional fuels.

The remainder of this section of the paper discusses the way in which particular policy weapons might be used in pursuance of the objective of sustainable transportation.

# The Integration of Urban alnd Planning with Transport Planning

Major breakthroughs in technology have the capacity to greatly reduce emissions while improving the availability of access services. However, in the absence of strategies for developing integrated urban and transportation planning that matches social and environmental needs with economic realities in a closer way, there are some longer-term unfavourable implications. The key issue is whether or not the environmental concerns and responses to those concerns give rise to a range of other incentives for more socially sustainable transport and how quickly these provide favourable outcomes. In the absence of change and success in these other areas, it is possible to identify a number of medium-to-long-term negative impacts associated with the technological changes identified in our scenario. Prominent among them are the social problems associated with urban sprawl, particularly social isolation.

Conventional transport solutions find it difficult or impossible to costeffectively address problems associated with the misfit between urban form and post-industrial employment growth. The problems include:

- a lack of employment in middle and outer suburbs developed since the 1970s;
- the concentration of social disadvantage;
- the lack of access of the low income and low skilled; and
- a lack of choice in opportunities.

Transport and land use planners may unintentionally prevent smaller scale investment and employment growth in the new economy because:

- arterial roads divide and separate communities;
- there is a lack of parallel routes that encourage diversified development;
- spatial monopolies exist that can best be exploited by big developers;
- large numbers of customers are delivered to major intersections; and
- there is lack of political impetus for the integration of transport and land planning (Kemp, 1999).

The dispersal of residential and commercial developments within greater

metropolitan areas in the United States have led to greater transport movements and increasing reliance on the motor vehicle. Public policies have most certainly contributed to dispersed land use patterns. Local zoning ordinances, for instance, have encouraged the separation of residential and commercial land uses, discouraging mixed-use developments that enable more walking and non-motorised travel (TRB, 1997).

Strategic planning allows governments to explore new techniques for environmentally conscious urban management. Strategic plan preparation generally entails a substantial research program and wide ranging consultation process. It also generally encapsulates a vision (or visions) for the future of urban regions and strategic proposals directed towards the vision's practical implementation. Strategic planning is also able to direct statutory policy without forcing the strategy to become a regulatory plan subject to costly legal test. Conflict is instead resolved in the process of strategic policy development, with its stress on consultation, refinement by way of research, and a shared vision (OECD 1996a).

# Encouraging Higher Urban Density and Mixed-Use Development in High Income Cities

Ginn (1999) argues that it was possible to reduce the need to travel through better integration of land use and transport, by means of the:

- Closer association between residential areas and areas of employment, personal services, education and recreation;
- Design of public transport interchanges that facilitate association with adjacent land uses; and
- Promotion of walking and cycling between land use activities.

Newman and Kenworthy (1999) list four steps required to transform a city from automobile-dependence to sustainability:

- Revitalise the inner city;
- Focus development around an existing rail system;
- Discourage further urban sprawl; and
- Extend the transit system into poorly served suburbs, including crosssuburban and orbital rail lines, and build new urban villages around them.

Cervero (1998) cites research based on statistical comparisons between cities and across corridors within cities suggesting that every 10 per cent increase in population and employment densities yields anywhere between a 5 and 8 per cent increase in transit ridership, controlling for other factors (such as lower incomes, restricted parking, and better transit services generally associated with more compact settings. Studies also consistently show that transit demand rises most sharply when going from very low to modest densities. The cross-national studies by Newman and Kenworthy (1999) appear to provide further support for this relationship in an international context. The doubts arise in relation to the social effects of high density living, with compact living more readily approved by European middle classes than those in North America. The challenge is to create more attractive compact places while attacking deeply rooted social problems as well.

The mixing of land uses adjacent to transit services is advocated to encourage transit riding, and reduce the need for separate trips. The idea is to design comprehensive, mixed use neighbourhoods instead of isolated subdivisions and developments. Newman and Kenworthy (1999) advocate channelling growth into the re-urbanisation of urban villages and to put severe curbs on growth at the fringe by the use of the green belt or urban growth boundary. The only kind of growth that ought to be countenanced outside the green belt or growth boundary, they argue, should be where development needs to occur around a particular resource or attraction and the possibility exists for a good transit connection. The dispersal of single homes or rural ranchettes based on an exurban location should be resisted as they are the basis of unsustainable automobile dependence. These policies need to be supported by other policies which price external costs (including transport-related externalities) into land use development (indeed, controls would probably be ultimately ineffective in resisting market forces in the absence of such pricing policies).

Finally, there is a need to re-examine the rules guiding the placement of new apartments and houses, schools and creches, shops, offices and even bicycle paths in heavily-trafficked areas. The geometry of street-fronting structures and the interplay of crosswinds are important considerations in modelling exposure (Fisher, 1999).<sup>16</sup>

Derelict and under-utilised land is a significant and growing problem for many cities within the OECD and innovations in this area are increasingly important for urban sustainability. Part of the problem is associated with the result of past environmental damage. Where substantial sites remain derelict, they act to blight adjoining areas and reinforce investment withdrawal to more favoured locations. This, in turn, exacerbates environmental degradation, producing a negative feedback loop. Land remediation is an important facet of urban development policies.

Many projects to improve the urban environment require some measure of coordinated land use and transport planning across many jurisdictions, and the allocation of tax revenues from many municipalities to projects of mutual benefit. When metropolitan areas are badly fractured politically, economically and socially, it is more difficult to convince some communities to invest more than others for the common good (OECD 1996a).

#### Walking and Cycling

An increase in walking and cycling is advocated to reduce vehicular travel

<sup>&</sup>lt;sup>16</sup> A 1997 study of six country districts in western Holland found that plumes of NOx can still be as much as 50 per cent of their peak (mid-motorway) value some 100 metres from the road. For the finer SPMs there was virtually no lessening as far back as 300 metres.

and for its contribution to personal heath and well-being. The commonly identified limits to which these modes of transport can contribute to reduced vehicle use are trip length, infirmity and climate, although this applies more to walking than cycling.

In order to promote walking as the preferred mode for person trips, the following measures are advocated:

- The design of public rights-of-way to encourage pedestrian use;
- Protection from inclement weather;
- Adequate lighting for safety and security;
- Accessibility for the disabled; and
- Street level establishments close to the sidewalk. (Transportation Association of Canada, 1993).

To increase opportunities for cycling as an optional mode of travel, several measures are recommended:

- Cycle lanes on the public right-of-way and separate cycle networks;
- Storage facilities at transit stations and on transit vehicles to encourage bike and ride; and
- Storage facilities in the downtown core, suburban town centers, and other key locations. (Transportation Association of Canada, 1993).

Newman and Kenworthy (1999) advocate traffic calming techniques to reduce traffic speeds and traffic dominance of the streetscape in order to facilitate enhanced pedestrian and street activity, reduced accidents and noise. While attempts to achieve a modal shift to walking and cycling in car-oriented cities is an obvious priority, the shift from these modes to vehicular travel in developing countries is a major concern. As Newman and Kenworthy (1999) point out, growth in car use is seen as being progressive, while walking and certainly cycling is seen as being backward, and the spaces for pedestrians and cyclists, never ideal, have deteriorated.

# **Planning and Transit**

There are several ways in which planning policies might influence travel demand to favour urban transit, including:

- Concentrating high-density residential development and new residential areas, together with trip-attracting facilities, in areas well served by public transport;
- Using developer contributions, or revenue from parking charges and tolls, to finance public transport infrastructure; and
- Restricting access to town centers by parking charges, tolls, or outright bans, while encouraging suburban residents to "park and ride" (OECD 1997c).

Many transit metropolises have matched provisions for pedestrians, cyclists, and transit users with restraints on motoring and auto ownership. In Singapore, Tokyo and Stockholm, this has mainly taken the form of punitive pricing: steep surcharges on petrol and automobile purchases, hefty vehicle import duties, and expensive central city parking. In other transit metropolises, automobile restraints have been achieved through regulations and physical design strategies. Examples include Tokyo's garaging requirements (checking the city's car population), Mexico City's alternating ban on car usage, and traffic calming and restraints in Munich, Zurich and Curitiba<sup>17</sup> (Cervero, 1998).

Where land use measures and transit investments are being coordinated in the United States, projected results have been positive but modest. Examples are cited from

- (a) the proposed western Portland (Oregon) proposed transit system expansion, which would be complemented by land use measures to induce higher residential and commercial densities near transit service areas, indicating a decline in motor vehicle usage of six-to-seven per cent, and
- (b) simulations for the Puget Sound metropolitan area in Washington State predicting higher-density development and greater transit-orientation would reduce vehicle miles travelled in the area by 10 to 15 per cent.

Most studies suggest that the provision of transit, even when integrated into a transit-oriented land use plan, can reduce motor vehicle travel, but only over relatively long time frames and by modest amounts unless accompanied by many other measures to control travel demand. The Portland study, for instance, projects that a combination of subsidised and demand-responsive transit services, complementary land use plans (such as residential and commercial development clustered around transit stops), parking fees, ridesharing inducements, and peakperiod road pricing would double the effect on travel, achieving a reduction of more than 10 per cent in the study area (TRB, 1997).

### **Parking Management**

Parking management is also an important area of policy. It is desirable to plan parking supply and price to be in balance with walking, cycling, transit and auto priorities. Elements of such a parking strategy should be:

- Detailed studies to determine current and future parking supply and demand;
- Emphasis on short-stay over long-stay parking downtown;
- On-street parking priced at a higher rate than off-street;
- On-street parking limited to off-peak periods;
- Off-street neighbourhood parking structures incorporating retail and commercial uses;
- Park-and-ride facilities integrated with the transit system; and
- Municipal enforcement to ensure a balance of parking supply with demand. (Transport Association of Canada, 1993).

<sup>&</sup>lt;sup>17</sup> Curitiba is a city in Brazil.

Portland was one of the first American cities to place a ceiling on downtown parking. The tightest parking restrictions apply to buildings fronting the bus mall. Among the 16 stops along the east-side line between the Lloyd District and Gresham, only five have park-and-ride facilities. Encouragement is instead given to bus-and-ride access to the light rail system. Portland has also embraced traffic calming to a greater extent than any other US city (Cervero, 1998).

At most of the 20 SkyTrain stations in Vancouver, little or no parking is available. Instead, transit bus routes have been reconfigured to efficiently feed into stations. Policies aimed at restraining parking in Ottawa have complemented transitsupportive design initiatives. When the Transitway opened in 1983, the federal government began eliminating free parking for its employees and reducing downtown parking supplies. The federal government also introduced flexible working schedules for its employees. Park-and-ride facilities have been restricted at the Transitway's terminuses to encourage the use of feeder and express buses as well as to maximise the development potential of selected stations (Cervero 1998).

Off-street parking in Singapore is limited and very costly. A surcharge applies to downtown-area parking. Off-street parking in the city center of Bangkok is not subject to significant controls, and is abundant and cheap. There are estimated to be 338 parking spaces per 1000 workers, compared with only 67 in Singapore; Hong Kong, China; and Tokyo, and higher even than the average for Australian cities (Poboon *et al.*, 1994).

# **Distribution Systems**

The efficiency of the urban goods distribution system can be improved through:

- Municipal authorities considering the total goods distribution system in all stages of urban planning and development, with cooperative efforts by the freight industry to give municipalities a better understanding of urban planning and development;
- The requirement of off-street loading facilities or zones for all new developments;
- Encouraging industry to make more use of consolidated delivery services to congested areas; and
- Improving the truck route network through designated routes, better road geometrics and stronger pavements. (Transport Association of Canada, 1993).

# Implementation Issues

Centralised land use planning and zoning restrictions have proved to be weak instruments for altering public choices about land use. One reason is that land use planning is rarely coordinated at the metropolitan level, which usually involves dozens of local jurisdictions with authority over neighbourhood zoning and community design. Even if institutional and jurisdictional issues could be overcome, the public at large would need to be persuaded of the benefits of land use arrangements that differ significantly from those that prevail.

The provision of better survey collections to support appropriate performance indicators and models on sustainable transport and land use is advocated by Ginn (1999). The possible expansion of travel blending, home interview travel surveys, and the expansion of census collections would be desirable,

#### **United States**

In the United States some states over the past decade or so have begun requiring local governments to develop plans for managing growth. These efforts have met with varying degrees of success but have stimulated interest in new community designs that place less emphasis on motor vehicle use and encourage people to walk more. These designs include mixed-use and clustered developments in which jobs, retail establishments, and housing are in close proximity and accessible to transit. They also include more comprehensive efforts to integrate investments in transit and non-motorised transportation facilities with land use policies. The idea is that such designs will engender greater interest among the public in denser development patterns, making state and regional growth plans more acceptable and effective (TRB, 1997).

Portland in Oregon is the most-quoted city in the US in terms of progressive land-use planning. As part of an Oregon State requirement, Portland adopted a rigid Urban Growth Boundary (UGB) in the early 1970s to prevent sprawl and contain development. The 26 constituent governments of the metropolitan region formed the Metro Regional Government to administer the designated growth boundary. Since that time, the Metro region has put in place

- a) a highly integrated growth concept and regional transportation plan,
- b) an energy policy,
- c) a CO<sub>2</sub> reduction strategy, and d) sustainable city management principles. More than 20 programs combine transportation, land use, housing and other efforts (Brindle and Lansdell, 1999).

The UGB stops at the state border with Washington on the Columbia River. Washington State lacks the statewide land use planning policies and powers that Oregon has, causing significant problems. In addition, recent acceleration in growth and structural change have put pressure on the integrity of the urban growth boundary. The adjacent land in Clark County and the city of Vancouver in Washington contains extensive low-density development, has low property taxes but imposes sales taxes, and has no urban growth boundary. These conditions encourage extensive low-density development with little employment and high commute rate and shopping trip rates across into Oregon. Two bridges currently serve this movement, and Portland is trying to limit cross-river road movement by not agreeing to build more crossings. Light rail is being promoted as an alternative, but Clark County taxpayers voted against their segment of the scheme. Arterials previously constructed towards the boundary will not be extended, and highways that extend outside the growth area are progressively being given more limited access. The boundary has also come under pressure form sources within Oregon: land across the boundary would realise large profits if it went to urban zoning.

The boundary is being defended in a number of ways. Surrounding communities are being encouraged to establish a better jobs/housing mix to reduce pressure on the corridor into Portland, with the State Department of Transportation being resourced to provide assistance. Constituent local governments within Metro have volunteered to aim at higher population targets than their allocation in the growth plan, and there are now incentive targets for each to aim at. Nevertheless, Metro now has to consider the possibility of its first major expansion of its growth boundary in nearly 20 years (Brindle and Lansdell, 1999).

## Canada

Regional land-use planning has been a feature of the development of a number of major Canadian cities. Toronto was the pioneer in the 1950s and 1960s. The development of a subway system was accompanied by policies to strengthen the development potential of subway stations. The CBD was significantly strengthened. However, Toronto's major successes lie in the past. Since the mid-1970s, regional development patterns have mimicked those of many American metropolises. The emergence of American-style suburbs outside compact, transitoriented Toronto is note worthy. Three-quarters of regional population growth from 1991 to 1996 occurred in areas outside the boundaries of the expanded City of Toronto (Cervero, 1998).

The Regional Muncipality of Ottawa-Carleton developed a long-term plan for the region after extensive consultation with citizens. The Transitway formed the core of a concept in which linkages to downtown Ottawa would be complemented by a hierarchy of primary and secondary urban centers linked to the Transitway. The long-term goal is for 40 per cent of the region's jobs to be within walking distance (400 metres) of the Transitway (in 1996, the figure was about 32 per cent). Regional shopping centers above a certain size are to be sited near the Transitway or future extensions. Most residential development is to occur contiguous to the primary and secondary employment centers (Cervero, 1998).

In Vancouver, the Livable Region Plan had already won broad-based support, providing a common vision for the region's future. While the region has no formal urban growth boundary, it has successfully contained development through an agricultural reserve policy that takes large portions of peripheral lands out of the speculative market. Mountains and water features have further restricted buildable land, driving up average densities. Various zoning mechanisms and design approaches have been used to spur center development around rail nodes to date. Transferable development rights and density bonuses are actively used to funnel development to station areas. Within most regional town centers, off-street surface parking is not permitted, allowing for more intensive use of land. The high cost of structure and underground parking has prompted some developers to orient their projects to take advantage of transit's proximity. At most of the 20 SkyTrain stations, little or no parking is available. Instead, BC transit bus routes have been reconfigured to efficiently feed into stations. Also missing from the local transportation scene is much freeway capacity. Partly because of grassroots freeway revolts in the early 1970s, the region has less than half the freeway capacity of US cities of comparable size. Moreover, all of the existing freeways terminate before reaching the city proper.

#### Tokyo

Tokyo's planning strategy is designed to try to take pressure off its crowded CBD area and inner area through development of a multi-nodal structure based primarily on rail lines. Tokyo's CBD contained 1.958 million jobs in 1980 and increased to 2.301 million by 1990. The development of large mixed subcenters a considerable distance form central Tokyo is a priority. These towns have high concentrations of housing within walking and cycling distance of centrally located commuter rail line stations, as well as significant retail and commercial development (Kenworthy *et al.*, 1994).

#### Singapore

Singapore's current long-run plan (the Constellation Plan) replaces the existing ring concept with a constellation scheme. The Central Area will remain the island's premier commercial and financial hub. The downtown area will be expanded and in-town housing added. A new CBD will be developed next century on land reclaimed from Marina Bay. It will be largely free of road traffic, with an extensive network of second-story moving sidewalks (travelators) linking periphery and interior residences to the commercial core). Plans call for private developers to finance the development as a precondition to receiving building permits. Pedestrian access will be above ground, and on-ground with public plazas, tree-lined promenades and outdoor refreshment areas, all of which will help to overcome the ever-present heat and humidity (Cervero 1998).

Under the Constellation Plan, Regional Centers will orbit the newly expanded CBD, each of which is slated for some 800,000 residents and will, in turn, be orbited by smaller center. The plan calls for the building of some 50 new towns of various sizes. The Plan also calls for a more equal distribution of jobs and housing through the island than the previous ring plan. By creating more self-sufficient communities, the plan seeks to contain trans-island commuting. It also places a great deal of emphasis on more varied housing (calling for more single-family and mid-rise structures), open space, and public access to shorelines - necessary amenities for attracting the highly-paid executives and professionals who will staff a global service-oriented economy.

The plan affirms and strengthens the role of the MRT in future transisland movement. The half-cobweb framework is explained. Light rail will become the favoured form of feeder connection to MRT stations in the future, with the first lines to be opened by century's end. Like the MRT, light rail services will be fully automated and grade-separated, though trains will have far less capacity and stations will be spaced closer together (Cervero, 1998).

The public ownership of land has been an important factor in urban plan implementation in Singapore. The Land Acquisition Act of 1966 empowered the state to take land for any public purpose, including the development of new towns. State land holdings increased from 31 per cent of the total land area in 1949 to 76 per cent in 1985. The Act greatly reduced the cost and streamlined the process of building new towns, setting up industrial estates, providing public housing, and investing in transportation infrastructure (Cervero, 1998).

# Hong Kong, China

The intense pressure on available land in Hong Kong, China is due to topographical constraints, and the potential for overwhelming congestion if the private car were to be unleashed, has meant planning principles in HK have always been strongly based on the need to create super-compact nodes of strongly mixed development in which people can access most local needs within a short walk. In practice, a great number of these nodes have been built directly above and around MTR stations. Much detailed planning and negotiation has been needed to make best use of land at station sites and effectively integrate commercial and residential land uses on tiny sites. The development has provided financial benefits by integrating rail and development, affording opportunities for returns on capital from property leases around stations and non-fare revenue flows from property leases around the station (Kenworthy et al, 1994).

### **Urban Planning in Developing Economies**

During periods of economic and demographic growth in the third world, real urban land prices will rise. Although the situation will vary from city to city, pressures tend to build that result in the exclusion of the poor from peripheral land in every city. The following issues relate to State intervention in the land market (note Gilbert, 1994).

# Controlling the urban perimeter.

There is a clear need to control and to direct the pattern of urban growth. Informal suburban development can get out of hand. It can spread too quickly, creating very low-density suburbs that are very difficult to service. In addition, it often occupies land that should not be urbanised - because it is too high to be supplied cheaply with water or too low to be drained, because it is environmentally attractive or because it is too close to polluting or dangerous neighbours.

Gilbert (1994) argues that free licence is undesirable, and total prohibition politically infeasible in most situations, and he made the following suggestions:

- Sites-and services schemes (often known as official slums) offer potential in smaller cities, but land costs are too high in the major cities;
- The introduction of sites-and-services projects needs to be linked to lower building and servicing standards, otherwise they will mainly benefit the middle class;
- The publication of guidelines by the authorities pointing out the dangers of participating in fraudulent informal subdivisions, which frequently result in new colonists being charged unexpectedly high costs as services are extended; and
- Landholders should be discouraged from selling their land without planning permission through fines.

### Treatment of existing informal settlements.

Programs of settlement upgrading are clearly critical for the future. They should aim to improve the quality of infrastructure and services. They should seek to improve the security of tenure for the occupants. They should try to involve the community in deciding the kinds of improvement to be made. However, there are some implicit dangers in upgrading programs:

- Some programs consist mainly of legalisation rather than increased benefits to the communities involved and bring with them liability to land and other taxes; and
- Upgrading can lead to displacement of settlers (in the worst cases, middle class families replacing the poor).

### Discouraging land speculation.

Within the urban perimeter, higher taxation on empty land is the obvious method of discouraging land speculation. This requires an effective cadastral system, but there are no major technical barriers to establishing such a system. The real reason why so many cities have such disastrously antiquated systems and why land and house values have not been updated is that owners do not wish to pay taxes, and governments are often highly sensitive to the complaints of landowners.

On the edge of the city, perhaps the best method of controlling land speculation is to maintain an adequate rate of growth in serviced and unserviced but authorised land. The provision of more serviced land obviously requires effective forward planning by the service authorities, something that cannot be relied upon in every mega-city. Similarly, the provision of authorised unserviced land requires competent management. Ultimately, the whole issue of land speculation is a matter of political will and of competent State management. Both are in question in most mega-cities throughout the world (Gilbert, 1994).

## Decentralising Development

The future pattern of metropolitan development will have a big impact on the sustainability or otherwise of urban transport. Urban planning needs to give greater consideration to issues such as integration of transport and land use, minimisation of the amount of travel required, and encouragement of higher levels of self-containment.

One objective of policy should be to decentralise development. Density in the central areas of some mega-cities, fed by downtown rebuilding, is raising densities higher than can be sustained by water, sewerage, and transportation systems (note Seoul, with more than 300 persons per hectare). Many businesses are caught in city centers because of the need for business services and allied economic activities that could decentralise altogether.

While decentralising from congested centers, a second objective of guidance is to raise the concentration of peripheral development, avoiding the nonsustainable consumption of agricultural land. A third reason for managing growth is to make more land available for housing within reach of work places, especially for the poor (Gakenheimer, 1994).

### **Decentralised Development**

In economies like the Philippines and Thailand where primate cities (Metro Manila and Bangkok) have held dominant positions during post-war economic development, decentralisation needs to go beyond the surrounding areas to the primate cities and look to other providing incentives to development in other regions within the national economy.

### Thailand

The emphasis in Thailand's Seventh Plan (1992-1996) was to provide measures that enhance the growth of the outer regions rather than to control the growth of the metropolis or to disturb its growth-generating characteristics. The plan allowed the metropolis not only to act as a major economic center in facilitating structural transformation and socio-economic growth in Thailand but also to enlarge its role and spatial coverage to compete with neighbouring countries and accomplish greater integration into the international economic system.

The Eastern Seaboard served as the country's main industrial base and a new gateway to industrial growth. The seaboard was seen as a counter-magnet, providing alternative investment locations to reduce congestion in the Bangkok metropolis. The northern part of the metropolitan region was envisaged as the industrial zone for the Upper Central Region, to which region it was desired that industrial activities should relocate from the Bangkok Metropolis. Direct transport links were to be established with the Eastern Seaboard for exports to relieve congestion in the capital.

The Plan also formulated measures to relieve congestion in the metropolis through construction of satellite cities and new towns, controls on building con-struction in the city core, and prevention of housing sprawl along the main highways. The following strategies were laid out in the Plan:

- Access roads to link with main roads to facilitate the connection of empty and unused land;
- The development of promotion zones with a high standard of services, especially in areas served by rapid mass transit; and
- The improvement and rehabilitation of urban communities (Kaothien, 1995).

#### **Philippines**

During the 1960s and 1970s various measures were tried to disperse regional development. These included investment incentives, a ban against new industries locating in Metro Manila, construction of export processing zones elsewhere, and the integrated development of rural areas and urban growth centers. Most new industries insisted upon locating in Metro Manila. Spatial development within and outside Metro Manila has therefore been shaped largely by private decisions (Ocampo, 1995).

#### **Likely Impacts**

There is a lively debate ongoing among urban and transportation planners about the effects of increasing development density to reduce motor vehicle travel. Some studies show meaningful effects, whereas others do not (Cervero and Graham, 1995; and Crane, 1996). Often the results from these studies are for specific locations, rather than for entire metropolitan regions or states where the influence would be diluted. In general, the application of land use measures and new community designs to increase metropolitan densities is likely to require considerable time to achieve appreciable increases in land use density and subsequent reductions in motor vehicle travel because of what Downs (1992) refers to as the "marginality problem". The marginality problem recognises that most development of the last 30 to 40 years has been dispersed, that new community designs emphasising transit and non-motorised travel are most likely to be adopted only in new developments at the periphery of established communities or in emerging metropolitan areas, and the new development would therefore have to be far denser to raise the average density of a metropolitan area.

Roughly half the US population now resides in areas that fit the general description of suburban, which is typically a density below that which will support conventional transit systems. Many years of denser growth patterns would be

required to alter this general pattern. For example, an exceptionally fast-growing metropolitan area might double its population within 10 years. If under these circumstances all new residents settled in areas accommodating twice as many residents per square mile as in the established development, a 50 per cent increase in population would lead to only a 20 per cent increase in overall metropolitan density. A slower-growing metropolitan area with such a design would take several decades to experience such an increase in residential density.

In principle it would be possible to increase the density of existing neighbourhoods or small towns within the metropolitan area through the replacement of old structures with higher-occupancy buildings or through denser development. Such change would take many years, however, because many structures can provide useful service for 50 to 100 years, and replacement would be resisted in areas where residents favour historic preservation. Indeed, as Downs (1992) argues, neighbourhoods are usually reluctant to accept any sort of change in their design and density characteristics.

Thus the most promising area for higher density is in new developments, which is currently occurring at low densities. Given the marginality problem, gradually increased densities in the typical metropolitan area would likely take many decades to influence aggregate metropolitan travel substantially. Nevertheless, such strategies are worth pursuing for the long-term gains that can be achieved.

In the developing economies, political and technical constraints limit the ability of regional governments to reshape the major cities, and an important strand of policy is to promote decentralised development to relieve the central cities of some of the strains of over-development. However, in Vietnam and in some of the medium-sized cities of China, where the beginning of accelerated urban growth is more recent, but the extent of possible growth in the next two decades is huge, there could be very big returns in the medium term from current investments in integrated urban land planning and transport planning.

# **Developing Transport Infrastructure**

It is desirable to assess all transport infrastructure proposals on a consistent basis that takes into account their economic, social and environmental impacts. Such assessments should view transport from an intermodal perspective, taking into account the interrelationship between road traffic and infrastructure, public transport, facilities for non-motorised modes and travel demand management. An important issue is to fully recognise the net social returns from infrastructure investments. The financial returns from some infrastructure investments, such as high-speed rail networks, are often only half as large as their social returns. Moreover, the secondary economic returns from such infrastructure investments can be very high, as research in the United States has shown, thus highlighting the importance of tracing multiplier effects associated with the investment (Euro-CASE, 1996).

The success of transit investments depends upon many supportive conditions, among them a strong regional vision and willingness of local governments within the region to exercise proper zoning. The failure of many transit systems in the United States to affect urban form may be explained in part by the size of the public investment in transit systems relative to investments in other transportation facilities such as highways. Other explanations include the lack of success in coupling regional transit investments with local land use planning and state road-building programs and changes in public preferences for modes of travel. Whereas many regional transit agencies have been created, local governments within the region tend to guard zealously their prerogative to regulate land use (TRB, 1997).

Cervero argues that planning processes need to be farsighted, pro-active and strategic in order for transit developments to prosper. He indicates that, in Stockholm, Copenhagen, Singapore, Munich and Curitiba classic approaches to urban planning and management have been carried out: the setting of clear goals and objectives; the formulation and articulation of land-use visions and comprehensive plans; the careful evaluation of transportation and infrastructure investment alternatives; the programming of capital improvements within realistic budget constraints; plan execution and follow-through; and the leveraging of transit and land-use programs. He also notes the case of the Japanese railway companies, which have major involvements in real estate, retailing, construction, and bus operations. Real estate speculation can be harnessed to the public good as indicated by the successful Japanese rail system.

Where land use measures and transit investments are being coordinated in the United States, projected results have been positive but modest. Examples are cited from

- (a) the proposed western Portland (Oregon) proposed transit system expansion, which would be complemented by land use measures to induce higher residential and commercial densities near transit service areas, indicating a decline in motor vehicle usage as six-to-seven per cent, and
- (b) simulations for the Puget Sound metropolitan area in Washington State predicting higher-density development and greater transit-orientation would reduce vehicle miles travelled in the area by 10 to 15 per cent.

The development of transit infrastructure is of critical importance in the major cities of the developing world. To begin with, car ownership rates are much lower than in the advanced economies, so an automobile focused transport and planning culture is less deeply embedded. Secondly, existing population densities and projected population growth in the major urban centers provide a potentially strong market for a wide range of transit infrastructure investments. Thirdly, existing and projected air pollution levels in such cities make the difference between the financial and social costs of such infrastructure investments especially large.

### Transport Infrastructure in the United States

Since 1991 there has been a renewed Federal involvement in transit in the United States, There has been increased funding and greater attention paid to environmental evidence in providing tied funding. However, major transit investments in the US have been unable to reverse the trend of population relocation from central cities to the suburbs. The existence of extensive transit systems that predate the major investments of the last 30 years or so has probably been helpful in maintaining the strength of urban cores in cities such as Boston and New York. Many established mass transit systems that receive public subsidy are struggling as this financial support has waned. Often, the size of the public investment in transit systems relative to investments in highways has been low, and there has frequently been a failure to link regional transit systems with local land use planning and state road-building programs (TRB, 1997).

Cervero (1998) argues that successful transit investment strategies have the following characteristics:

- They occur in healthy regional economies so that development proposals are available that can be attracted by the transit-related transportation changes;
- Radial rail systems can strengthen downtown cores (examples include San Francisco, Washington D.C. and Baltimore);
- Regional transit investments generally reinforce decentralisation trends; and
- Pro-active planning is necessary if decentralised growth is to take the form of sub-centers.

An absence of coordinated and comprehensive planning, carried out on a regional scale, is one of the factors behind transit's poor showing in the US. An outstanding example of this is putting a point-to-point rail system in a sea of auto-oriented development.

A few American cities have made successful investments in transit. Notable examples are the metropolitan areas of St. Louis, Houston and San Diego.

- 1. In St. Louis, the light rail line known as MetroLink has exceeded projected ridership volumes by a substantial margin. It has been successful because it links a number of traffic-generating land uses-sports complexes, universities, medical centers, the airport, entertainment and gambling sites.
- 2. Houston has developed a High Occupancy Vehicle (HOV) network. This provides dedicated lanes on Houston's extensive road network for buses, vanpools and carpools. It is also experimenting with advanced vehicle control systems for its bus system.
- 3. San Diego has developed an extensive commuter rail system and is developing an even more extensive light rail system. These systems are

complemented by America's largest minibus dial-a-ride services, as well as jitneys (Cervero, 1998).

#### Transport Infrastructure in Canada

The post war period has seen significant developments in transit infrastructure in the major Canadian cities. Toronto's subway system, first opened in 1954 and significantly extended up to 1966, has more recently been complemented by a fully automated advanced light rail transit line. Vancouver in 1986 opened its fully automated driverless SkyTrain system. Ottawa has developed a system known as Transitway. It consists of exclusive busway lanes set in an open-cut, grade-separated from the surrounding road system, and supplemented by reserved freeway shoulder lanes within the greenbelt. Other major investments include a new-generation rail system in Montreal, and light-rail systems in Calgary and Edmonton (Cervero, 1998).

# Transport Infrastructure in Australia Sydney

During the 1980s and 1990s, road and rail infrastructure development has provided some of the required structural linkages, but infrastructure development has not kept pace with travel demand resulting in increasing road congestion. In particular, Parramatta, the natural hub of Western Sydney and the second CBD, remains poorly served by existing transport corridors and services. Commercial movement is inhibited by a poorly connected network of freeway-standard roads and poor truck access to Sydney's eastern freight gateways.

In 1999 the NSW Department of Transport published 'Action for Transport 2010 - an integrated transport plan for Sydney' detailing a proposed network development for the Sydney region out to the year 2014. Considerable emphasis is given to extensions of the heavy rail network, including connections to the airport, Bondi Beach, Parramatta-Chatswood, Hornsby-Newcastle High Speed Rail, North West (Castle Hill-Epping), Sutherland -Wollongong High Speed Rail, Hurstville-Strathfield, and Liverpool Y Link. Rapid bus-only Transitway services are proposed linking Parramatta with Liverpool, Blacktown, Mungerie Park and Strathfield, additional linkages from Blacktown and between St Mary's and Penrith. An extension of light rail and five areas of major arterial road improvements are also scheduled. The main emphasis of investment plans is on transit (Kilsby and Prince, 1999).

#### Melbourne

Melbourne today has one of the ten largest rail networks in the world - 490km along 15 lines serving 206 stations. It functions primarily as a commuter service, centering on the CBD, with an underground city loop putting 85 per cent of CBD workers within a five-minute walk of a station. Melbourne also has a 230km tram system that functions both as a distributor, feeding into central-area train stations, and a circulator in its own right, interconnecting the core and inner-ring suburbs.

Generally, trams share the roads with other traffic, but occasionally run along dedicated median strips. Buses are the gap-fillers. Contractors are rewarded for paying customers with patronage-related subsidies.

The quality of transit services is less impressive than the coverage. However, steps have been taken over the past decade to rectify this. Rolling stock has been modernised, routes expanded, rail stations refurbished, and information technologies adopted. An intermodal ticketing system has been installed. In 1999, the rail and tram services were privatised, contracts being awarded on the basis of increased investment in facilities and rewards for increasing patronage. Patronage stabilised during the 1980s and has been rising during the 1990s (Cervero, 1998).

## Adelaide

Adelaide's most distinctive mainline bus service is its track-guided busway, the O-Bahn. Track guidance blends bus and rail service in one vehicle. Rollers directly connected to the steering knuckle of the bus guide the vehicle along a raised concrete track. Designed and first used in Germany, O-Bahn is the name of the patented technology. Track guidance allows buses to reach high speeds safely along mainline corridors, comparable to railway services. However, unlike rail cars, buses can leave the guideway, filtering into residential neighbourhoods. This allows the same bus to function as a feeder and mainline carrier. It also reduces the need for transfers. Adelaide today has the world's fastest and longest guided busway.

The O-Bahn was built to service the north-east corridor, the only axis from the city unserved by rail, and also one in which post-war population and employment growth was especially rapid. Traffic delays made some sort of high-capacity dedicated trackway necessary. Cost considerations ruled out commuter rail and, after significant costings, light rail. A busway was not favoured because of issues connected with right-of-way (more is required with manual steering), safety, air pollution, noise and comfort (rollers act as stabilisers).

The first stage of the O-Bahn opened in 1986, and the full 12km corridor was in place by 1989. Today, buses from 18 different routes wind through the residential streets in the northeast suburbs before entering the guideway at one of two access stations. With steering completely controlled by the guideway, buses reach speeds of up to 100km per hour. There are only three interchanges along the guideway (the third is five kilometres from the city). The capacity of the system, allowing for the superior traction of rubber-tired vehicles and the consequent short interval between buses, is in the ball-park of what the most advanced light-rail systems can handle. Adelaide has also got the largest fleet of CNG buses in Australia: 110 out of more than 700 buses, with plans to replace some 100 existing diesel buses by the year 2000 (Cervero, 1998).

# Perth

A strong political push for a rail service resulted in the Northern Suburbs

Rapid Transit System. This electric rail service runs 33km, has only seven stations (allowing a very rapid service reaching a maximum speed of 100km/h), and it runs down the center of a freeway. It also features trains that are linked by bus services interchanging passengers directly onto the stations. This also allows cross-suburban bus services to be provided, since the CBD is no longer the focus for bus routes. Rail patronage has increased, and average speeds are greater than for motoring (Newman, 1996).

#### Transport Infrastructure in Singapore and Hong Kong, China

Around half the population of Hong Kong, China lives within a 500 metre walk of a MTR station. Furthermore, almost 70 per cent of passengers do walk to the train at both ends of their trip, only 28 per cent require a feeder service at one end, and a mere 2% require such a service at both ends (Newman, 1996).

Singapore's mass rapid transit system (MRT) is not quite as well integrated with population centers as in Hong Kong, China, although 65 per cent of passengers do walk to and from MRT stations. The Singapore MRT is eight years younger than in Hong Kong, China and the city has a much lower population density.

Singapore is now moving rapidly towards an urban structure consisting of a series of five long radial MRT lines focussed on the central area, together with three circumferential lines - a core area 'circle' line, an inner/middle 'semi-circle' and an outer, sweeping semi-circle line. Some circumferential links will consist of a new light rail transit (LRT) system. The basic strategy is to locate the large regional centers at MRT/LRT stations on the junction between radial lines and the outer circumferential line. Sub-regional centers will be on the junction of the radial lines and the inner/middle circumferential lines. Fringe centers of the CBD will be located on the core area 'circle line' (Newman, 1996).

#### Transport Infrastructure in Bangkok

There are four major transport infrastructure projects in Bangkok.

- Bangkok Transit System (BTS) 23.5 km elevated mass rapid transit system, two lines (inoperation since 5 Dec 1999), with 34km of MRT Green Line extensions, feasibility being investigated.
- 2. Metropolitan Rapid Transit Authority.
  - MRTA Blue Line, 22km underground;
  - MRTA Blue Line extensions, 10km elevated, 10km underground;
  - MRTA Orange Line, 33km.
- 3. Department of Highways.
  - Outer Ring Road, 140km expressway;
  - Don Muang Tollway, 25.5km elevated tollway;
  - Bangkok-Chonburi Motorway, 82km expressway;
  - Highway 338, 13km of elevated road.

- 4. Expressway and Rapid Transit Authority.
  - Bangna-Chonburi Expressway (Green), 55km, open for service 2000;
  - Bangpain-Pakkret Expressway (Light Blue), 34km, open for service 1999;
  - Third Stage Expressway System 46.0km, construction commencement 2001. (Chaimankong, 1999).

### Transport Infrastructure in Other Developing Economies

Planning for the expansion of the Light Rail Transit in Metro Manila ran into problems at the time of the 1997 financial crisis. The government will now rely on a Build-Operate-Transfer arrangement to finance the scheme. The full implementation of the LRT lines in Metro Manila will displace major jeepney routes. Jeepneys, mainly using diesel engines, are a significant contributor to air pollution, and their future role in an integrated transport system is now in doubt (Abanes, 1999).

The Beijing subway system has old facilities, insufficient capacity, and inadequate route coverage. Ridership is declining. Significant investments in new subway capacity is planned, along with the establishment of a guideway public transit system (Huapu Lu, 1999).

# **Public Transport Reforms**

Cervero uses the term *transit* to describe generically the collective forms of passenger-carrying transportation services. These range from vans and minibuses serving multiple origins and destinations over non-fixed routes to modern, heavy rail trains operating point-to-point over fixed guideways. The services may be provided by public or private enterprises.

### **Categories of Transit Services**

The smallest carriers often go by the name of *paratransit*. They represent a spectrum of vans, jitneys, shuttles, microbuses, and minibuses that fall between the private car and conventional bus in terms of capacities and service features. Often owned and operated by private companies and individuals, paratransit services tend to be flexible and highly market-responsive, connecting multiple passengers to multiple destinations within a region, sometimes door-to-door and, because of multiple occupants, at a price below a taxi. While being most prominent in the cities of the developing world, a handful of US cities today allow private minibus and jitney operators to ply their trade as long as they meet minimum safety and insurance requirements.

Urban *bus transit* services come in all shapes and sizes, but in most places they are characterised by 45 to 55-passenger pneumatic-tyre coaches that ply fixed

routes on fixed schedules. Buses are usually diesel-propelled, though in some larger metropolises (such as Mexico City and Toronto) electric trolley buses powered by overhead wires also operate. Because they share road space, buses tend to be cheaper and more adaptive than rail services. However, on a per passenger kilometre basis, bus transit is generally a less efficient user of energy and emits more pollution than urban rail services. Guided busways are used in some cities.

The oldest and slowest rail services - *streetcars* in the US and *tramways* in Europe - functioned as mainline carriers in an earlier era, but as metropolitan areas grew outward, those that remained intact were relegated to the role of central city circulators. Trams are enjoying a renaissance in central-city use. The modern-day version of the electric streetcar, *light rail transit* (LRT), has gained popularity as a more affordable alternative to heavy rail systems, particularly in medium-size metropolitan areas of under 3 million in population. Compared to tram services, LRT generally operates along exclusive or semi-exclusive right-of-ways using modern, automated train controls and technologies. The LRT vehicles tend to be roomier and more comfortable than tram cars, with more head clearance and lower floors. LRT is considered safer than heavy rail because electricity comes from an overhead wire instead of a middle third rail, saving the need to fence the track.

In the world's largest cities, the big-volume transit carriers are the *heavy rail* systems, also called *rapid rail transit*, and known as *metros* in Europe, Asia and Latin America. Metros work best in large, dense cities. Indeed, the relationship is symbiotic. Today, worldwide, there are some 80 metro systems, including 27 in Europe, 17 in Asia, 17 in the former Soviet Union, 12 in North America, seven in Latin America, and one in Africa. In contrast to light rail systems, few metros are being built today, partly for fiscal reasons and partly because most areas that can economically justify the costly outlays already have them. The niche market of heavy rail services is high-volume, mainline corridors.

In terms of operating speed and geographic reach, *commuter rail* or *suburban rail*, stands at the top of the transit hierarchy. Japan dominates the world's commuter rail market. There is something of a commuter rail renaissance in North America. Commuter rail services typically link outlying towns and suburban communities to the edge of a region's central business district. They are most common in big metropolitan areas or along highly urbanised corridors and conurbations. Commuter rail is characterised by heavy equipment, widely spaced stations, and high maximum speeds that compete with cars on suburban freeways (although trains are slow in acceleration and deceleration). Services tend to be of high quality in terms of comfort. Serving commuters means that ridership is highly concentrated in peak hours, more so than any other form of mass transit service. (Cervero, 1998).

#### The Advantages and Limitations of Transit

Transit has the important advantage of being able to utilise low-emission transport technologies to move large numbers of people without generating the

same external costs as private motorised transport. Rail transport, usually the centerpiece of proposals for sustainable transport, can move large numbers of people reliably, offering substantial energy savings per traveller over other powered modes, and it has the capacity to generate land development and local centers. An extensive rail network can have some negative effects in terms of sustainability. The electricity provided for rail services may be generated by the use of polluting fossil fuel technology. There is also the likelihood that improved rail service (particularly at lower prices) increases overall travel.

Transit services do, however, have some important deficiencies at present. Four main limitations stand out:

- The inefficiency in serving areas with low population or employment densities (in such circumstances there is a negative interaction of low usage leading to infrequent service which, in turn, deters users);
- Fixed transport systems, such as rail lines, quickly become obsolescent as travel patterns change;
- Investments in public transport infrastructure rarely recognise opportunity costs the net social rate of return when compared with alternative investments (for example, flashy new subway lines compared with undramatic repairs of existing facilities or additional bus lanes); and
- People are not attracted to choosing public transport for most trips because it is too complicated, too unpleasant, and too time-consuming.

Deteriorating service levels have undermined transit in many cities. Declining ridership often triggers service cuts, which in turn drive even more customers away, forcing even further service cuts. Only through an infusion of government subsidies has it been possible to sustain transit service levels in most wealthy countries. Nevertheless, shifting political priorities, tight budgets, and government's retrenchment from the public transit arena have in many cases cut into subsidy transfers.

Critics point out, with some justification, that aid to transit in the United States has produced relatively little payoff. Studies have shown that a large share of government subsidies to transit get consumed by higher labour costs and fewer kilometres of service per worker (Cervero, 1985, Pickrell, 1985). Where transit agencies enjoy a protected monopoly status and face little competition from other common-carrier services, operating subsidies have led more to lax management practices and overly generous worker compensation packages than they have increased ridership. Competitive contracting of public transit services has been used in many countries to contain rising costs (Cervero, 1998).

Despite these current limitations, public transport does have some considerable potential in the long run. Developments in long-distance rail are a good illustration of what public transport can accomplish when new technologies are harnessed to addressing growing areas of demand. With respect to intra-
metropolitan transport, new technologies could increase the flexibility of peoplemover transport, and reduce its cost. At the same time, mass transit and light rail systems are becoming an increasing focus of attention in the APEC region. In the longer run, intelligent vehicle- highway systems offer the prospect of low-emission, automatically driven taxi-type transport, which could offer highly customised services.

### Strategies for Improving the Competitiveness of Transit

Five major strategies are required if the competitiveness and flexibility of public transport is to be increased substantially in the future.

Firstly, new technologies should be harnessed to provide innovative new transport equipment and infrastructure. The goals to be addressed should be increased flexibility of transport services and the facilitation of consumer requirements, thereby increasing substitutability with private motor transport. Consumer surveys suggest issues such as door-to-door travel times, safety and security, convenience and flexibility rate high as factors affecting transport choice.

Secondly, as argued by the OECD (1997c), there is a case for the extension of network coverage, capacity and frequency.

Thirdly, the operational flexibility of public transport should be increased with customisation being the primary objective. Specific attention should be given to:

- The provision of clear and accurate customer information, including dissemination of information via the internet and through road linkages;<sup>18</sup>
- Improved service reliability and comfort;
- Addressing personal safety issues;
- Focusing on customer demands;
- Tailoring vehicle mixes to customer demands; and
- Better designed transit interchanges (in terms of comfort, accessibility, security, weather protection) with customer-focused services.

Fourthly, intermodality and substitutability both between different forms of public transport (such as rail and bus) and with private transport (such as through park-ride interchanges) should be increased. This should encompass transfer ticketing across different forms of transport and encompassing park-ride facilities and intermodal traffic information as well as the timing of connections between different forms of transit services.

Fifthly, transit-oriented developments along public transport corridors should be encouraged.

<sup>&</sup>lt;sup>18</sup> Including whether timetables, maps, and other information are provided at every stop, and whether the system is actively marketed and sold through innovative advertising campaigns and marketing strategies such as specialised destination maps for different purposes.

What are the institutional requirements for giving effect to such policies? The most important requirement is for a transport regulator to be established with oversight of urban transport. It should be quite detached from any operational responsibility for transport. Secondly, transport operators should be subject to overall regulation which specifies community service obligations and sets goals for service provision and overall efficiency.<sup>19</sup> The corporatisation or privatisation of transport operators may be seen as being necessary to secure the above goals.

## Transit in Tokyo

Tokyo's metropolitan rail network, 2100 km in length and extending more than 50km from Tokyo station, is by far the world's largest. Headways between trains in central Tokyo average two minutes and waits are usually under one minute. Most suburban railways average six-to-eight minute headways during peak hours. Overall, Tokyo's train system is extremely punctual and reliable and enjoys a superb safety record. Despite short train headways, the average commute time, one-way, within the region is long - about 66 minutes. About 21 per cent of commuters, or 1.85 million people, spent more than 90 minutes one way getting to work. The sheer size of the Tokyo megalopolis and its monocentrism in terms of employment have inflated commuting times.

A dominant center and an extensive radial rail network have led to huge ridership on transit in Tokyo. About half travel during peak hours under extreme crowding. Rail handles 67 per cent of all commutes into central Tokyo.

Tokyo's private railway companies started up in the early part of the century and branched, over time, into real estate development, retailing, bus operations, and electric power generation. Presently, eight private railway companies own and operate suburban rail services in Greater Tokyo. In transportation, they provide bus services that feed into their rail operations, taxis, car rentals, trucking, shipping, freight forwarding, package delivery and manufacturing of rolling stock. In real estate, they are involved in the construction, sale and leasing of housing, office space and hotels; architectural and engineering services; and landscaping. In retailing they have interests in the construction and operation of department stores, supermarket chains, station kiosks, catering services and specialty stores. In leisure and recreation they are present with respect to the construction and operation of resorts and spas, amusement parks, baseball stadia, multiplex movie theatres, fitness clubs, golf courses and the operation of travel agencies.

By and large, the feeder bus services run by the rail companies incur slight deficits (but are valuable in funnelling traffic into the stations and rail networks), a modest positive return on rail services, and, before the 1990s problems, big returns on operations related to real estate. Japanese companies historically acquired low-priced agricultural land prior to rail construction and thus captured the appreciation

<sup>&</sup>lt;sup>19</sup> It may also oversee the introduction of a ticketing system integrated across different modes of transit services.

in land values that accrues from increasing the accessibility of properties near rail stations (Cervero 1998).

### **Transit in Mexico City**

Mexico City's congestion and pollution would be much worse were it not for the dynamic and wide-ranging transit system that has evolved over the years. At the top of the transit hierarchy and forming the backbone of the system is Metro, a predominantly rubber-tyre, high-speed subway network that crisscrosses the federal District. The capillaries of the transit network are the paratransit feeder services known locally as *colectivos* (micro-buses and minibuses). Supplementing these modes are intermediate carriers - electric trolley buses, suburban diesel buses, and an advanced light rail service. Government is the main provider of the mainline, high-capacity services, and the private sector largely takes care of most branch connections.

The Metro, first opened in 1969 as a single 12 km line with 16 stations has gradually expanded to a network of ten lines with 154 stations spanning 178km, the fifth-largest metro system in the world. The system now forms a super-grid. Originally modelled after the Paris subway and built by a French-Mexican co-venture, trains on nine of the ten lines run on pneumatic tyres, providing relatively smooth, quiet rides. Trains can accelerate and decelerate faster with rubber tyres, allowing for short station spacing in the dense city core. Moreover, since pneumatic trains can negotiate tighter turns, subway tubes could be more easily aligned to connect major activity located in the core. Minimal vibrations also made pneumatic services well suited to Mexico City's unstable soils, and also allowed for extensive air-rights development above tubes and stations. The major drawback of pneumatic services has been higher maintenance expenses and a higher incidence of in-service breakdowns from deflated tyres. Partly for this reason, the 17 km Line A, which serves several low-income communities in the State of Mexico and which opened in 1991, is the system's first section of steel-wheel services.

Presently, Mexico City's metro services are the most intensive in the world, with more train cars per rail kilometre than anywhere. Fares are quite cheap. Services are extensive and frequent. Daily ridership nears 5 million; only Moscow and Tokyo exceed that. However, congestion is significant at peak periods, with substantial overcrowding on rail cars. The cost structure on a unit basis is the lowest of any subway system in the world, although the debt burden is substantial.

There has been little clustering of urban development around Metro stations to date. Only a few outlying stations have spurred new office building construction. Urbanisation in Mexico City has occurred so rapidly that master planning has not been possible. Metro's greatest impact on urban form has been to further spur decentralisation. Mammoth new town developments have occurred on the fringes. At the same time, these fringe developments are also providing strong employment opportunities. Radial commutes to the center are being replace by heavy movements from adjacent low-income communities in the State of Mexico to new employment centers in the Federal District. Decentralisation has resulted in exceedingly long average per trip travel times - in 1994, 46 minutes for the region as a whole.

In response to mounting decentralisation pressures, the Mexican government has announced plans to significantly extend Metro services. New extensions and lines will add 31km by the year 2003 by 2020, if all goes according to plan, 27 Metro lines - a combination of subways and elevated commuter tracks - will be in operation, more than doubling Metro's current trackage.

A patchwork of intermediate-capacity transit services has evolved to largely fill in service gaps left by the Metro. The two publicly supported intermediate carriers - trolley buses (19 lines in all) and the 27 km Tren Ligero light railway largely supplement Metro services by operating parallel to Metro lines, filling in mainline service gaps of the subway. Functioning mainly as intermediate-distance distributors are the District's more than 100 diesel bus routes, called Ruta Cien. Their suburban counterparts, providing longer-haul links between peripheral communities in the surrounding states of Mexico and Morelas and metro's stations, are privately owned diesel buses. The share of these private buses, now more than 10 per cent of daily unlinked trips, is steadily growing. Ruta Cien's ridership and service quality has improved since services were recently turned over to the private sector under a concessionary arrangement. New services include more premium commuter services.

Where the intermediate carriers falter, especially when compared to privately operated paratransit feeders, is with respect to service and fare coordination. There are no obvious efforts to synchronise timetables, although with such frequent Metro timetables, this is not a significant problem. However, the lack of fare integration is. Although tariffs are relatively cheap, multiple fare payments can be quite burdensome. Other problems for surface-street intermediate carriers are the worsening traffic congestion and air pollution associated with SPM from diesel buses.

Mexico City's paratransit sector has grown and adapted over the years in response to Metro's rapid expansion. It has provided short-to-intermediate -distance feeder connections to mainline carriers, as well as serving poor and politically powerless neighbourhoods outside the Federal District that have been bypassed by bus operators, in part because of their inaccessibility. It has also helped to compensate for the region's poor hierarchy of roads and highways. In particular, there is a serious lack of collector streets to distribute traffic onto the main arteries. A significant portion of collectors are discontinuous, abruptly ending and then picking up again a kilometre or so further on. The tertiary network of local roads is poor. Many roads are too narrow to accommodate oncoming vehicles, have irregular alignments, lack parking, and above all, are invaded by street vendors, peddlers, auto repair shops, and other activities that spill onto the right-of-ways.

A broad range of services is offered by paratransit services in terms of seating capacity, geographic coverage, levels of comfort, and fares. Taxis provide on-call,

curb-to-curb services - both exclusive and shared rides -whereas other paratransit modes ply principal routes. Pesero sedans, carrying up to 5 or 6 passengers, tend to serve the lowest volume corridors and make slight route detours at riders' requests. Combis normally carry around 10-14 passengers and concentrate mainly on intermediate-volume markets in the suburbs. Minibuses seat up to 25 passengers with room for an equal number to stand. The vehicles have segmented themselves geographically, with smaller vehicles serving shorter-haul customers (more often in the suburban-exurban fringes of the State of Mexico) and larger vehicles traversing longer distances (more often within the Federal District).

Presently, there are about 100 paratransit routes in Mexico City, and each route averages about 15 deviations or branches. Central Mexico City is virtually saturated with peseros and minibuses during peak periods. Middle-class suburbs are also well served. Many barrios and slum areas on the periphery receive thinner services, not only because their residents are less able to pay market-rate fares, but also because roads leading to these areas are often substandard and steep. Still, paratransit manages to penetrate some of the narrow and poorly maintained roads and alleys that buses can not. The routes of nearly all peseros and minibuses in the surrounding State of Mexico end at a Metro terminal station.

Where Mexico City's paratransit services fall short is in vehicle quality, as they are victims of constant, heavy usage. Fleets are often minimally maintained and toward the end of their service lives. It must be kept in mind, however, that First World quality transit services equate to First World price levels, something few Mexican transit patrons can afford. Outside oversubscribed peak hours, however, peseros and minibuses usually provide reasonably comfortable rides. Moreover, drivers are generally no more aggressive than other motorists, unlike in most other developing countries with thriving para transit services. This is mainly because Mexico City's paratransit routes are controlled by associations, thus easing some of the competition for customers (Cervero, 1998).

### **Smart Paratransit**

Paratransit involves the use of small transit vehicles to provide more flexible scheduling and more varied rider pickup and drop-off points. Since passage of the Americans with Disabilities Act in 1991, many public transit authorities have introduced paratransit services for disabled and elderly riders. Some transportation planners and researchers envisage the expansion of paratransit to provide services to the more general population of travellers, operating in a manner similar to that of airport jitneys, though for more varied purposes and employing more sophisticated reservation, scheduling and dispatching systems (Sperling, 1995). Paratransit services would therefore offer an alternative to automobile travel.

The attraction of paratransit in principle is that services can be tailored to the schedule needs and other circumstances of individual travellers, increasing transit utilisation. However, a disadvantage of existing paratransit programs is that many have proved expensive to operate reliably. Dispatching, routing, and scheduling of paratransit services are costly and complex (Stone *et al.* 1994). To overcome these problems, automated transit and paratransit systems are being explored as part of the federal government's research and development program for intelligent transportation systems.

Developments in computer and communications technologies may permit paratransit vehicles to be dispatched and scheduled on a more efficient and timely basis, enabling operators to provide more dependable service at lower cost. Riders may have a more direct role in making and adjusting reservations by using computerbased reservation systems such as air travellers do today (Stone *et al.* 1994). Envisioning travellers using cellular telephone and computer-modem connections to make real-time reservations, Sperling (1995) anticipates the expanded commercial availability of smart paratransit or smart ridesharing systems as an alternative to conventional transit vehicles and single-occupant automobiles.

The first probable application of smart paratransit technologies will be to improve the operation and services of systems dedicated to the elderly and the disabled. Whether these applications will make paratransit service more practical for other travellers remains unclear. This kind of application, however, may warrant more emphasis in ITS research and development programs (TRB, 1997). In cities like San Diego, Houston, Mexico City and Bangkok, where paratransit services are both considerable in size and facing significant growth prospects, there are early opportunities for the deployment of new paratransit technologies.

# **Transport Management**

## Highway Capacity and Traffic Flow Improvements

Motor vehicle fuel use is a function not only of vehicle size and design but also of how vehicles are driven, especially how fast they travel and how frequently travel speeds fluctuate as a result of stopping and starting. In general, fuel use is lowest for vehicles travelling at cruising speeds between 35 and 45 miles per hour. At higher travel speeds -such as in freeway driving - aerodynamic drag has the greatest effect in increasing fuel use. At lower speeds, engine and tyre friction, airconditioning, and other accessories have a relatively larger effect. If vehicles are subject to frequent braking, idling, and acceleration, fuel use is increased even more.

Given these influences, traffic flow measures that seek to moderate travel speeds by lowering top cruising speeds and minimising repeated acceleration and braking could be expected to increase fleet fuel efficiency. Speed limits are now tending to be promoted for safety reasons rather than fuel saving, reflecting the lower priority of the latter objective currently.

The emphasis today is on finding ways to alleviate congestion. Such measures have the by-product of reducing stop-go traffic and thereby saving in fuel and emissions, including what can be lethal local concentrations of SPMs. Common

and inexpensive measures taken by highway agencies to smooth traffic flow include synchronised traffic lights, reversible travel lanes, left-turn signals, on-street parking restrictions during peak hours, and ramp metering. Higher-cost measures can range from improvements in the layout and physical condition of existing roadways to the construction of new travel lanes on existing routes and the addition of new roads.

While the prime motivation behind these measures is to reduce congestion, their proponents often point to reduced petroleum use and emissions as important side benefits. On the other hand, opponents of highway enhancements often argue that such efforts have transitory effects and do little to reduce motor vehicle emissions and fuel use largely because the roads fill up again with even more vehicles and traffic flow again begins to decline. They contend that the additional highway capacity will spur further residential and commercial development in the areas served (TRB, 1997).

In the light of this debate, a Transportation Research Board (TRB) study committee recently examined the effect of highway capacity improvements on motor vehicle travel, energy use, and emissions (TRB 1995). The committee found that the relationships among highway capacity, energy use, and emissions are highly complex because of secondary effects on travel demand. Evidence was found that incremental traffic control measures, such as synchronised timing of traffic lights, channelisation of turn lanes, and ramp metering, could increase and smooth traffic flow without having a significant effect in generating additional commercial and residential development and associated motor vehicle use (TRB 1995). Other studies have found that when implemented together, measures that improve traffic flow can reduce travel times in congested urban areas (Downs 1992, Deakin 1993 and OTA 1994). How these improvements would translate into reduced fuel consumption and emissions remains unclear. Because such measures apply mainly to congested areas during peak travel times, their marginal effect on total motor vehicle use and emissions is probably small.

Intelligent transportation systems, which have the potential to change dramatically the way motor vehicles are driven and used, could have a much broader influence on motor vehicle fuel use and system efficiency (TRB, 1997).

#### Traffic Management in Inner-Urban Areas

Parking controls are still the most common means of restraining traffic in the inner-urban areas of most OECD countries. They seem to be accepted by the public and are reasonably enforceable. Wider use of measures affecting the availability and price of parking include limiting the amount of parking provided with new commercial developments, and shifting the supply of parking from central to suburban districts (to favour park-and-ride). Significantly higher charges for parking, coupled with strict enforcement, can effectively discourage motorists from driving into city centers. Restricted access, such as through pedestrian zones and streets reserved for public transport, pedestrians, and cyclists, seem to find public acceptance in spite of initial misgivings. Some additional road infrastructure may be warranted in this context if it serves to route traffic around closed areas. Experience in OECD countries with using tolls to regulate access to city centers remains limited, but has been shown to be feasible.

In order to further restrain motorisation, Singapore has also introduced a series of use-related charges, beginning with the introduction of the world's first area licensing scheme (ALS) in 1975. Initially a special license enabling a car to enter the central city area during morning peak times, it was extended to a full day in early 1994. Between 1995 and 1997, road pricing, in the form of a peak period license, was introduced along inner-city stretches of three major expressways.

Singapore has now begun to phase out the ALS, replacing it with a full-blown electronic road pricing (ERP) system. The system applies a highly sophisticated combination of radio frequency, optical detection, imaging, and smart card technologies. With ERP, a fee is automatically deducted from a stored-value smart card (inserted into an in-vehicle reader unit) when a vehicle crosses a sensor installed on overhead gantries at the entrances of potentially congested zones. The amount debited varies by time and place according to congestion levels. Cameras mounted on gantries snap pictures of violating vehicles to enforce the scheme.

The first phase of ERP was introduced along the East Coast Parkway in March 1998, and by mid-1999 the system was in place along all expressways and throughout the CBD. Planners are now concentrating on fine-tuning the toll system to sharpen price differentials between the currently heavily subscribed peak hour (0800-0900) and the more lightly utilised shoulders of the peak (0730-0800 and 0900-0930). Charging peak-hour motorists twice as much as those travelling on the shoulders of the peak failed to shift traffic as much as was hoped.

Traffic calming can be achieved by stricter enforcement of existing speed limits, reducing speed limits, re-routing traffic, and by the use of telematics to adjust traffic flow to current conditions. Employer-based programs can reduce demand for low-occupancy commuter travel such as through teleworking, initiatives to support multi-occupant travel through parking restrictions or financial incentives, and substitution of free public transport passes for free parking (OECD, 1997c).

## Measures to Reduce Fuel-Intensive Large-Truck Travel

In the United States medium- and heavy-duty trucks account for 7 per cent of annual miles travelled and about 20 per cent of petroleum consumed by highway vehicles. Although the average fuel consumption of the large-truck fleet has improved in recent years, medium- and heavy-duty trucks average only one-fourth the distance per litre of fuel consumed as gasoline-powered passenger cars. Because distance travelled by trucks has grown faster than travel by car, the influence of the freight sector on motor fuel use and emissions has grown. The most commonly discussed approach to reducing energy consumption in freight is shifting truck traffic to rail. Freight-carrying trucks consume nine times more fuel per tonne/km than does rail transport (TRB, 1997). Specific policies proposed range from increasing excise taxes on diesel fuel to providing subsidies for the use of lower-energy-intensity modes (such as rail and water). Stricter regulations governing vehicle fuel economy and other related characteristics, such as truck size and weight, have also been proposed.

Many such proposals, however, prove more complicated when all of their potential ramifications are considered. For example, restriction of truck size and weight may succeed in diverting some shipments to other modes, such as rail, but is likely to affect mainly long-haul shipments of high-density commodities, accounting for only a small proportion of truck traffic. The fuel savings resulting from this diversion, however, may be largely or entirely offset by the reduced fuel efficiency of smaller trucks that would remain on the road (TRB, 1997).

Recent examinations of the possibilities for reducing energy consumption in the freight sector have concluded that the potential for mode shifts, induced by either price or regulatory mechanisms, is limited. The constraints reflect the different characteristics of the cargo moved by each freight mode and shipper and customer operational needs. A 1994 Office of Technology Assessment study concluded that the amount of truck traffic that is a strong candidate for diversion to other transport modes is likely to be too small to have an appreciable effect on total transportation energy use (OTA 1994). These findings suggest that, if the intent is to reduce fuel use and  $CO_2$  emissions from truck travel, more direct pricing measures, technological change and a greater commitment to transport logistics provide the most promising avenue to sustainability. New technologies for inner-city freight distribution may yield promising alternatives to trucks, and international support for research in this area should be secured.

#### **Road Pricing**

The regulatory approach to traffic demand management suffers from its inability to provide correct market signals to induce the most efficient trips to be undertaken. In contrast to pricing incentives, it generates virtually no revenues for the public sector. Recent technological breakthroughs have brought electronic road pricing much closer to reality.

The imposition of an externality-corrective tax, the road toll, initially creates a major beneficiary in the government, the collector of the toll revenue. At the same time, a number of groups are made worse off. Firstly, it can be shown that, for those motorists who remain on the road, the tax payment made exceeds the monetary value of the time saving (the optimal toll per trip has to be higher than the value of the time savings per trip, reflecting the downward sloping demand curve for travel, although individuals who place a high value on their time may be made better off)<sup>20</sup>. Secondly, those who are tolled off the road to an inferior mode of time or travel are clearly worse off. Thirdly, those who remain on the tolled road at other times or on other roads or modes of travel are worse off to the extent that a new source of congestion arises. The political implication of this analysis is that the tolled and the tolled-off need to be compensated, and congestion toll revenues utilised (Hau, 1997).

To achieve a larger reduction in emissions by preventing major shifts in travel from toll roads to unpriced routes, road pricing programs would need to have broad coverage, affecting road networks over large geographic regions for much of the day. Advances in automated toll collection systems have increased the technical feasibility of such area-wide networks. Automated toll-collection technologies, such as electronically scanned tags, have been deployed successfully in the United States and elsewhere.

Many daunting institutional and jurisdictional issues would need to be overcome to enable area-wide road pricing. Most large metropolitan areas consist of dozens of state, county, and municipal governments, each having partial or exclusive authority over the bridges, highways, and streets within its jurisdictional boundaries. A major challenge will be to coordinate road pricing programs and overcome the political and jurisdictional issues (TRB, 1997).

Many studies have examined the feasibility of alternative policy options to internalise the environmental and social costs of transport. Despite this, the policy response has been comparatively slow, and there remains a marked divergence between the policies which are often advocated and their acceptance into transport policy. For example, road-pricing to help optimise urban traffic flows has been given serious consideration by several OECD countries, but none has moved beyond the exploratory stage (OECD 1997c).

Perhaps the most important policy issue associated with electronic road pricing is the persuasion of motorists that road pricing is good for them. The use to which revenues are put is crucial in convincing voters that road pricing is desirable. Borrowing against future revenues allows spending on better public transport or other transport infrastructure to be brought forward so as to coincide with the introduction of road pricing. This has been the key to the success of Norway's road pricing initiatives.

Compensation needs to be carefully handled. If compensatory payments to motorists depends on car usage, motorists would be induced to drive more, so economic efficiency would be violated. This would tend to rule out fuel tax rebates,

<sup>&</sup>lt;sup>20</sup> For each stretch of road, short-run marginal cost pricing is fulfilled by charging a toll that is equal to the difference between short-run marginal cost and short-run average variable cost. The short-run is literally as brief a period of time as particular hours in the day. This implies that the congestion costs of peak periods are priced into the toll rate.

for example. The earmarking of funds to an independently administered transportation fund is the ideal solution. This fund could finance both road construction and improvements in public transport, utilising the above principles for investment in infrastructure.

Finally, a potentially greater obstacle to road pricing is the development of public trust and acceptability of road pricing technologies and intentions. Road pricing represents a radical change in practice. Public concern over unanticipated and unpleasant side effects of new pricing programs, such as the privacy issues arising from the potential use of vehicle tracking and toll billing systems for law enforcement, are often cited as significant impediments to public acceptance of comprehensive systems.

# **Technology Development Policies**

The accumulation of environmental problems in cities points to the need for a new wave of innovation. The record of innovation suggests that the cities and national governments that risk change also reap the benefits of change. Cities that are pursuing innovations to improve their environment are among the most successful in the system of places making up the global economy. The evidence from projects presented as case studies is that innovation need cost no more than traditional approaches and can sometimes be cheaper, especially when lifetime costs are included (OECD 1996a).

Industry policy has a role in encouraging the process whereby new technologies are developed and pushed into the market place. The earlier analysis has indicated that there is significant potential for new technologies in such areas as:

- materials technology and vehicle bodies;
- hybrid-electric vehicles;
- fuel cells;
- batteries;
- on-vehicle electronics;
- inter-city trains;
- new types of people movers;
- satellite road pricing technologies; and
- intelligent vehicle-highway systems.

The industries that will be supplying equipment utilising these new technologies include motor vehicles, other transport equipment, and electronics. There are important technological synergies with defence electronics and military and civilian aerospace manufacturing. In addition, the development of electronic commerce is of major importance to advances in transport logistics. The process of technological development will benefit from synergies with defence industries. The OECD literature suggests that wide-scale adoption of best available technology already in use would, of itself, bring significant reductions in fuel consumption and pollution, especially if strong enforcement, inspection and maintenance programs were implemented in all OECD countries. Further significant gains could be attained if technologies that are already at the prototype/demonstration stage were adopted. Market forces have so far failed to generate widespread use of best available technologies, so that the case appears strong for government intervention to progressively tighten standards and develop economic instruments designed to accelerate the adoption of today's optimal technology.

The effective use in the past of such approaches (mandatory standards, differentiated taxes on fuels, vehicle purchase and road taxes favouring cleaner, more efficient vehicles) suggest that this is one way to go. The fact that the average time for technological improvements, once commercially available, to diffuse through the entire vehicle car park is about 10 to 15 years argues for the early adoption of these policies, with a tight calendar for their implementation, and on an internationally coordinated basis (OECD, 1997c).

#### **Cooperative Research Development**

As is the case with defence, cooperative research programs involving both the public sector and companies will have an important role to play in developing basic technologies. Because petroleum prices have been stable or declining in recent years, motorists have not been demanding further gains in vehicle fuel economy, providing little incentive for automobile manufacturers to explore and adopt new fuel-saving designs and technologies. Aiming to accelerate research, development, and implementation of fuel-saving technologies, the federal government and major US automobile manufacturers have been working since 1993 to develop an affordably priced and consumer-acceptable "new-generation" vehicle. This joint venture, known as the Partnership for a New Generation of Vehicles (PNGV), is seeking to develop a new type of passenger car that is equivalent in price, function, and performance to popular mid-size passenger cars but has up to three times the fuel economy (TRB, 1997).

The goals of the PNGV program are among the most ambitious of any R&D activity under way. PNGV seeks to develop a new passenger car that is comparable with current vehicles in performance and price while achieving up to three times the fuel economy. It is important to note that the PNGV program is under a tight deadline to develop a concept vehicle by 2000. The deadline has influenced the kinds of technologies being explored, particularly limiting the consideration of technologies requiring much longer development, such as the fuel cell. Hence, one of the recommendations of the Research Council review of the PNGV program is that complementary capabilities be explored to further the development of longer-range technologies that cannot meet the more ambitious prototype deadlines (National Research Council 1996 and 1997).

Another National Research Council committee charged with reviewing the PNGV program has noted the importance of maintaining a compatible long-term technology program that avoids the singling out of one or two technologies for concentration of public resources (National Research Council 1997). The committee has urged the continued development of non-conventional technologies under a long-range sustained R&D program. This recommendation is further supported by the findings of this study, which suggest that the introduction of new vehicle and fuel technologies may require significant infrastructure changes and take many years to develop and introduce in quantities that will significantly influence trends in greenhouse gas emissions. Thus, early and persistent efforts to explore a varied array of options may help to ensure that significant lead time is not lost by pursuing a small number of technologies that may encounter unforeseen technical and economic barriers or not met future emission reduction needs (TRB, 1997).

Finally, another area in which public-sector support may be valuable is in stimulating the exploration and development of infrastructure to support alternative-fuel vehicles, which may differ significantly from that now in place for conventional vehicles. For instance, if new technologies require radically different energy production, transmission, and distribution systems, as is likely for fuel cells, the early exploration of these needs may be valuable in overcoming obstacles to private-sector development and technology deployment. The need for such a complementary program was also identified in the Research Council review of the PNGV program (TRB, 1997).

Above all, at the international level it will be important to work on exchanges of information that facilitate the development of a shared vision for the technological future of such industries as motor vehicles, other transport equipment, and transport logistics and management. It is important to recognise that government spending on research may not be adequate by itself and that a mix of policies to encourage private-sector R&D on advanced technologies will likely be essential to achieving progress. Finding the right mix of inducements will require experimentation and study. The automobile and oil industries have spent hundreds of millions of dollars over the past three decades in developing and introducing catalysts, reformulated fuels, and other products and technologies to achieve pollution abatement goals. Further inducements for the private sector to take a long-term perspective in advancing alternative transportation fuels and technologies may yield similarly beneficial returns over the next several decades (TRB, 1997).

## Mandates for the Supply of Fuel-Saving Vehicles

The most significant US effort to encourage the development and use of lowcarbon technologies is under way in California. In 1990, the California Air Resource Board instituted a requirement that major automobile manufacturers begin selling so-called zero-emission vehicles (ZEVs) in California by 1998.<sup>21</sup> The states of New York and Massachusetts have adopted similar ZEV requirements. To spur demand for new technologies and fuels, several states, led by California, also offer tax and rebate incentives for private and commercial use of very-low-emission vehicles and inducements or requirements for government agencies to use alternative-fuel vehicles in their fleets (TRB, 1997).

The California ZEV mandate targets air pollutants rather than CO2. As a practical matter, the mandate for early production of ZEVs was tantamount to requiring the mass production of electric-battery vehicles, whose potential effect on greenhouse gas emissions is large in California but elsewhere depends on the source of electricity and whether it is carbon-intensive.

The longer-term intent of the California mandate is to generate greater automobile manufacturer interest in a variety of electric-drive technologies. Proponents of such performance-oriented mandates argue that they provide the incentive for R&D, the latitude to explore other technologies, and more certainty about the future. This technology-forcing approach focuses the task of R&D on the private sector. Opponents of this approach argue that if the performance standards are unrealistic in recognising technological constraints, leading to impractical time frames for research, development, and deployment, they can be costly to suppliers and consumers and - perhaps worse - can serve as a distraction, drawing attention away from other more valid options for controlling emissions (TRB, 1997).

## Encouraging the International Spread of Advanced Technologies

It is important that the particular needs of major urban centers in the developing economies for sustainable transport systems are taken into account. The development of manufacturing industries like motor vehicles in developing economies through the investments of multinational companies has often low-cost designs and technologies, whereas the particular needs of these countries may suggest the need for advanced technologies to meet rapidly increasing environmental pressures. In addition, cities in the developing economies may provide a big market for new technology paratransit vehicles and for low-emission motorcycles. China is one country that is endeavouring to come to terms with these issues in developing policies for a more sustainable automobile industry in the 21<sup>st</sup> century (Lin Gan, 1999).

Technology foresight methodologies can be used to increase awareness of technology options for dealing with sustainability problems. This is desirable both within individual economies and at an international level.

<sup>&</sup>lt;sup>21</sup> As of the amended regulations of March 1996, major automobile producers are to place up to 3750 advanced battery ZEVs in California by 2001, with sales of ZEVs to reach 10 per cent of total in-state sales of light-duty trucks and passenger cars.

# The Fiscal Issues

Taxes are seen by many as an important means of shaping transport demand and encouraging the adoption of more sustainable technologies in transportation.

In Japan, the national government has traditionally imposed stiff controls on car ownership through a vehicle acquisition tax, an annual registration tax and a surcharge based on vehicle weight. Japan's petrol taxes are three to four times higher than in the US. In addition, all Japanese intra-urban and interurban expressways are tolled. In addition, there are onerous garaging requirements: anyone wishing to register a car must present evidence of an off-street parking space at their residence. In Tokyo today, a permanent off-street parking space today can cost as much as a small condominium, parking spaces being severely controlled. Car ownership rates in metropolitan Tokyo are less than half those of most US cities (Cervero 1998).

In the United States, in contrast, there are:

- Relatively low vehicle registration and sales taxes compared with European and Asian countries;
- Relatively low fuel taxes compared with most other industrialised nations; and
- Tax-exempt parking privileges frequently used in salary packages.

### Vehicle Ownership and Acquisition Taxes

Vehicle registration and sales taxes tend to be much lower in the United States than in European and Asian countries, which often impose high vehicle taxes to generate revenue. In cases where fees are uniformly high for all vehicles, the main effect is to discourage vehicle ownership. Hong Kong, China doubled its tax rates on vehicle ownership during the 1980s, and this led to a 20 per cent decline in vehicle ownership rates.

Singapore has made the most aggressive use of vehicle ownership and acquisition taxes. Car owners wishing to register their cars must pay a 45 per cent import duty on the car's open market value (OMV), a registration fee of S\$1000 for a private car (and S\$5000 for a company-registered car) and an Additional Registration Fee of 150 per cent on the OMV. In addition, car owners pay annual road taxes based on the engine capacity of their vehicles. There are higher road taxes for company-owned cars, and a diesel tax six times the road tax of a petrol vehicle.

To encourage people to replace their old cars with newer, more efficient models, a preferential Additional Registration Fee (PARF) system was introduced in 1975. Private car owners who replaced their cars within 10 years were given PARF benefits that they could use to offset the registration fees they had to pay for their new cars.

Any person wishing to purchase a vehicle first has to obtain a vehicle entitlement in the appropriate vehicle class, through a bidding system, the entitlements being issued through a quota system (the allowable vehicle stock is based on an assessment of prevailing traffic conditions, and there are separate categories for different types of vehicles) and a monthly bidding system applying. Cars can be registered at a lower rate under the weekend car scheme. Such cars can only be driven between 1900h and 0700h during weekdays, after 1500h on Saturdays , all day on Sundays and on holidays; a special red licensing plate is issued for these cars (Schwela and Zali, 1999). The quota system has been used to control the growth in the car fleet in Singapore to around three per cent per annum.

Among the advantages of vehicle fees is that they can be straightforward to implement and administer. If sufficiently high, they can lead to a smaller fleet by restraining ownership, leading to less travel overall. The major drawback of most vehicle fees is that they do not diminish the intensity of vehicle use since the size of the fee is usually independent of the number of miles driven. In drawing crosscountry comparisons, Schipper and Eriksson (1995) conclude that sales taxes and registration fees, unless exceptionally high, have had less effect on motor vehicle travel than levies on fuel, principally because vehicle fees in most countries are onetime sales taxes or annual fees that do not increase with miles driven.

## **Fuel Taxes**

Higher taxes on gasoline and diesel fuel are the principal means by which governments can raise fuel prices to engender a broad set of fuel-conservation responses. Fuel taxes also have the advantage of being straightforward to devise and administer, providing a dependable source of government revenue. In the United States, fuel taxes are imposed primarily as a means of funding the highway system. Currently fuel taxes from all jurisdictions account for about one-third of the price paid for gasoline at the pump in most locations (TRB, 1997).

By comparison, motor fuel taxes are much higher in most other industrialised nations, and the revenues generated by them are used for more varied purposes. The central function of these taxes is to raise revenue, although several Scandinavian countries have recently instituted a motor fuel tax on the basis of fossil carbon content. A fossil carbon tax is much more likely to generate greater consumer and supplier interest in energy sources that produce very low net carbon or none at all. Many very low- and zero-carbon energy technologies are still in their technical infancy; hence, a carbon tax probably would not prompt a rapid switch to radically different vehicle technologies and energy sources (TRB, 1997).

The econometric estimates of the determinants of fuel demand provide estimates of short -term price elasticities, but less evidence on long term elasticities. Examples of the range of values given for key elasticities are:

- -0.4 to -0.9 for fuel demand/fuel price;
- -0.2 to -0.4 for vehicle kilometres travelled (VKT) with respect to fuel price;
- -0.1 to -0.35 for VKT with respect to fuel cost of driving;
- 0.4 for the elasticity of fuel economy with respect to fuel price.

Elasticities do not say what combination of technical changes and behavioural adjustments are actually responsible for the link. The difficulty with the literature is that too few studies have isolated the fuels used by automobiles and the prices paid for those fuels. Generally, prices of gasoline have been used and diesel and LPG neglected. Further uncertainties arise because of the possibility of a non-systematic rebound effect. The rebound effect in this case is the amount by which the own fuel price elasticity of fuel demand is smaller than it otherwise would be if it were not for the fact that some of the energy savings as a result of a change in fuel economy are taken up by increased VKT.

Gasoline prices currently reflect levels of fuel taxation that are equivalent to the order of magnitude of hundreds, if not a thousand \$US dollars per tonne of carbon. Moreover, relatively short term increases in gasoline taxes, in real terms, can be as much as of the order of magnitude of a marginal \$US300 per tonne carbontax. Levels of carbon tax which some believe might possibly be agreed of \$US10-30 per tonne of carbon across fuels would have little effect on final gasoline prices. However, the impact of such a fuel tax on power generation is proportionately many more times that of the vehicle fleet (IEA 1997).

Fuel prices reflecting the high social costs linked to fuel use could both restrain growing demand for fuel consumption and stimulate demand for more fuel efficient technologies. Higher fuel prices could also be one means of beginning to internalise some of the environmental and social costs of road traffic. Options include shifting the burden of taxation from vehicles to fuel, ensuring that governments recuperate the costs of providing transportation-related infrastructure through fuel taxes and indexing fuel costs to pay for uncovered costs associated with traffic congestion, accidents, air pollution, noise and land-use impacts (OECD 1997c).

#### **Feebates**

Several countries have investigated indexing a portion of vehicle purchase taxes according to fuel efficiency or emissions. Such mechanisms would tax vehicles with high fuel consumption or emissions while providing consumers with rebates for purchasing vehicles with low fuel consumption or emissions. Other countries have indexed vehicle sales taxes according to the vehicle's purchase price and/or engine size. These indirectly account for fuel economy since, in general, higher priced vehicles tend to have lower fuel economy (because of heavier weight, greater number of energy-consuming features such as air conditioning and more powerful engines). However, such sales taxes may not be the most effective vehicle taxation option since they do not provide a direct incentive to improve energy efficiency. Feebates, on the other hand, provide such an incentive - even in those cases where gains in energy efficiency add a cost to the vehicle purchase price (OECD 1997c).

# **Parking Taxes**

Acknowledging the near-term obstacles to road pricing, some metropolitan areas have explored the use of parking taxes as a simpler means of discouraging motor vehicle travel and encouraging transit use and ridesharing. Parking taxes and fees are commonplace in the United States but seldom used to reduce vehicle use. Some large cities impose a sales tax on parking garage users. However, Shoup (1994) estimates that at least 90 per cent of commuters who drive to work are not charged directly for parking.

One area of importance concerns the tax treatment of employer-provided parking in high demand areas. In the United States, most workers are exempt from paying federal and state income taxes on parking privileges provided by employers. This exemption, it is argued, encourages employers to offer, and employees to demand (in lieu of taxable wages), parking privileges in locations where private parking is expensive. A study surveying commuters to downtown Los Angeles found that changing these incentives by substituting equivalent cash payments (in after-tax value) for parking benefits would cause average vehicle miles travelled per employee to decline by 15 to 20 per cent (Shoup 1994). To produce such an effect on a larger scale, some researchers have proposed that federal and state tax codes be changed to treat parking benefits as taxable compensation (TRB, 1997).

Similar problems arise in several other economies (notably, Australia). Taxes and/or tax breaks in relation to executive transport packages are recommended to steer demand away from executive cars and parking that is fully paid, towards transit and share-transport packages.

## **Utilising Tax Revenues**

There is a need to create better ways to pay for future urban transportation systems. Some suggested methods include:

- the allocation or dedication of taxes currently levied on the transportation sector to transportation spending;
- dedicated fuel taxes, licence fee surcharges and frontage levies; and
- road pricing (Transportation Association of Canada, 1993).

Newman and Kenworthy (1999) suggest that the main components of a more user-pays, commercial transportation system that improves urban sustainability are:

- An increase in fuel taxes to cover the full external costs of transportation;
- A channelling of funds into innovative sustainable transportation projects that reduce automobile dependence;
- Giving local authorities the right to tax congestion and use it for better transit;
- An increase in neighbourhood responsibility for local streets to use them for purposes other than the flow of traffic; and
- Encouragement of the contracting out of the maintenance and operation of road works and transit systems, within a tight regulatory system.

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#### **Revenue Needs in Developing Economies**

The cities of the developing world with large populations and rapid urbanisation find themselves in an extremely difficult situation. The demand for services and infrastructure such as water, sanitation, health facilities, housing, power and transport is immense and growing. At the same time, many of these cities are ill-equipped to provide these services; many lack the administrative and technical ability; some cities are hampered by higher levels of government. Most important, however, is the fact that in many cities the poor provision of social and physical infrastructure is due to the difficulty of financing the expenditure necessary to provide these services.

Is it possible for cities to find ways to finance the ever increasing demands that are made upon them? Past studies have shown that the ability of developing countries to maintain and expand their stock of urban infrastructure in response to rapid population growth depends upon astute administrative and management skill with financial resources on the part of those in charge of financing urban services (Bahl and Linn, 1992). Numerous studies have argued that, in order for the provision of social and physical infrastructure to be improved, more responsibilities have to be delegated to municipalities and a better correspondence between local expenditure and revenue authority needs to be established (for example, Bahl and Linn, 1992) and World Bank, 1988).

Motor vehicle taxation can make a major contribution to urban government tax revenue. It is an important source of revenue for Jakarta, for example. Such taxes take advantage of a rapidly growing tax base, they are an effective means of recapturing the fiscal costs of motor vehicle use, and of reducing the difference between the marginal private cost of motor vehicle use and the marginal social cost of its use. Moreover, local government has to deal with most of the costs that result from rapid growth in car use, and it is local residents that suffer most from pollution and congestion due to heavy traffic.

Taxes can take one of three forms:

- Annual licence taxes on all motor vehicles whose owners reside in the particular taxing jurisdiction, at a flat annual rate that may differentiate between the type of vehicle and, perhaps, its size and/or age;
- A one time tax on the registration of motor vehicles or a tax on transfers of vehicle ownership; and
- A tax on fuel.

Unrestricted licences and fuel taxes can make major contributions to local revenue generation without causing major efficiency losses. Restricted licence taxes and parking fees and taxes could then be imposed mainly to control urban congestion and thus reduce the cost of maintaining urban roads. Only in Singapore has a concerted effort been made to restrain central city congestion by the application of area- and time-specific licence fees and parking charges. Singapore's experience should serve as an example for other cities. However, any attempts to follow Singapore's example should take note of the various practical aspects that helped the system work: adequate study and preparation; simplicity of regulation and flexibility of implementation; and unfettered authority by the metropolitan government to impose whatever scheme was regarded as most appropriate. The fact that such schemes have not been implemented elsewhere, even where explicitly considered and ostensibly adopted (as in Bangkok), reflects the powerful political opposition to any serious efforts to limit the use of private automobiles in large cities (Linn and Wetzel 1994).

# **OTHER POLICIES**

# Inducements for Ridesharing

In the United States there has been a gradual decline in carpooling and multiple occupancy of vehicles during the past two decades (DOE, 1996). Faced with these trends, many state and local governments are seeking to encourage more ridesharing by dedicating traffic lanes to high-occupancy vehicles (HOV), providing commuter parking lots near HOV facilities, offering ridesharing information services, and reducing tolls paid by drivers with multiple passengers. More than 400 miles of HOV lanes are now in operation in the US, up from less than 100 miles in 1980 (TRB, 1997).

It is still unclear as to what the net effects of ridesharing programs are on total travel. It is argued that the construction of HOV lanes has the effect of increasing road capacity, which may increase overall system travel. One reason for this effect is that HOV lanes may draw ridership from transit and commuter rail. Another is that they may stimulate travel by improving traffic flow generally, inducing travel by motorists who otherwise would not have driven because of the time penalty of congestion (TRB, 1997).

The ultimate success of ridesharing programs in reducing motor vehicle travel will depend on local traffic conditions and the specific types of programs implemented. In general, however, it appears that ridesharing programs offer only indirect and incremental benefits in curbing aggregate travel demand and resultant fuel use and emissions. The main influence of these programs has been on a subset of urban motorists travelling to and form work during peak driving hours. Such motorists account for less than one-fourth of total miles travelled (DOE 1996). Advances in ridesharing technologies, such as the smart paratransit services discussed in the next section, may one day enhance the appeal of ridesharing for a wider variety of travel purposes (Wallbridge 1995). Such a broadening of appeal, perhaps facilitated by further advances in computer and communications technologies, may make ridesharing a more promising approach to reducing motor vehicle emissions.

# **Transport Saving Policies**

Some public agencies have sponsored telecommuter demonstration projects

using their own workforces. California requires large employers in the Los Angeles area to establish programs for reducing commuter travel, which may include telecommuting options. In addition, the state's Telecommuting Advisory Council serves as a clearing-house for telecommuting information.

Recent experience suggests that further advances in telecommunications will continue to have effects that extend beyond the work environment and commuting patterns. Teleshopping, teleconferencing, and telebanking services are already being offered widely.

The implications of the telecommunications revolution for transportation could be tremendous, yet they remain vague. Whereas new information and communications systems could result in less travel by reducing the need for personal mobility and freight movement, travel demand could be stimulated by the more dispersed development patterns enabled by telecommunications (OTA 1995). There are other implications. For example, telecommunications and computer advances that facilitate just-in-time inventory systems could lead to more travel by freight trucks carrying smaller shipments and at the same time improve the efficiency of trucking (through fewer empty backhauls and more efficient routing) so that aggregate travel would be reduced. As a practical matter, it is not yet possible to determine whether telecommunications advances will lead to more or less motor vehicle travel, much less to speculate on the magnitude of this influence (TRB, 1997).

#### **International Policies**

In view of the strong international competition on automobile markets, and the pressures of national manufacturers on their governments, effective action needs to be taken at the international level to ensure simultaneous decisions, common goals and constraints, and fair competition. Governments should work together to develop economic and regulatory frameworks that are stable, equitable and internationally coordinated.

Internationally agreed standards for air quality, motor vehicle emissions and fuel economy and quality would greatly facilitate the necessary adjustment by vehicle and fuel manufacturers. The adoption of compatible testing and measurement procedures would be an important step in this direction (OECD, 1997c).

The development of a cooperative framework for controlling greenhouse gas buildup and climate change was a focal point of the 1992 United Nations Conference in Rio de Janeiro, Brazil. More than 160 countries are now parties to the United Nations Framework Convention on Climate Change, with undertakings being given to reduce  $CO_2$  emissions.

Similarly, coordinated action at the international level may be the only way that fiscal and pricing mechanisms for restraining transport demand, notably fuel or energy taxes, could work effectively (OECD 1997c).

Finally, there is significant scope for cooperation within the APEC region on sustainable transport policies and strategies. Three international programs are suggested. They cover research and development, developing a framework for evaluating policy options against sustainable transportation goals, and inter-city exchanges of information on sustainable transportation initiatives and practices.

The critical need in research and development is to accelerate the process so that technological solutions can be found within a medium-term time frame to some of the most pressing problems of unsustainability in transportation. Significant research and development on sustainable transportation technologies is being conducted within the advanced APEC economies, most of which is focused on problems arising within the advanced economies. There is a danger that issues pertaining more to the developing economies will not be addressed. These include the need for low-emission motorcycles, low-cost but low-emission passenger cars and minibuses suitable for transit, and low-emission paratransit vehicles. These issues could form the basis of an international R&D program. There is scope, too, for the utilisation of foresight methodologies in developing a climate favourable towards the development of sustainable technologies.

The second international program suggested relates to policy evaluation frameworks. Sustainable transportation policies should be based on clearly articulated goals, policy options need to be assessed in the context of a detailed understanding of the determinants of transport demand, and policies should be regularly re-evaluated. A program of technical assistance should be launched that would enable major APEC cities to adopt such policy evaluation frameworks. Drawing on research conducted by the OECD, ECMT, US Transportation Research Board, WHO and the United Nations, quantifiable goals for transport sustainability can now be articulated, and models developed that link transportation policies, traffic movements and the impacts of traffic on sustainable transportation goals, albeit with some sweeping assumptions about some of the specific linkages. The frameworks established should reflect the aspirations of individual cities while enabling international benchmarking of specific outcomes. APEC, in conjunction perhaps with the Asian Development Ban and the World Bank, as well as the Overseas Economic Cooperation Fund of Japan, is well placed to develop such a program.

The third international program advocated is inter-city exchanges. The APEC region offers a rich diversity of experience in terms of transportation developments. While inter-city exchanges do occur, this is usually in the context of cultural and trade exchanges. Inter-city exchanges that focus on issues of urban and transport planning could yield substantial results in terms of increasing the range of policy options in dealing with sustainability problems. APEC could provide the organisational means for such exchanges. It could also provide a framework for sharing information on the experience gained in attempts to implement particular sustainable transportation policies.

#### Protecting the Environment

Ecologists increasingly view environmental effects from a broad perspective (in time and space), recognising that individual ecosystems are seldom independent but almost always interconnected and share many of the same natural resources such as a drainage basin or watershed. To ecologists, the term "landscape" refers to the diverse mosaic of local ecosystems or land uses covering an extended geographic area and containing a variety of habitats and species (Forman 1995). Inasmuch as landscapes rarely conform to political boundaries or transportation corridors, individual environmental disturbances from transportation systems are seldom viewed in such a comprehensive manner during transportation system and land use planning (TRB 1997).

There should be a general set of goals about environmental expectations for a given area that can serve as guidelines for information gathering and decision making. Some explicit environmental goals, such as no net loss of wetlands, protection of endangered species, and preservation of floodplains, are already prescribed in state and federal regulations in the United States. Other goals, such as maintaining a certain level of biodiversity, minimising disruption of stream quality and flow, keeping major wildlife corridors intact, and protecting steep slopes, may be developed for specific areas, depending on prevailing conditions and expectations. Such goals would assist in the development of key environmental indicators to inform policy choices and measure the performance of highway systems in minimising ecological disturbances.

Highway agencies are seldom in a position to set such goals by themselves, especially for habitat protection. Early definition of environmental goals and expectations will be essential to enabling the anticipatory actions necessary to monitor and control adverse ecological effects over time. Well-defined goals and early planning activities would allow ecologists to work with public officials in developing ecological principles that could be used to inform and guide land use planning and regulation and educate the public about the importance of minimising adverse ecological effects (TRB, 1997).

A master plan, mapping the environmental conditions of a large area to the existing, planned, and optional road systems and associated developments, should be developed well in advance of individual project planning and updated often. Unfortunately, environmental impact statements (EIS) seldom serve this purpose or facilitate this process since they are often conducted on a site-specific, project-by-project basis, thereby neglecting area-wide and cumulative results of projects over time. Deakin (1993) urges the adoption of transportation system- or corridor-level EISs that consider the broader implications of a long-term highway plan and related projects, permitting anticipation and assessment of cumulative area-wide results and with ground rules for professional practices in project development. The Netherlands has been active in developing and using system-wide plans of this type and has found timely ecological information provided by such early planning

increases the options available for avoiding or mitigating environmental problems likely to arise later. Newly available technologies such as geographic information systems are making such comprehensive and landscape-level mapping more accurate, easy to update, and affordable (TRB, 1997).

The ongoing reconstruction of the US highway system will offer the opportunity to explore alternative mitigation measures and begin a systematic process of reducing the ecological effects of the 4-million-mile system. The vast size of the road system actually provides an opportunity for improving the understanding of preventive and mitigative measures. More systematic monitoring and evaluation of these efforts and how the road system interacts with ecosystems throughout the country would offer highway planners, designers and ecologists a better-informed means of predicting problems and devising preventive or mitigative measures. While the total number of road miles is growing at a relatively slow rate in the US, much of the growth will be in metropolitan fringes, where adverse effects on wildlife can be significant. In addition, many highways are being widened and reconfigured to handle more traffic, thus creating the potential for further habitat fragmentation and loss and disruption of wildlife movement and other flows across landscapes (TRB, 1997).

None of the above steps can be taken without active collaboration among highway engineers, planners, policy makers, and specialists in ecological sciences. The role of ecologists should become more influential in a highway agency's routine maintenance and operational activities as well as in its major construction and reconstruction projects (TRB, 1997).

## **Ensuring Social Sustainability**

Specific additional policy initiatives may be required to achieve socially sustainable transportation. The two issues of accessibility and safety are addressed.

# Accessibility.

Integrated urban land and transport planning involves the planning of new areas of urban development and the redevelopment of existing urban areas. In both cases, care needs to be taken that low-income groups are not squeezed out of highly-accessible developments. There is a need to ensure that a proportion of accessible space is reserved for low-price development or redevelopment.

To be accessible to all groups in a city, transportation services need to be affordable. At the same time, they need to meet economic and environmental criteria. Government subsidies for transport services are an expensive way to meet policy goals in that they reward all users of such services, and not just the poor. Assistance is better targeted on the poor through the provision of publicly-funded transport concessions. The concessions should be targeted on the needy. Such an approach pre-supposes the capacity to provide general welfare policies, which is not yet present in some of the APEC economies. However, it is relevant to the middle- and high-income economies of East Asia and Latin America. The provision of transport concessions are justified, over and above general welfare assistance, in order to deal with the specific geographic disadvantages suffered by many lowincome residents forced to live in the least accessible parts of major cities.

#### Safety.

The six major policy instruments that are recommended to achieve sustainable transportation have significant implications for the safety of transportation. Measures such as integrated urban and transport planning, more competitive transit services, advanced traffic management, safer vehicles, and the development of intelligent vehicle-highway systems should all have a significant impact on safety.

These general measures should be accompanied by a specific framework for transport safety. The OECD (1997d) has developed a set of safety indicators which can be used to internationally benchmark safety strategies in particular cities. The development of internationally comparable safety data sets should enable the eventual benchmarking of safety strategies. It would also facilitate the development of safety audits and benchmarking in terms of transport infrastructure, vehicle design, vehicle maintenance, traffic management and other features of transport operation and driver training.

## The Impact of Policies

The adoption of comprehensive sustainable transportation strategies can have a big impact on cities. The transformation of Hong Kong, China, and Singapore from third-world cities some three decades ago to international benchmarks for sustainable transportation owes much to the policies pursued in those cities, particularly the integration of urban planning and transport planning, the development of transit infrastructure and the attention given to traffic management.

Recent analysis of sustainable transportation strategies in the United States and Europe provides some interesting insights into the possible impact of such strategies on the environment, the social situation, and the economy.

## Environmental Impacts Land Use Planning

It is very difficult to assess the impacts of adopting more restrictive land use programs as a means of curbing motor vehicle travel. What is clear is that changes in land use would need to be accompanied by fundamental changes in incentives and preferences. Because land use patterns are a function of so many social, economic, and institutional influences, attempting to change these patterns as a means of achieving changes in travel behaviour and carbon dioxide emissions would be especially challenging. The OECD argues that a comprehensive approach to land use planning along with the adoption of active traffic management policies could substantially reduce congestion and pollution. Noise would continue to be a problem, particularly in the absence of strong action aimed at motor bikes, motorcycles and heavy-duty vehicles. Safety levels would improve and people without cars would be able to travel more easily. Car owners would have more attractive alternatives to travel by public transport, on foot or by bicycle. Dependence on cars would be reduced and traffic growth in urban areas might cease altogether, though overall travel levels and  $CO_2$  emissions would continue to rise (OECD 1997c).

The US Department of Transport has constructed some projections on vehicle travel, petroleum use and carbon dioxide emissions out to the year 2040. The scenario incorporating efforts to reduce motor vehicle travel through demand management methods and land use planning reduces motor vehicle travel relative to the baseline trend on the order of 5 per cent by 2020 and 10 to 15 per cent by 2040. This still leaves situation in which petroleum use continues to grow by around 40 per cent between 2000 and 2040 (TRB, 1997).

# Travel Demand Measures

Considered individually, most travel demand measures offer prospects for incremental decreases in motor vehicle travel: their collective effort, however, could be of major significance. Their overall impact is considered alongside that of urban planing (see above, TRB 1997).

# The Effect of Raising Conventional Vehicle Fuel Efficiency on $CO_2$ Emissions

The scenario developed in TRB (1997) allows for increased fuel economy of 1.5 per cent per year, and partial offsets associated with greater travel. It would reduce growth in petrol consumption and emissions to negligible levels (TRB, 1997).

# The Impact of Raising Fuel Prices on CO, Emissions

The scenario put forward by the US Transportation Research Board (TRB, 1997) assumes a 3 per cent annual increase in petroleum prices and a long-run price elasticity of demand for petroleum of -0.4. The scenario demonstrates that changes in petroleum prices can have a large influence on petroleum demand. The projections developed show that the amount of petroleum used by motorists after 20 years would be about 15 per cent lower than under the baseline scenario and 35 per cent lower after 40 years.

Not considered in this simplified scenario are the many economic, political, and social implications of rising fuel prices and their effects on travel and vehicle technology. Nor are the means of achieving these higher prices considered (e.g., through tax policy or supply and demand forces). In the event of rising petroleum prices, motorists may switch to alternative fuels as part of their response,

and these alternatives may or may not produce significantly less CO<sub>2</sub> than traditional petroleum motor fuels. In this regard, a graduated energy tax based on fossil carbon content or greenhouse emissions would offer more incentive for motorists to demand and suppliers to develop technologies low in fossil carbon emissions.

The OECD (1997c) adds to the adoption of best practice land use, demand management and transit policies a progressively increasing fuel tax to significantly reduce vehicle travel. Taking into account IPCC targets, the example considered is that of a seven per cent annual rise in real terms in the price of fuel over the next twenty years. This is estimated to reduce the amount of fuel used to about a third of the forecast level of consumption 20 years from now, i.e. to about half of today's consumption, with a corresponding reduction in  $CO_2$  emissions.

This saving would reflect a reduction in car trip lengths of approximately a third, and much slower growth in car ownership and car travel over the next twenty years (perhaps 10 to 15 per cent instead of the forecast 50 per cent). High fuel prices should lead to more economical driving styles, smaller and less powerful vehicles and further improvements in fuel economy (perhaps as much as a third) arising from improved engine design. High fuel costs would provide a strong incentive to improve the efficiency of road freight transport and to shift freight to other modes.

# The Impact of Low-Emission Technologies on $CO_2$ Emission Trends

The best that can be done is to make some general projections of how long it might take for new technologies to be developed and introduced into the fleet and of how much they will lower emissions of  $CO_2$  and other greenhouse gases on a per-vehicle or per-mile basis. A hypothetical scenario developed by the US Transportation Research Bureau (TRB 1997) assumes that new vehicles emit only one-third as much  $CO_2$  per mile as conventional (baseline) vehicles. Starting in 2010, the new vehicles are introduced into the fleet so that by 2020 they account for five per cent of total VMT. Their popularity quickly grows as the technologies become more mature and consumer familiarity increases. Thus, by 2030 they account for 20 per cent of VMT, rising to nearly half of all VMT by 2040. Emissions of carbon dioxide are reduced below the base projection by four per cent by the year 2020 and by 32 per cent in 2040.

The purpose of this scenario is to illustrate graphically that the development and introduction of new technologies - even with fairly aggressive assumptions about effectiveness in reducing  $CO_2$  emissions and introduction - may require several decades to bring  $CO_2$  emissions back to present levels. Most evident are the years of lead time required for low-emission technology development and the lags that are likely in expanding consumer acceptance and use. Although this is only one of many plausible scenarios, it portrays the importance of early research, development, and demonstration.

# Social Impacts Social Equity

The distributional impact will depend in large part on the nature of the compensatory tax changes. Higher fuel charges will have proportionately less impact on households with lower incomes than those with higher incomes, given the pattern of fuel consumption. Charges per car kilometre not taking into account the size of the car affect low and middle income groups more than households with high incomes, while annual vehicle taxes put the largest burden on middle income groups. It all then depends on the compensatory packages (ECMT 1998).

The traditional policy emphasis has been on transportation rather than land use policy approaches, and private cars are favoured over public transportation. This has had the impact of increasing inequity. The use of integrated land use and transportation policy solutions that reduce the need for car travel and make transit more viable can improve equity, as could technological advances that increase the range of transit services available to improve geographic access to services. Nevertheless, special government subsidies or other forms of support may be needed to ensure complete accessibility. There is also the danger that partial approaches to urban restructuring could price out poorer people from the most accessible sites, leaving them concentrated increasingly in the more isolated areas. Equity considerations need to be built into urban planning frameworks.

# Safety

If safety strategies are encouraged to play a prominent role in shaping new technologies, changes in vehicle design, traffic management and the development of intelligent vehicle highway systems could lead to marked reductions in road traffic accidents. If transit gains a greater ridership at the expense of cars, this will also reduce accident rates. Pedestrian safety can also be increased by urban design improvements aimed at encouraging pedestrianism. Improved security policies in managing transit services would also increase safety.

## **Economic Development**

An imperative for sustainable transportation is that traffic modes and flows that are socially costly are restrained, either through the pricing mechanism or by regulatory means. Such a strategy would, of itself, impose a cost penalty on cities that could impact on their economic competitiveness and capacity to deliver increased employment opportunities. However, this potentially harmful impact could be offset by technological and managerial improvements that provide qualitatively improved access for individuals and major efficiency improvements in the whole freight system.

The analysis of the impact of the internalisation of external costs associated with transportation conducted by ECMT (1998) indicates benefits to government finances in the first instance. Internalisation will reduce government expenditure on infrastructure, health care and social security. Furthermore, governments will

collect the higher use-charges for transport. The ECMT analysis assumes that the full financial gain to governments will be recycled in the economy through lowered tax rates.

Companies face higher transport costs resulting from higher use-charges and stricter vehicle standards, benefits from compensatory tax cuts, and reductions in costs associated with congestion and losses associated with traffic accidents. The net effect can be expected to be positive, because higher use charges are fully compensated for by lower taxes, and because of benefits from other cost reductions. However, this does not mean that every individual company benefits (see earlier), but logistic and locational adjustments could offset much of the net loss.

Consumers are confronted with higher use-charges, which will reduce growth in mobility. This represents a welfare loss, at least in the short run before spatial patterns of organisation adapt. This change is compensated for by lower taxes of one kind or another. In addition, there are gains in non-financial types of welfare, less personal distress associated with fewer accidents, fewer time losses in congestion, and a safer, healthier, more pleasant environment. The net result is expected to be a small financial gain and an increase in total welfare. As a con-sequence, reduced mobility - and thus expenditure on transport - results in extra consumption of other goods and services (ECMT, 1998).

The ECMT analysis suggests that the competitive position of European industry is affected by internalisation policy in three ways:

- a) more expensive transport resulting form stricter vehicle standards and higher use-charges;
- b) reduced general taxation; and
- c) reduced costs from congestion and less loss of production from traffic accidents.

Although the net result can be expected to be positive for business as a whole, specific subsectors might face higher costs. A few general remarks can be made about this issue:

- Transport intensive industries face both higher transport costs and lower congestion related time losses, the net effect depending on specific circumstances;
- The policy measures to be selected largely determine the dis-tribution of costs and benefits among subsectors;
- If the competitive position of an industry is harmed by internalisa-tion, specific compensating policy measures can be considered in the total policy package;
- End-use transport prices rise by around 20-30%, but transport costs make up only a few per cent of total production costs; and
- Companies will probably adapt their logistics and spatial economic organisation a little, reducing the impact of total costs in the longer term.

Assuming that the competitiveness of industry is not substantially affected by internalisation policy, what are its likely impacts on economic growth and employment? The Central Planning Bureau, the economic institute of the Dutch government, has modelled the impact of measures such as very strict vehicle standards, an increase in fuel taxes, VAT on flights in Europe and speed limiting devices on trucks. A substantial reduction in growth of road and air traffic is expected. The revenues of the fuel tax are recycled through relief in labour taxes and employer contributions to social security payments.

The main conclusion of the model calculations is that the macroeconomic impact of the policy package is small, despite the substantial shift in consumption patterns. Households shift their consumption patterns away from car driving towards luxury goods (such as furniture and appliances) and tourism. A similar shift takes place in production: less transport, more services. As a consequence of these shifts, total employment increases a little, mainly because of the reduced labour costs. There is no recurring inflation effect; prices rise by a few tenths of a per cent but only in the first few years.

Other economic studies assess the impact of environmental policy in general and also integrated with economic policies. With respect to the first, there is a slight negative impact on GDP and a zero impact on employment, with a slight increase in prices. With respect to the second, there is a slightly positive impact on GDP and a marginally higher impact on employment then GDP, and an increase in prices (ECMT, 1998).

# The Implementation of Policies

## Governance

There are a number of barriers that exist to the development and implementation of innovative projects and programs. Faced with the breadth and complexity of ecological thought and planning, actors at the local level may succumb to inertia, uncertainty and confusion. Other implementation difficulties include shortages of appropriately qualified staff at national or local level, problems with territorial integration across political boundaries, difficulties with combining sectoral and territorial integration across political boundaries, and inexperience with new forms of cooperative agreements and partnerships (OECD 1996a).

Integrated policy-making for transport remains hampered to a large extent by fragmentation of a policy responsibility both horizontally (across transport, environment, energy, finance and industry ministries and departments) and vertically (across central, regional and local governments). A more coherent approach would help to avoid the many instances of measures -aimed at developing the transport sector, improving the environment or at conserving energy - working at cross purposes with one another (OECD, 1997c). A problem in managing the growth of mega-cities is developing the appropriate institutional framework. Municipal administrations cannot perform this task well because their jurisdictions are "underbounded" and they are usually preoccupied with the day-to-day problems of routine administration, service provision, and finance. In many mega-cities, metropolitan development and planning authorities have been established, but they tend to languish as weak institutions with nothing to do and little to say (for example, the Metro Manila Commission and the Bangkok Metropolitan Administration) or have evolved into public works agencies. Other mega-cities, such as Mexico City, Jakarta and Seoul, do not have a metropolitan planning authority. In some cases there are conflicts between a metropolitan planning authority and the municipality, with the latter often turning out stronger. In other cases, key urban services and major metropolitan investments are the responsibility of the central or provincial governments instead of a metropolitan authority (such as in Seoul, Metro Manila, Bangkok and Jakarta, Brennan, 1994).

Transit metropolises such as Stockholm, Ottawa, and Singapore owe much to their efficient institutional structures and regional forms of governance that promote the close coordination of transportation and land use. In these areas, decisions affecting the built environments and transportation take place within a geographic context that matches regional commuter-sheds.

A successful institutional approach to coordinating regional transit services and fares has been the Verkehrsverbund, presently found in Germany, Switzerland, and other parts of central Europe. These umbrella organisations ensure that problems that commonly plagued regional transit services - such as fare penalties for transferring, conflicting timetables, and inter-agency rivalries - are eliminated. With a Verkehrsverbund, transit is designed and operated like a regional service (Cervero, 1998).

# Case Studies in Regional Governance Portland

Portland saw the need to take early action on air quality because topographical conditions created a more evident problem than would be expected for a city of its size (1.17 million in 1990). It is unusual among US cities in having a directly-elected regional government. The Metro government's charter gives it responsibility for land use and transportation (Brindle and Lansdell, 1999).

Formed in 1978 to manage regional growth, Metro powers were expanded in 1990 when it was granted a home rule charter, making it the first directly-elected regional government in the US. Its powers include the ability to override municipal zoning decisions that are inconsistent with regional plans. Metro has worked closely with local governments, the business community, environmental interests, and citizens to forge a consensus on the region's preferred future settlement pattern in a process known as Region 2040. The adopted growth strategy, Framework 2040, calls for concentrating future growth in regional centers that are served by multi-modal arteries and high-capacity transit. Nine regional centers are to be interconnected by light rail links. Up to 85 per cent of new growth in the region is to occur within a five-minute walk of a transit stop (Cervero, 1998).

## Canada

A large number of Canadian planning studies embrace sustainable transport principles. They include the Transportation Plan for the Greater Toronto Area, the Metropolitan Official Plan of Toronto; Vision for Urban Transportation in Ottawa-Carleton; Hamilton-Wentworth Vision 2020 and Regional Transportation Review; the Provincial and Regional transport planning in Quebec (including a plan for the Montreal region); Vancouver Liveable region Strategic Plan and Vancouver Transport 2021.

Ottawa-Carleton, while being the seat of the federal government (which provided 20 per cent of jobs in 1996, down from 33 per cent in 1981), is home to Canada's largest concentration of high-technology companies and continues to attract jobs in business services and health-related industries. The regional government (Regional Municipality of Ottawa-Carleton, or RMOC) was formed in 1969 by the Province of Ontario to carry out comprehensive planning, invest in major infrastructure, and provide regional services within a geographic spread almost four times the size of Metro Toronto. Local governments regulate land use through zoning laws and subdivision approvals, the regional Council holding veto powers to ensure broad compliance with the region's official plan. The Provincial government subsidises transit services and empowers the RMOC, and at the federal level, the National Capital Commission owns large amounts of land in the region (Cervero, 1998).

## Singapore

Singapore's planning framework for the island corresponds with the scale of regional planning carried out by many medium-sized jurisdictions around the world. However, Singapore's government wields considerably more power than any regional planning body in North America or Europe. And the absence of multiple levels of government, made possible by Singapore being a tiny island-state, has allowed for efficient and streamlined decision-making. Also unlike other places, authorities in Singapore are widely respected and rarely challenged. The government has a vast talent pool. Each year, some of the best and brightest high school students are recruited into the ranks of civil servants. They are sent to top international universities and upon their return are given compensation packages pegged to the best-paying private sector jobs (Cervero, 1998).

# Bangkok

In 1972, the Bangkok Metropolitan Administration (BMA) was created as an autonomous local government headed by an appointed governor. The post of governor was made elective in 1975, although the governor was kept under the jurisdiction of the Ministry of the Interior. Central government dominance was also assured by the fact that many urban functions were carried out by central government agencies such as the National Housing Authority, the Expressway and Rapid Transit Authority, the State Railway of Thailand (SRT) and others.

Bangkok has a municipal council that is part of the BMA but it has extremely limited powers. The BMA can collect revenue, but proceeds from the landdevelopment tax, the house and land tax, the tax on signboards, and the animal slaughter tax - the only taxes the BMA collects - account for only 8 per cent of annual municipal income. The BMA does not even have the authority to develop its own plans, as this function rests with the central government agencies (Laquian, 1995).

Over 30 government agencies are responsible for Bangkok's transport policy, management and operation. Moreover, there are three statutory committees and four ad-hoc inter-agency committees to oversee and coordinate the responsible agencies. These overlapping mandates cause great confusion and obstruction to Bangkok transport planning and implementation (Poboon et al, 1994). In 1992 the Commission for the Management of Land Traffic was established. The Commission comprises the main agencies which have responsibilities for transport infrastructure, planning, and the implementation of regulatory functions. It is normally chaired by a Deputy Prime Minister, and is serviced by the Office of the Commission for the Management of Land Traffic as its secretariat.

#### **Community Perceptions**

- Getting community consensus presupposes that there is a factual agreement about the causes and remedies to unsustainability. The Canadian exploration of sustainable transport (NRTEE 1997) highlighted several areas of divergent opinion and uncertainty. These are likely to be generally applicable:
- Doubt about the long-term viability and effects of technological responses to emissions and fuel concerns;
- Controversy over the extent to which non-renewable fossil fuels can continue to be used in a "sustainable transport" system;
- Disagreement about the public acceptability of moving to more compact, mixed use urban areas;
- Concern, on both economic and social grounds, about the use of fuel taxes to change travel behaviour;
- Uncertainty about what course governments will tend to take in an era of tighter budgets: is this a time when full social costs will be taken account of more than in the past?
- Lack of the data required to make fully-informed decisions about the likely social and ecological costs leads to two contradictory views do

we act now rather than use uncertainty as an excuse for inaction, or should we insist on getting full inforamtion and greater certainty before we commit to making radical changes?

- Divergence of opinion about the economic consequences of forcing a shift from road-based transport to lower energy modes; and
- Uncertainty about what can be done to reduce greenhouse gas emissions from air travel.

The achievement of sustainable transport will require changes in terms of both the types of different transport choices available and people's attitudes and behaviour with respect to the choices they make. This, in turn, implies that we must be able to consider not only what choices are made in the present, but what choices might be made in different circumstances, particularly when those circumstances either do not currently exist at all. Furthermore, it is important to have some sense of what actually drives such choices and the relative magnitude of such drivers. Such understanding allows examination of the overlap between various outcomes or options necessary to facilitate sustainable transport and those changes. What is important here is that the conclusions arise from a measurement framework that allows choice dynamics to be measured and the likely efficacy of alternatives to be objectively assessed and compared (Sadokierski and Shaw, 1999).

It is difficult to overstate the critical nature of diffusion of information for the ecological city. In the short term, more reliance must be placed on innovative strategies for diffusing information, using the media, and exercises such as simulations that advance the cause of public information and participation. In the longer term, attention will need to be paid to increasing environmental literacy so that understanding in government and beyond can be adequate to the task (OECD 1996a).

Education to broaden environmental literacy is a key requirement for more sustainable cities. Individuals have also shown a greater propensity to change when the worth of new proposals can be clearly seen and understood. Recent comparative research (OECD, 1995) suggests that environmental education must begin early and preferably be integrated into mainstream curricula at school and university level. Successful environmental education allows the dynamic, inter-sectoral nature of problems to be reflected in the process by which it is considered. Environmental education increases personal involvement and improves understanding of environmental complexity, and, through interdisciplinary learning and research, allows for development of dynamic qualities: initiative, independence and responsibility (OECD, 1994). This understanding of the dynamic nature of environmental issues and responses stands in opposition to traditional approaches to learning which stress a static and unchanging knowledge base. Armed with such conceptual tools, individuals are better prepared to apply a dynamic, ecological approach to the multitude of environmental issues facing cities.

If governments are to respond successfully to pressing environmental issues, a key requirement will be to work actively to improve each community's cross sectoral

environmental knowledge base and to legitimise "action oriented" knowledge in educating children and the broader community. A critical educative task is to broaden understanding of ecological decline in cities. Specifically, ecological awareness is required to understand the city and the environment as an ecosystem that is worthy of individual and policy concern.

There is a danger that current spatial and social trends in city development will make these tasks harder for governments. The decline of the public realm, especially at the expanding periphery, is important in this respect. Urban spatial arrangements which provide no more than a framework for private life and consumerism may prompt citizens to think of the public domain and public action as meaningless. The strength of local initiatives demonstrates the key importance of empowering individuals and communities to believe that they can make a difference, that the problems faced are not overwhelmingly difficult and outside their control (OECD 1996a).

Finally, it is worth noting the severe policy constraints that exist in developing economies:

- Land use constraints related to legal and political difficulties;
- Financial constraints in relation to the public sector;
- Difficulty of applying advanced technologies and efficient techniques because special interests wish to preserve the status quo; and
- Shortage of appropriately qualified staff.

#### **Policy Evaluation**

Evaluation of projects, policies and plans is an important but underrated area for government activity at national and other levels. Evaluation is important to test the usefulness of different approaches over time and against alternatives. Evaluation can be used to avoid repeating mistakes and to refine techniques, where these are to be more widely disseminated and applied. Evaluation assists in defining progress towards objectives and analysing priorities in the light of implementation experience.

Evaluation has the capacity to link up with other innovative techniques for sustainability planning. Evaluation can be seen as a further step in the process for measuring the environmental carrying capacity of cities and regions. The ecological footprint provides a sustainability indicator against which policy can be evaluated. Evaluation can thus be seen as a refinement of the development of indicators for sustainability (OECD 1996a).

# The Diversity of Experience within APEC

#### Differentiating Policy According to the Local Situation

The purpose of launching these discussions on sustainable transport is to start an interactive process whereby our understanding of future options for policy in the context of possible technological developments is enhanced. In addition, it should provide an opportunity to assess the differences that may exist in the transport situation within individual metropolitan centers within APEC and promote an understanding of the diversity of approaches that may work in promoting sustainable transport.

There is a great diversity within the major metropolitan areas of APEC. Per capita income levels, size, and the historical evolution of the urban form and transportation infrastructure vary enormously. As a result, the environmental and social pressures resulting from traffic movements also differs between cities. Prospective trends in transport demand also vary widely, with some metropolitan areas facing the prospect of stable populations and limited incomes growth, while others face rapid growth in both population and per capita incomes. The political and administrative framework within which urban planning, infrastructure development, traffic management and public transport services will evolve also differs from city to city. A variety of solutions to transport problems, whether involving choice in technology or the detail of policies, can be expected.

Despite this diversity, there is much to be learned from the experience of others. The APEC region includes around half of the world's major metropolitan areas. Each city has something to offer others in terms of lessons from its past and its plans for the future. A process of interactive research and discussion has benefits for all.

## Singapore

Sing Mong Kee (1999) says there were four principle thrusts of Singapore's transport strategy.

- 1. Integrating the planning of transport with land use planning to minimise the need to travel.
- 2. Developing a good road network and harnessing technologies to maximise its capacity through the comprehensive use of transport telematics.
- 3. Managing the vehicle population (through a complex system of vehicle registration and licensing) and demand for road usage (through fuel taxes and an electronic road pricing system).
- 4. Improving public transport to provide quality public transport choice as an alternative to the car. The mass rapid transit system, integrated with other transit services, is a key feature of Singapore's transportation.

Sing Mong Kee (1999) argues that four factors have contributed to Singapore's success in transportation:

- The problem was anticipated early when car ownership and use was still low, and there was time to progressively apply fiscal measures and develop public transport;
- Pragmatic and competent management enabled comprehensive planning and policy making for all aspects of land transport;
- The relative ease of planning and decision making in a city state with one level of government; and
• A dare-to-do attitude - Singaporeans are disposed to believe that Government acts in the general social interest, although the measures taken may appear painful.

### Hong Kong, China

Hong Kong, China relies on fiscal measures and a lack of significant road capacity increases, plus excellent transit facilities ( the majority of the population resides within walking distance of a metro station), to hold motorisation at a low level compared with the high level of income. The metro system in Hong Kong, China covers even its capital costs (Barter et al, 1994).

Five new initiatives are proposed for future transportation in Hong Kong, China as a result of an extensive consultation exercise conducted in 1998:

- 1. Accord priority to the railways (integration of railway and land use planning, and facilitation of access and interchange of railway stations).
- 2. Provide infrastructure in a more timely manner (isolating the factors that are most important in defining the traffic demand in the corridor of a new transport infrastructure project).
- 3. Enhance the coordination and integration of public transport modes (formulation of a trunk and feeder transit system, provision of suitable interchange points, promotion of park and ride facilities, creation of a consistent fare system, and the development of an information system).
- 4. Manage traffic through the use of new technologies (the use of increasingly powerful in-vehicle computers linked to external information sources by means of modern communications, a range of solutions to improve vehicle safety, traffic management of the transport network and provide travel information).
- Put emphasis on pedestrianisation (need to reallocate space from cars). Lam (1999).

#### Tokyo

Tokyo is the largest city in the world, with employment highly concentrated in the inner city. Not surprisingly, the degree of congestion in Tokyo transportation imposes great costs and fatigue on the population. Rail cars in peak periods are packed to between 200 and 240 per cent of capacity. Work trip times in Tokyo - 70 per cent of people spend more than 45 minutes one way for work trips, 50 per cent more than an hour each way (Pendakur, 1995).

Notwithstanding such congestion, Tokyo does mange to handle huge movements of people without the degree of transportation-induced pollution experienced in the cities of many other advanced economies. The following policies have contributed to this relatively favourable outcome:

- 1. Meeting world standards in emission controls on new vehicles, incentives to contain the age of the car park, and investing heavily in the development of more energy-efficient technologies for motor vehicles.
- 2. Tough garaging requirements in Tokyo, and high motoring-related taxes.
- 3. Maintaining and enhancing the strength of Japan's rail services, both inter-city and intra-city, as the primary means of handling peak traffic requirements.
- 4. Thorough extensions in the rail network, developing new decentralised nodal concentrations of activity.

### The United States

Cities in the United States are characterised by:

- Low overall metropolitan population density compared with European and Asian cities;
- The highest rates of car ownership in the world;
- The highest rates of petrol consumption per capita, negatively correlated with population density;
- A low proportion of passenger trips on transit;
- A low proportion of workers walking or cycling;
- High levels of road constructed per person;
- The highest percentage of parking spaces per jobs;
- Low transit provision;
- High car speeds versus transit speeds;
- High rates of job dispersal away from central city areas to sub-centers in the suburbs and edge cities on the fringes of existing metropolitan areas; and
- Increasing social differences between prosperous suburban and exurban areas and depressed city centers.

Policies for sustainable transportation in the US have concentrated on the development of low-emission motor vehicles and the implementation of increasingly stringent vehicle emission standards. While these policies have recorded success in reducing some types of emissions, they have not proceeded far enough in relation to many other types of emissions, and the social problems associated with urban sprawl have yet to be tackled in a cohesive manner. Portland, in Oregon, is usually quoted as an example of innovative urban planning. A number of cities are attempting to develop revitalised urban transit systems.

### Canada

Canadian cities occupy an intermediate position between those of the US and Europe. Energy emissions from transportation are markedly less than in US cities but well above the average European city. This intermediate position also applies for car passenger travel (below the US and above Europe) and transit travel

(below Europe and above the US). Planning for sustainable transport has been more prominent in Canadian cities than is the case of the United States. They have been assisted by the development of regional planning frameworks. Development strategies for transit have also been more prominent in Canada than in the US.

#### Australia

Like the major cities in Canada, Australian cities occupy an intermediate position between those of the US and Europe. Urban density is as low as that in the US, but fuel consumption is lower, and the growth in car use has been reducing, reflecting reurbanisation in older suburbs, nodal sub-centers, better urban environments, and less tendency to develop edge cities as in the US. Australian cities are still second in their degree of auto-dependence to North America, however. Recent trends show a slowing down in the use of cars, with higher densities in the inner suburbs facilitating a return to transit oriented urban life (Newman, 1996).

Australian enterprises are making a significant contribution to innovation in transport technologies as the following examples demonstrate:

- The Orbital two-stroke engine originally developed by Ralph Sarich;
- The SYTech scotch yoke engine developed by Graham Fountain and Dr Hans Rosenkranz;
- The OX2 engine designed by Steven Manthey;
- ZBB Technologies' zinc bromide battery;
- Pinnacle VRB's Vanadium Redox Battery;
- The aXcess car, a new-tech electric-hybrid concept car, coordinated by the CSIRO and involving novel technologies for the battery, generator, electric traction motor and incorporating the SYTech engine (see above);
- The Oztrack A115 In-Vehicle Unit which is used to provide a car theft prevention and breakdown assistance system that can track cars by GPS within 10 metres of their location;
- The Austrans inner-urban people mover; and
- Tritram, a revolutionary new traffic simulation system.

The major Australian cities of Sydney, Melbourne, Brisbane, Adelaide and Perth are giving increased emphasis to the development of transit infrastructure and to reforms in the management of transit services.

#### Bangkok

Traffic congestion and air pollution are major problems for Bangkok, although there are signs of stabilisation in traffic congestion and selective improvement in air pollution indicators. Bangkok was not originally designed for cars and its are devoted to road space is very low. Moreover, in the outer areas of the metropolis, local road networks are quite inadequate. At the same time, public transit carries a far lower proportion of traffic than is the case for the richer Asian cities, which also have twice as much road provision as Bangkok. Buses dominate public transit services, which adds to total road congestion.

However, despite this picture, policies have tended to encourage car purchase and use with low taxes, and the construction of more road and expressways. This has encouraged rapid growth in the number of cars and other private vehicles particularly motor cycles and pick-ups. Parking provision in the CBD is extremely generous, being at the American level and about five times the richer Asian level. The car has great status in Bangkok, and people buy them often well before they can adequately finance them.

Buses are the main mode of transit, yet congested roads reduce their capacity to provide adequate or reliable services for commuters. Improvements in rail or mass transit services have been impeded by delays in infrastructure development. Other modes of transit, such as water transport<sup>22</sup>, receive less attention. Walking and cycling are hindered by the lack of infrastructure (a lack of footpaths on many streets, no ramps or kerbs on existing footpaths and an absence of bikeways), and severe air pollution.

In the past, the lack of efficient urban and transportation plans and, of more importance, the flaws in their implementation has resulted in haphazard growth. New residential sites in the outer area are beginning to be located where they are not accessible by any modes of public transport or they are far from employment centers. As a consequence, those inhabitants have to rely on private cars or motorcycles.

The current strategy for achieving sustainable transportation in Bangkok comprises three main elements:

- Incentives for decentralised development (both within the broader Bangkok Metropolitan Area and also the encouragement to development in other regions within Thailand) which will hopefully slow the rate of growth of transport movements into Bangkok's inner city;
- Tighter emission standards for vehicles and for fuel; and
- Massive investments in transit and expressway infrastructure.

In addition, attention is also being given to improving safety and increasing inter-modal linkages.

This strategy should yield significant returns, although additional attention may be required with respect to paratransit services. However, the accessibility of transportation to low-income groups within Bangkok poses significant problems. Public bus services are run at huge deficits to ensure that fares are low. While this benefits some low-income, middle-income groups are also significant beneficiaries.

<sup>&</sup>lt;sup>22</sup> The Chao Phraya River and a number of canals provide a comprehensive waterway network for Bangkok. They provide a useful means of transport via different types of boats for residents living near the river or canals. Waterways account for about 10% of Bangkok daily passenger trips.

Moreover, many low-income people live in the outlying areas of the Bangkok Metropolis and require two or three journeys on unsubsidised paratransit services before reaching subsidised bus services. Their needs could better be met by the development of an integrated ticket system and the introduction of transport concessions for the poor.

Integrated ticketing systems embracing mass transit, buses and paratransit services would be the ideal situation to aim for, although in practice, complete coverage of the paratransit sector would be difficult to achieve. The public bus services could be run on a more profitable basis through allowing significant fare rises, and transport concessions introduced targeted on the most needy groups. Such policies could be an accompaniment to the development of a more general welfare system in Thailand.

### **Other Asian Cities**

The following features of transportation systems in other Asian cities is noteworthy:

- Manila has very high transit use with its jitney system, although many of these trips are very short; as car use grows, the competitiveness of such services is threatened, and Manila is therefore preparing to build more segregated electric rail services;
- Jakarta has the lowest levels of both car use and transit use, but with the structure more favourable for automobile use, threatening a future move down Bangkok's path;
- Transportation in Kuala Lumpur is dominated by the car, and infrastructure development emphasises road construction;
- Beijing is facing imminent explosive growth in the use of motor vehicles, and sees the development of improved transit infrastructure as the key to more sustainable transportation outcomes.

#### **Mexico City**

Along with Tokyo, Mexico City has had to face the biggest growth in demand for travel over the past fifty years. By the beginning of this decade, Mexico City was experiencing rapid growth in the fleet of cars and buses, highly polluting vehicles with a high proportion in need of repair, difficult physical conditions contributing to a massive pollution problem, and increasing distances covered in journeys to work as the population spread over bigger distances.

The strategy that has been adopted to meet these problems includes:

- Significantly upgraded emissions standards for cars and trucks;
- Traffic management emphasising bans on cars on high-pollution days;
- The continuing expansion of the Metro transit service;
- Growth in the level and range of paratransit services.



### 1. Definitions

Sustainable transport means finding ways of meeting transportation needs that are environmentally sound, socially equitable and economically viable. The key symptoms of unsustainable transportation, present in some measure in most of the major cities within APEC, are traffic congestion, poor traffic safety, the lack of accessibility of transport for many groups, significant air pollution, and growing contributions for transportation to global warming.

### 2. The Drivers of Change

The expected growth in the demand for transportation services over the next few decades will pose problems for the environment, traffic congestion, safety and for transport accessibility. On current trends, all cities will experience health risks associated with emissions of nitrogen oxides, volatile organic compounds and suspended particulate matter. In addition, there could be global problems stemming from the contribution of transport to emissions of carbon dioxide and the consumption of oil. Technological change and innovation in transportation can make a major contribution to resolving the problems of unsustainability. However, the net impact of new technologies on transport sustainability will depend on the policy environment. In some circumstances, new technologies could reduce emissions per vehicle while stimulating the demand for transportation and adding to transport congestion and aggregate emissions. The most significant of the new technologies are likely to be electric and hybrid vehicles, intelligent vehicle-highway systems, new types of transit vehicles, alternative urban freight systems and transport logistics.

### 3. Policies for Sustainability

The policy process for sustainable transportation should incorporate:

- Consultative measures involving all stakeholders;
- The use of technology foresight methodologies to explore future possibilities;
- Goals that are clearly articulated and, where possible, quantified;
- An estimate of how actual developments will impact on such goals, including an assessment of the impact of particular policy initiatives; and
- The periodic assessment of overall progress in attaining goals including the evaluation of specific policy initiatives.

Sustainable transport strategies should make use of each of the six major policy instruments:

- The integration of urban land planning with transport planning;
- The development of transport infrastructure with special emphasis on transit infrastructure;
- Reforms to public transport designed to improve its competitiveness;
- The management of traffic flows;
- Policies to accelerate the development of new transport technologies and innovations; and
- The utilisation of specific taxes as a means of shaping transport demand.

## 4. The Impact of Policies

The adoption of comprehensive sustainable transportation strategies can have a big impact on cities. The transformation of Hong Kong, China, and Singapore from third-world cities some three decades ago to international benchmarks for sustainable transportation owes much to the policies pursued in those cities, particularly the integration of urban planning and transport planning, the development of transit infrastructure and the attention given to traffic management.

Over a forty year period, the introduction of the recommended policies could reduce transport emissions to the point where health risks were negligible and

contributions to global warming substantially reduced in absolute terms. However, there is a danger that the situation will get worse before it gets better, and this adds to the urgency of better controlling transport demand, improving transit services and accelerating technological change.

The social impacts of sustainable transport policies are expected to be positive as a result of increased traffic safety and the provision of a wider range of transport services. However, specific additional measures may need to be taken in some cities to ensure that city redevelopments do not reduce access. In addition, transport concessions specific to low-income groups may be necessary in situations where fares are relatively high and the geographic isolation of the poor remains an unresolved problem.

So far as the economic impacts of sustainable transportation policies are concerned, the important point to note is that government will collect higher taxes or use-charges for transport. This will allow increased government finance of infrastructure improvements and other sustainable projects and, possibly, reductions in other taxes. Companies will face higher charges for transportation but less traffic congestion, fewer accidents, and improved transport services. Consumers will pay more for transport, but enjoy safer, higher-quality transport services. The impact on aggregate economic activity is expected to be small, but positive.

## 5. The Scope for International Policies

International action to achieve sustainable transportation can be considered under four headings. In each case, there is considerable scope for actions to be taken within the context of APEC forums.

# Regulation

The main policies advocated are the adoption of internationally agreed standards for air quality, motor vehicle emissions and fuel economy; the further development of protocols in relation to global warming; and coordinated action on fiscal and pricing mechanisms for restraining transport demand.

### Technological Development and Innovation

It is important to address technological issues specifically connected with the needs of cities in the developing economies. A program of international collaboration in the development of technologies in such areas as low-emission motorcycles, low-cost and low-emission passenger cars and minibuses, and lowemission paratransit vehicles, is recommended. There is scope, too, for the utilisation of foresight methodologies in developing a climate favourable towards the development of sustainable technologies.

#### Policy Evaluation Frameworks

A program of technical assistance, under the auspices of APEC and in conjunction perhaps with the Asian Development Bank and the World Bank, should be launched that would enable major APEC cities to adopt sustainable transportation policy frameworks. These frameworks should reflect the aspiration of particular cities while enabling international benchmarking of specific outcomes. These frameworks should reflect the aspiration of particular cities while enabling international benchmarking of specific outcomes.

### Inter-City Exchanges

Inter-city exchanges that focus on issues of urban and transport planning could yield substantial results in terms of increasing the range of policy options in dealing with sustainability problems, as well as providing a framework for sharing information on the experiences gained in attempting to implement sustainable transportation policies.

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## Appendix

# List of Participants Experts Meeting on Sustainable Transport Melbourne, 27-29 July 1999

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- Professor Greg Tegart Director (now Executive Advisor) APEC Centre for Technology Foresight National Science and Technology Development Agency (NSTDA) 73/1 RAMA VI Rd. Rajdhevee, Bangkok 10400 AUSTRALIA/THAILAND Tel. 662 6448150 Fax. 662 644 8194 gregtegart@ozemail.com.au
- Professor Ron Johnston Executive Director Australian Centre for Innovation and International Competitiveness Ltd (ACIIC) Faculty of Engineering University of Sydney NSW 2006 AUSTRALIA Tel. 02 9351 3934 Fax: 02 9351 3974 rj@aciic.eng.usyd.edu.au
- Mr. Ainsley Jolley Director Emerging Technologies and Asian Growth Project Centre for Strategic Economic Studies Victoria University PO Box 14428 Melbourne City MC VIC 8001 AUSTRALIA Tel. 03 9248 1004 Fax: 03 9248 1048 Ainsley.Jolley@vu.edu.au

- Dr. Chatri Sripaipan Co-Director APEC Centre for Technology Foresight National Science and Technology Development Agency (NSTDA) 73/1 RAMA VI Rd. Rajdhevee, Bangkok 10400 THAILAND Tel. 662 6448009; 662 6448150 ext. 703 Fax. 662 6448194 chatri@nstda.or.th
- 4. Professor Peter Sheehan Director Centre for Strategic Economic Studies (CSES) Victoria University PO Box 14428 Melbourne City MC VIC 8001 AUSTRALIA Tel. 03 9248 1031 Fax: 03 9248 1048 Peter.Sheehan@vu.edu.au
- Mr Crisostomo F. Abanes Undersecretary & Chief of Staff Department of Transportation & Communication Colombia Tower Ortigas Av Mandaluyong City 1555 PHILIPPINES Tel. 632 724 6465 Fax: 632 726 ?104 cabanes@pacific.net.ph

- Mr Chaiyos Chaimankong Inspector General Ministry of Transport and Communications 38 Ratchadamnoen Nok Bangkok 10100 THAILAND Tel. 662 280 0521 Fax: 662 280 5863
- Professor Mark Diesendorf (Day 1 only) Director Institute for Sustainable Future University of Technology Sydney PO Box 123 Broadway NSW 2007 AUSTRALIA Tel. 02-9209-4350 Mark.Diesendorf@uts.edu.au
- 11. Dr. Peter Gipps Manager Transport Infrastructure CSIRO
  CSIRO BCE, PO box 12072, Elizabeth St BC Brisbane QLD Australia 4001 AUSTRALIA Tel. 07 3864 4135 Fax: 07 3864 4438 Peter.Gipps@dbce.csrio.au
- 13. Mr. Derek Kemp Transport Planner Strategy Branch Queensland Dept of Transport PO Box 673 QLD 4006 AUSTRALIA Tel. 07 3253 4397 Fax: 07 3253 4233
- Dr. William Lam Associate Professor Dept of Civil & Structural Engineering Hong Kong Polytechnic University Hung Hom, Kowloon Hong Kong, China Tel. 852 2766 6045 Fax: 852 2334 6389 cehlam@polyu.edu.hk

- Mr. Leigh Crutchley Deputy Director International Trade and Service Team Dept of Transport & Regional Services GPO Box 594 Canberra ACT 2601 AUSTRALIA Tel. 02 6274 7047 Fax: 02 6274 6739 Leigh.Crutchley@dotrs.gov.au
- 10. Mr. Simon Ginn

  Land Use and Transport Planner
  Strategy Branch
  Queensland Dept of Transport
  PO Box 673
  QLD 4006
  AUSTRALIA
  Tel. 07 3253 4397
  Fax: 07 3253 4233
  Simon.P.Ginn@transport.qld.gov.au
- 12. Mr. Sing Mong Kee Manager Transport Technology 460 Alexandra Road #27-00 PSA Building SINGAPORE 119963 Tel. 65 375 7252 Fax: 65 375 7209 Mong\_Kee\_SING@lta.gov.sg
- 14. Dr Jeff Kenworthy Senior Lecturer Urban Environments Institute for Science and Technology Policy Murdoch University Murdoch WA 6150 AUSTRALIA Tel. 08-9360-2876 (w) Tel. 08-9335-6870 (h) Fax: 08 9360 6421 kenworth@central.murdoch.edu.au

- 16. Dr Huapu Lu Vice Director Institute of Transport Engineering Department of Civil Engineering Tsinghua University Beijing 100084 CHINA Tel. 86 10 6278 7157 Fax: 86 10 6278 7157 Email: Luhp@tsinghua.edu.cn
- 18. Craig Townsend PhD Student Institute for Science & Technology Policy Murdoch University South Street, Murdoch Perth WA 6150 AUSTRALIA Tel. 08 9360 6293 Fax: 08 9360 6421 townsend@central.murdoch.edu.au
- 17. John McKerral Warren Centre for Advanced Engineering University of Sydney Engineering Building J13 NSW 2006 AUSTRALIA Tel. 02-9351-4048/3752 Fax: 02 9351 2012
- 19. Joe Perone Anne Spurritt Jane Homewood Robin Leeson Economic Strategic Planning City of Melbourne GPO Box 1603M Melbourne VIC 3000 AUSTRALIA Tel. 9658 9957 Fax: 9650 3572