ELECTRIFYING HONG KONG: MAKING TRANSPORT SUSTAINABLE

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Table of Contents

Summary

This document's title, *Electrifying Hong Kong*, reflects its central proposal, which is that over the next 30 years transport in Hong Kong should become essentially entirely fuelled by electricity generated from renewable sources. This is proposed as a way of *Making Transport Sustainable* in Hong Kong—hence the second part of the title.

Hong Kong's transport is proposed to be electrified in part by a major increase in passenger rail services. This is nothing new; indeed much of what is proposed here has also been proposed by the Hong Kong Government. Additions are proposed here for implementation between the Government's planning horizon of 2016 and this document's horizon, which is 2032.

What is entirely new is the proposal that the rest of the passenger transport system be electrified. The main feature of this electrification is transformation of the existing fleet of large and small diesel buses to trolleybuses, with development of necessary infrastructure.

Proposals made in the document regarding goods transport are less specific. This is because less is known now about goods transport, there is more uncertainty about how it might unfold, and less experience with a central part of the strategy that is proposed. This strategy involves the use of trolley lorries, similar to trollybuses, but replacing lorries rather than buses. There would also be an unspecified increase in the amount of freight transport by rail, and perhaps also more trans-border freight transport by water.

The overarching framework for the development of the proposed transport scenario is a proposed energy scenario for Hong Kong. The energy scenario accepts as likely projections that the end of cheap

oil will occur during the present decade and the end of cheap natural gas before 2032. The scenario has Hong Kong moving towards an all-electric energy economy based on renewable generation.

The early part of this document is a substantial review of the Hong Kong transport system and its impacts. The review concludes that, mostly because of its settlement density, Hong Kong is perhaps the closest to transport sustainability among the world's affluent urban regions. However, there are disturbing trends in transport activity and transport-related impacts.

The critical matter is that although Hong Kong's overall emissions of pollution from transport are relatively low, they occur in such a small space there are major and worsening air pollution problems. Noise is also a potential concern.

The document contains elaboration of what is meant by 'sustainable transport' and how it can be quantified. Sustainable transport is defined for Hong Kong taking into account what has been agreed elsewhere and adapting it to Hong Kong's particular circumstances.

The proposal that Hong Kong should become the all-electric city is made in direct response to the consideration of what sustainable transport should mean for Hong Kong.

The document concludes with recognition that what is proposed for Hong Kong is dramatic and far-reaching, and that it could also bring major economic benefits. These benefits would arise from being a technology leader in the matter of tethered vehicles, including road vehicles such as trolleybuses and trolley lorries, and also trains and trams. Establishment of a Tethered Vehicle Institute is proposed to ensure exploitation of this opportunity.

Also proposed is a massive public education system to alert citizens as to the need for change and the reasons for the particular changes that are proposed. If the proposed scenarios are adopted, Hong Kong will be forging new paths. Hong Kong residents as a whole should support such ventures into the relative unknown.

1. Introduction

1.1. Sustainability: securing the well-being of seven generations of new faces

Sustainable has become a popular word

Sustainable has become a popular word among policy-makers. It is used instead of *well-performing* or *viable* or just plain *good*. When policy-makers describe a road system as *sustainable*, they could mean many things: the roads go where people want to travel; they carry traffic with little congestion and few collisions; or, perhaps above all, their construction and maintenance costs are affordable.

Special use of 'sustainable' by environmentalists

Environmental scientists use the terms *sustainable* and *sustainability* in a special way. They are concerned with *long-term impacts* on plant and animal systems including human populations. They are concerned too about the use of non-renewable resources such as oil and natural gas.[1†] Something is sustainable if it can keep going more or less indefinitely. This means it has to use renewable resources and have small, non-cumulative impacts on the environment.

† The superscript numbers refer to 155 End Notes that begin on Page 118. The End Notes contain details of the sources cited in the text as well as additional information and discussion.

Food production is sustainable if it could continue for ever

Many things we do now are sustainable. For example, some food production uses only fertilizers and pesticides that can be readily replaced, seemingly for ever. Also, some food production is at such a small scale, there could be little in the way of lasting, harmful impacts on the natural environment.

Other things we do are evidently not sustainable. Food production that depends on artificial inputs can continue only as long as the feedstocks for these inputs are available (e.g., petroleum for fertilizer production). Moreover, it can continue only if it doesn't result in topsoil loss or in climate change resulting in drought.

This idea of sustainability has led to some pithy definitions:

> "Sustainability … treating the world as if we intended to stay."
>
> Rob Gray et al.[2]

> "Sustainability … can be expressed in the simple terms of an economic golden rule for the restorative economy: Leave the world better than you found it, take no more than you need, try not to harm life or the environment, make amends if you do."
>
> Paul Hawken[3]

A focus on the longer-term future can be at odds with the demands of the present

The problem with the environmental scientists' idea of sustainability is this: Its focus on the longer-term future can be at odds with the demands of the present. For example, use of lorries is essential today, but it consumes irreplaceable oil as well as causing emissions that change the global climate and damage the local environment, perhaps irreversibly.

This kind of conflict led to the notion of *sustainable development*, popularised in the report of a United Nations commission as the following:

> "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs."
>
> World Commission on Environment and Development[4]

Hong Kong's definition of sustainable development

An adaptation for Hong Kong of this definition has been developed by the Government of the Hong Kong SAR's Planning Department:

> "Sustainable development for Hong Kong balances social, economic, environmental and resource needs, both for present and future generations, simultaneously achieving a vibrant economy, social progress and a high quality environment, locally, nationally, and internationally, through the efforts of the community and the Government."
>
> HKSAR Planning Department[5]

The balancing act can be very difficult. Meeting present needs can be at odds with the potential interests of future generations, and vice versa. Which should prevail?

This is a moral question with no easy answer. Do we continue with unsustainable practices now, knowing that our grandchildren's grandchildren could suffer decades from now? Or do we stop, knowing that we and our children will suffer tomorrow and in the months and years ahead? Moreover, if we and our children become poor and even malnourished, might not our grandchildren and their grandchildren also be disadvantaged?

These are weighty questions that are not usually considered when planning for transport. Our preoccupations are mostly with the present. Sometimes we seem to have lost—and perhaps never had—a strong interest in the well-being of generations ahead.

Planning for seven generations ahead

Many cultures have this tradition. Canada's Royal Commission on Aboriginal Peoples reflected the tradition in the title of its massive final report: *For Seven Generations*.[6] Volume 2 of the report mentions the Kaianerekowa—or Great Law of Peace—of the Haudenosaunee (Iroquois) Confederacy as the most frequently cited example of traditional Aboriginal law. It included the following:

> "The lawmakers, in weighing any decision, must cast their minds seven generations ahead, to consider its effects on the coming faces. The lawmakers must consider the effects of each decision on the natural world."
>
> Paul Williams and Curtis Nelson[7]

Other accounts suggest there should be symmetry in decision-making. We should make use of the wisdom of the *previous* seven generations, and have regard for the well-being of the next seven.

Thus, *sustainability* should at least mean thinking up to a century ahead in making our decisions about important, potentially damaging matters such as transport. Meeting present needs is important—not the least to ensure that future generations can be raised in a well-functioning society—but every immediate benefit should be weighed against the well-being of the faces to come.

1.2. Sustainability and sustainable transport

Sustainable transport is the expression of sustainable development within the transport sector.

At the United Nations Conference on Environment and Development held in Rio de Janeiro in 1992, more than 150 national governments endorsed *Agenda 21*, which states that the various sectors of human activity should develop in a sustainable manner.[8] *Sustainable transport* is the expression of sustainable development within the transport sector. (The term *sustainable transportation* is more common in North America; *sustainable mobility* is also used, particularly in Europe.)

Given the importance of transport to human societies, should the requirements for this sector be as stringent as those for human activity as a whole?

A case in point is the 1997 Kyoto Protocol, which could bind nations who ratify it to reduce emissions of greenhouse gases to an average of 5.2 per cent below 1990 levels, by about 2010.[9] Not only has transport—along with electricity generation—shown worldwide the largest percentage increase in emissions,[10] reductions in transport's emissions could be much harder—and more costly—to achieve than reductions in other sectors.

Should transport be exempted from the full effect of the Protocol, with the resulting shortfall being picked up by other sectors? This kind of exemption could be justified not only because it may be difficult to reduce emissions from transport, but also because changing transport practices could impair the ability of other sectors to meet their targets.[11]

Why transport should not have an exemption from sustainability requirements

Three factors suggest that transport should *not* have an exemption from sustainability requirements. One is that there are potential benefits from progress towards sustainability—e.g., reduced air pollution—that should be secured as soon as possible. Another is that so much progress is required towards sustainability, we should be taking advantage of all the time we have available. The third factor—and not the least important—is that an exemption granted for transport could result in claims for exemptions by other sectors, with resulting major disagreements that could detract from progress towards sustainability.

1.3. Definitions and vision of sustainable transport

The Kyoto commitment is only about greenhouse gases and would only be a first step towards what might be reasonably regarded as sustainable transport. In 1997, the Toronto-based Centre for Sustainable Transportation developed a **vision of sustainable transport**. The vision for 2030 included the following:

> "The impacts [of transportation] are so low they no longer provide reason for concern about people's health or any part of the natural environment, in the present or the future. In particular, emissions of carbon dioxide and other greenhouse gases from transportation are less than one fifth of the total of such emissions in the 1990s." [italics added]
>
> Centre for Sustainable Transportation[12]

Box 1
Definition of sustainable transport

Thus, transport's environmental impacts would have to be greatly reduced before it could be considered sustainable.

A sustainable transport system is one that:

- allows the basic access and development needs of individuals, companies and societies to be met safely and in a manner consistent with human and ecosystem health, and promotes equity within and between successive generations;
- is affordable, operates fairly and efficiently, offers choice of transport mode, and supports a competitive economy, as well as balanced regional development;
- limits emissions and waste within the planet's ability to absorb them, uses renewable resources at or below their rates of generation, and, uses non-renewable resources at or below the rates of development of renewable substitutes while minimizing the impact on the use of land and the generation of noise.

The Centre's vision was also about the economic and social aspects of sustainable transport. The vision was captured in a definition that, slightly changed, has been formally adopted by ministers of the 15 nations of the Europe Union (see Box 1).[13]

The closest the HKSAR Government has come to defining sustainable transport may have been in a 1999 Transport Bureau document on future transport strategy. The fifth of five 'betters' set out in the document is 'better environmental protection', the objective of which was stated to be:

> "Transport infrastructure and related services will be provided in an environmentally acceptable manner to ensure the sustainable development of Hong Kong.
>
> Transport Bureau, HKSAR Government[14]

Definitions of sustainable transport from Hong Kong

A more elaborate definition had been provided in May 1998 by L.H. Wang, Chair of the Hong Kong Institute for Infrastructure Development:

> "Taking into consideration the spatial and temporal contexts of development, and the uniqueness and diversity of Hong Kong society, a sustainable transport development scenario should be such that its accessibility, efficiency, and equity levels so achieved do not and will not compromise the ability of any group as well as any area within the city to satisfy their needs now and in the future. In short, a sustainable transport development system allows an equal opportunity for all to commute within an affordable cost and time constraint, now and in the future. Further, the level of spatial and temporal externalities so generated should be kept to its minimum."
>
> L.H. Wang[15]

Another definition rooted in Hong Kong's experience was provided by Wing-Tat Hung, who noted, "it is difficult to define sustainable transport" and added:

> "Sustainable transport is defined as a transport system without unrecoverable destruction to the natural environment, i.e., minimal land destruction, noise, air, and water pollution.
>
> Wing-Tat Hung[16]

Finally from Hong Kong is a definition of a '*more* sustainable transport system' contained in a 1999 submission to the Legco Panel on Environmental Affairs by a group from the University of Hong Kong:

> "A more sustainable transport system is one which reduces health and safety threats to the local population, while meeting the public's needs for affordable and convenient mobility. From a regional and planet-wide perspective, a more sustainable transport system is one which reduced overall environmental damage from transport's use of energy, and draws on relatively plentiful and safe fuels."
>
> William Barron et al.[17]

Evident tensions between present and future concerns

Thus concern for the social and economic aspects of sustainable transport, as well as the environmental aspects, is important in Hong Kong as elsewhere. The tensions between environmental and other requirements and between present and future concerns are also evident.

1.4. Environmental imperatives set the framework for sustainability

In working out how to balance environmental factors on the one hand, with economic and social factors on the other hand, it may be useful to consider two statements made at a conference on sustainable development indicators held in Ottawa in March 2001. David McGuinty of Canada's National Round Table on the Environment and the Economy said, "The economy is a wholly owned subsidiary of the environment, not the other way around." Robert Smith of Statistics Canada noted that "The economy is physically embedded in the biophysical world."[18]

Environmental requirements should set the framework for sustainability

In other words, environmental requirements should set the framework for sustainability. Economic and social requirements are profoundly important, but they must be made compatible with the environmental requirements.

These last remarks characterise the position taken here, namely that the pre-eminent requirement of sustainability is environmental. Progress towards sustainable transport means providing for the best possible social and economic outcomes, but *only* to the extent that environmental requirements are met. It's not a matter of balancing environmental and other factors—relaxing environmental requirements, for example, if the economic consequences are too onerous. Such relaxation usually means that future needs are being sacrificed for present needs, thus denying the key feature of sustainability.

There is no sustainable transport if there is no transport

On the other hand, the transport system must actually do the job of moving people and freight around, or else it is not a *transport* system. There is no sustainable transport if there is no transport. **Thus, the simple-minded path to sustainable transport of winding down transport activity to the point where impacts are negligible is not acceptable.** The challenge is to devise and implement transport that works for present generations without working against future generations.

A key consideration is that of the environmental requirements for sustainable transport. This matter is discussed in further in Chapter 6. For the moment, it can be noted that the most onerous of the requirements proposed there concerns emissions of greenhouse gases (GHGs). Generally speaking, if this criterion for a globally acting emission is met, criteria for locally acting emissions are also met, but this may not be true for Hong Kong. Criteria for noise and land use are not necessarily met. Noise particularly may require special consideration in Hong Kong.

Globally acting impacts have the most potential to affect the continued existence of life as we know it

There is another kind of reason for focussing on globally acting emissions such as GHGs. Globally acting impacts have the most potential to affect the continued existence of life as we know it on this planet. If we change the planet's climate, damage the stratospheric ozone layer, destroy the world's forests, or severely pollute the oceans, then the future of life on our planet—the only place in the universe known to support life—could be in jeopardy. Local impacts, e.g., air pollution and groundwater contamination, are also important because they are what concern people most, and because if they are numerous and severe they can become global impacts.

Attainment of sustainable transport is first and foremost an environmental matter

In summary, the approach here is to consider attainment of sustainable transport as first and foremost an environmental matter, and above all a matter of reducing transport's global impacts. However, local impacts are far from neglected. Moreover, important consideration is given to the economic and social implications of different strategies for meeting environmental sustainability criteria. Indeed, an attempt is made in what follows to propose a strategy that would result in a transport system that would be environmentally sustainable and make a positive contribution to Hong Kong's economic and social sustainability.

Exactly what sustainable transport could mean for Hong Kong is set out in Chapter 6 of this report. It takes into account the particular features and impacts of transport in Hong Kong as well as world trends, notably trends in energy use and availability. The intervening chapters provide a portrait of transport today in Hong Kong, including recent trends and current projections. Chapter 2 puts Hong Kong in a world and Asian context. Chapter 3 focuses on transport activity, and the associated matters of vehicle ownership, infrastructure, and land use. Chapter 4 is concerned with transport's impacts, above all the environmental impacts but also economic and social impacts. Chapter 5 deals with all-important energy considerations.

2. Hong Kong in world and Asian contexts

2.1. Hong Kong: the extraordinary affluent urban region

Hong Kong is extraordinary in many respects

Among the 60 affluent urban regions worldwide represented in the *Millennium Cities Database,*[19] Hong Kong is extraordinary in many respects. **Hong Kong leads or is second on the following indicators**:

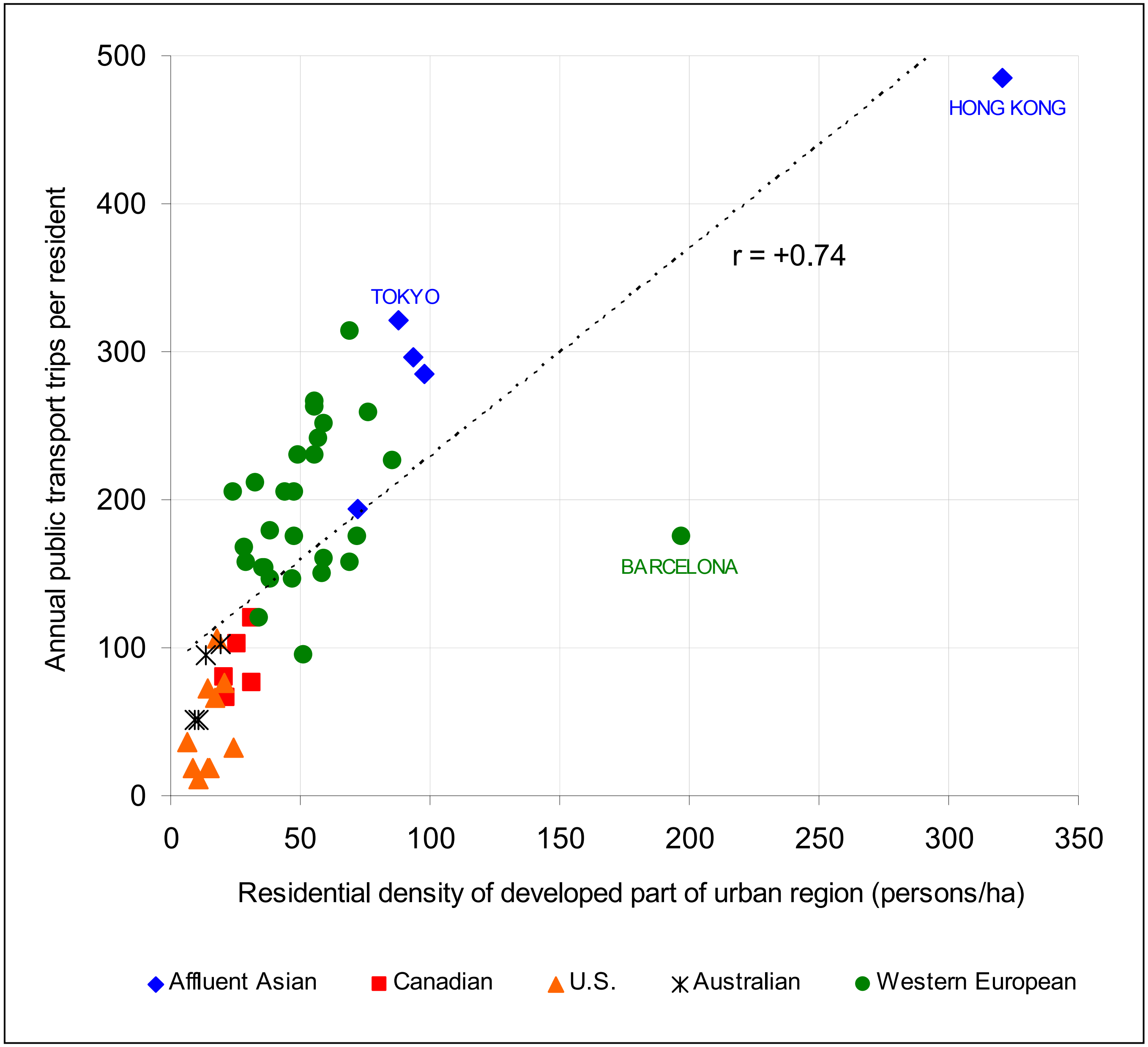
- Settlement densities (residents and jobs per hectare of developed land)
- Intensity of public transport service (vehicle-kilometres of service per developed hectare and—second to Zurich—per capita)
- Extent of public transport use (trips per person)
- Modal split (public transport trips as a share of all motorised trips)
- Taxicab use (trips per person—second to Singapore)
- Cost of car use (overall cost and operating cost per passenger-kilometre)
- Intensity of road investment (annual investment per kilometre of road)
- Spatial intensity of emissions of pollutants from passenger transport (weighted total per developed hectare)

More indications of Hong Kong's extraordinary features

Among affluent urban regions with available data, Hong Kong is last or next to last on the following indicators:

- Intensity of heavy rail network (metres of subway and surface rail track per person)
- Intensity of road network (metres of road per person)
- Car ownership (vehicles per person)
- Car use (trips per person)
- Journey length by car (average trip distance, next to last just ahead of Marseille)
- Parking spaces per employee (in central business districts only)
- User cost of transport (overall cost per passenger-kilometre for all public and private transport)
- Total passenger transport energy use per capita (all modes, in common energy units, i.e., megajoules)
- Energy use by metro systems (in megajoules per passenger-kilometre, tie last with Singapore and Tokyo)
- Energy use by suburban rail systems (in megajoules per passenger-kilometre)

Box 2
Public transport use and residential density for 52 affluent urban regions in 1995, showing trend line and correlation (r)



Surprising features

Thus, compared with other affluent urban regions, Hong Kong has a higher settlement density, higher public transport use, and lower car ownership and use. **Two surprising features stand out**. One is that Hong Kong has per person the lowest extent of heavy rail network, a mode often thought to make high levels of public transport use possible.

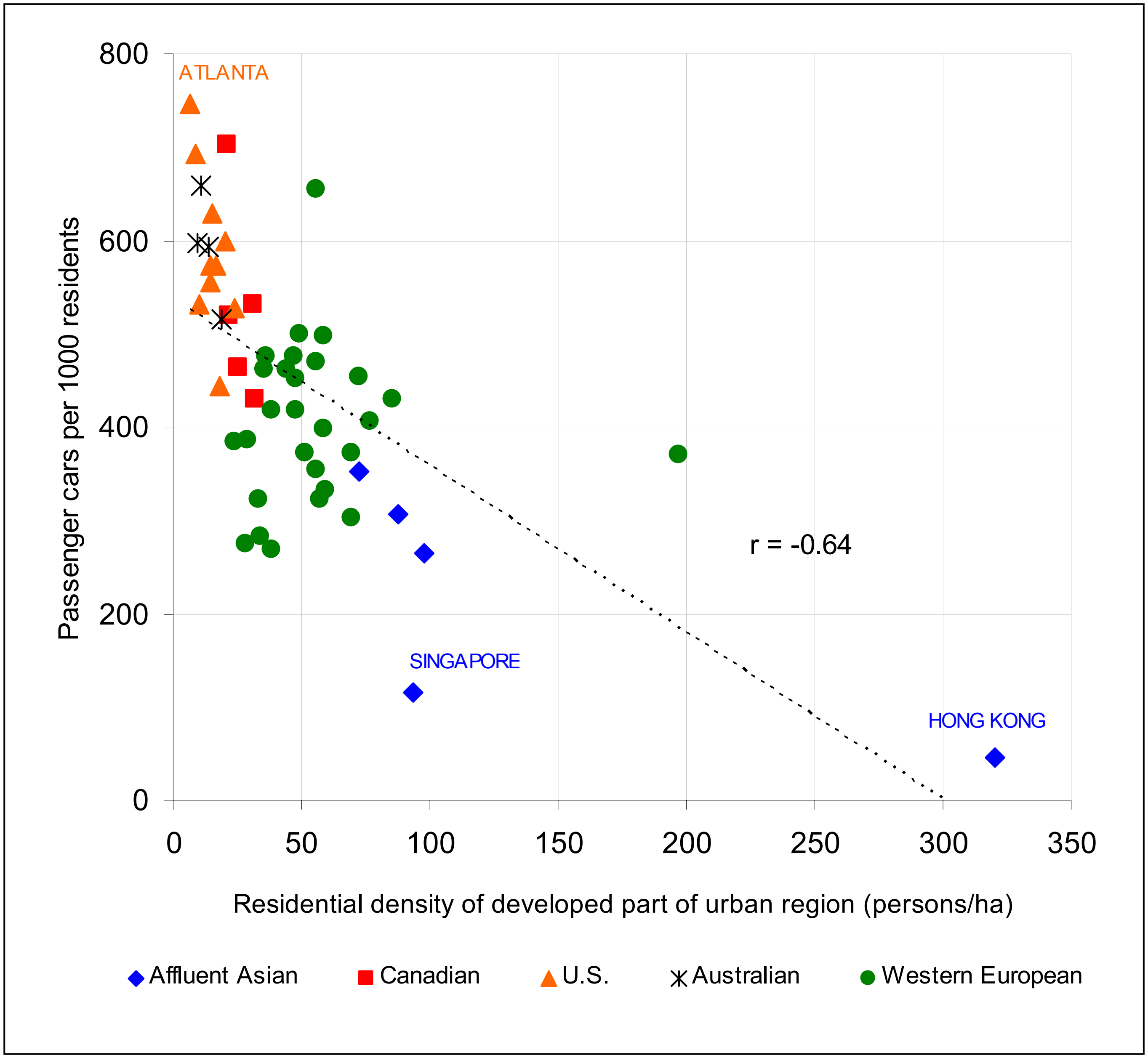
Hong Kong has the highest spatial intensity of emitted pollutants from passenger transport

The other surprising feature is that Hong Kong has the highest spatial intensity of emitted pollutants from passenger transport.[20] The region's low level of car use would suggest the opposite. Indeed, Hong Kong ranks near the bottom in the *amounts* of individual pollutants emitted from passenger transport (see Box 23 in Section 4.3.1). However, they are emitted within such a small area the cumulative *intensity* of emissions is the highest (see Box 30 in Section 4.3.3).

Box 2 illustrates the extreme nature of both Hong Kong's **residential density** (considering the developed area only) and its **public transport use**.[21] It also shows the high correlation between public transport use and residential density among the world's affluent urban regions.[22] The trend line in Box 2 suggests that use of public transport in Hong Kong is actually slightly *below* the level that could be expected from density considerations alone.[23]

The range in annual public transport use among the urban regions is large, from 11 (Phoenix) to 485 journeys per resident (Hong Kong), a 44-fold difference. Hong Kong is especially distinctive in that its public transport use is 50-per-cent above the urban region with the second highest use (Tokyo, 321 journeys per resident).

Box 3
Car ownership and residential density for 52 affluent urban regions in 1995, showing trend line and correlation (r)



Hong Kong stands out again

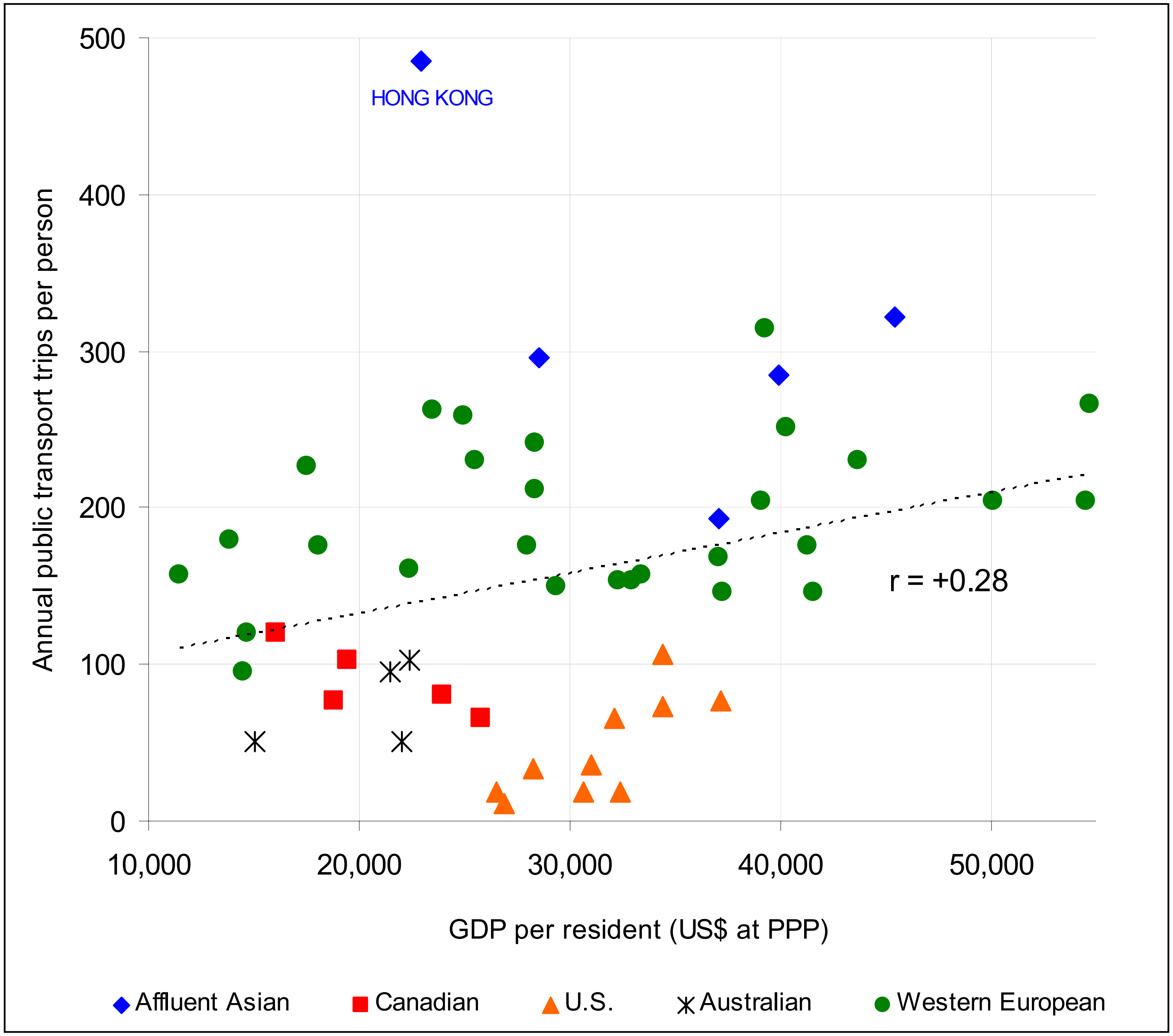
The range in residential densities is almost as large, from 9 (Houston) to 320 persons per hectare (Hong Kong), a 36-fold difference. Again, Hong Kong stands out not only because it is the most densely settled urban region but also because it is more than 50-per-cent denser than the region in second place (Barcelona, 197 persons per hectare).

If public transit use is one side of the urban density coin, **car ownership** may be the other. Box 3 shows how car ownership and density are related. Again, the range is large, from 46 (Hong Kong) to 746 cars per 1000 residents (Atlanta), a 16-fold difference.

Residential density is a strong factor in restraining car ownership

Hong Kong's level of car ownership is not dramatically lower than that of the region with the next lowest ownership rate: Singapore (116 cars per 1000 residents). However, Singapore is far below the trend line in Box 3 for the 52 urban regions. This could be because there are special factors restraining car ownership in Singapore.[24] Hong Kong's level of car ownership is close to the trend line in Box 3, suggesting that residential density is perhaps the strongest factor in the restraint of car ownership.[25]

Box 4
Public transport use and regional GDP (PPP) for 52 affluent urban regions in 1995, showing trend line and correlation (r)



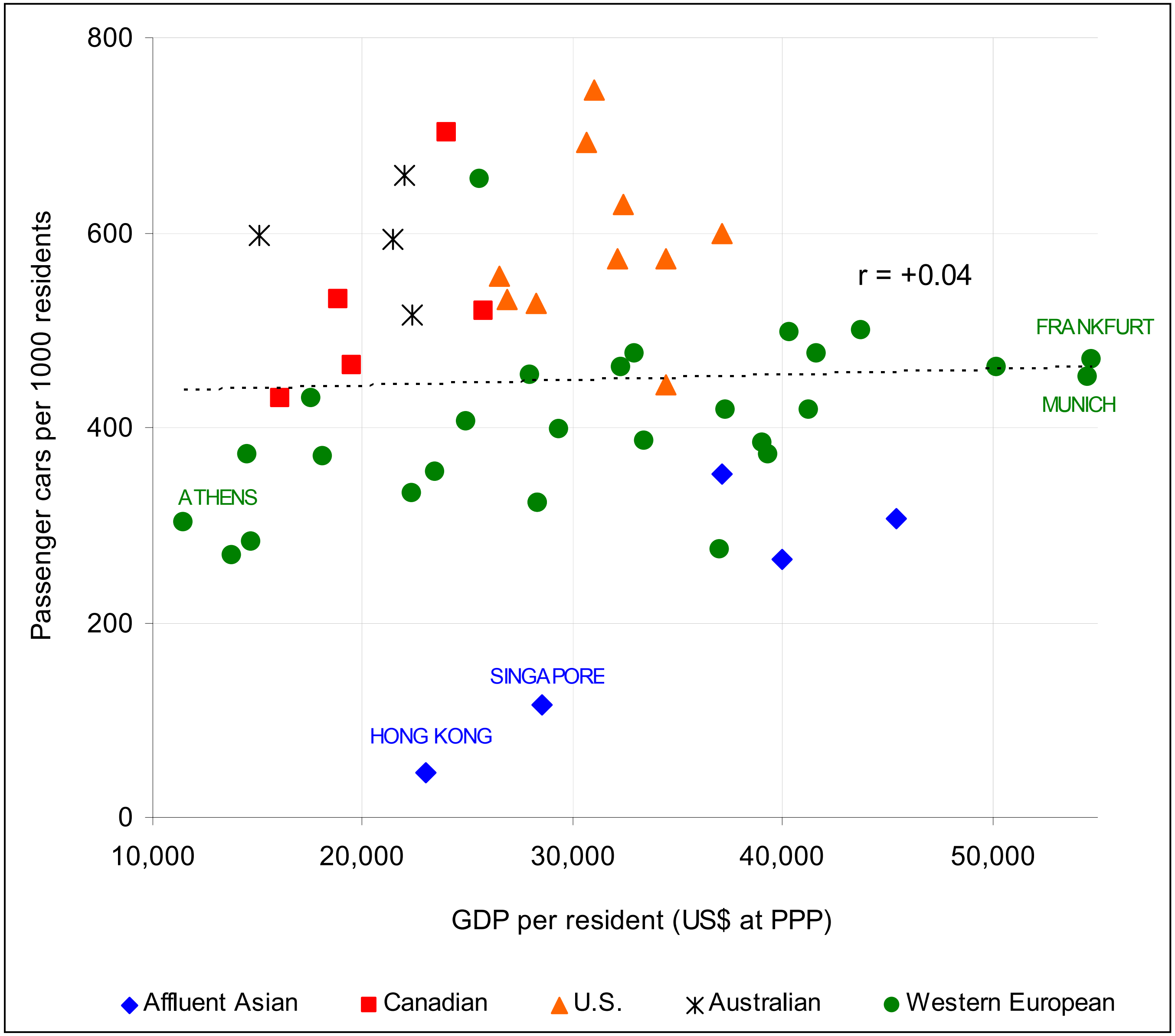
Thus, among the world's affluent cities Hong Kong is truly extraordinary in respect of urban density, public transit use, and car ownership. The evidence in Box 2 and Box 3 is correlational, meaning it is hard to say which are the causes and which are the effects. However, other information suggests that the important causal links could be the following: High density results in low car ownership that in turn results in high public transport use.[26]

Hong Kong is not extraordinary because it is poorer than the urban regions with which it is compared

A simple explanation for Hong Kong's extraordinary features could be that Hong Kong is at one end of the scale in terms of **affluence**. It could be the case, for example, that Hong Kong is relatively poor, that more affluent urban regions are inclined to favour automobile use, and that less affluent regions favour public transport. As a consequence, density is an incidental factor. However, taking regional GDP per resident as a measure of affluence, Hong Kong is not the least affluent among the 52 urban regions represented in Box 2 and Box 3. It comes about one third of the way up the list in this respect, as indicated in Box 4 and Box 5.[27]

Moreover, the premises of this kind of argument are unsound. Box 4 suggests that among these urban regions public transport use *increases* with affluence.

▶ Box 5
Car ownership and regional GDP (PPP) for 52 affluent urban regions in 1995, showing trend line and correlation (r)



Box 5 suggests that there is no relationship between car ownership and affluence (except perhaps among the affluent Asian urban regions). It is clear from these boxes, however, that there are major regional differences in all these factors. For any particular level of affluence, U.S., Canadian, and Australian regions have lower-than-average public transport use and higher-than-average car use. Western European and Affluent Asian regions have lower-than-average car use.

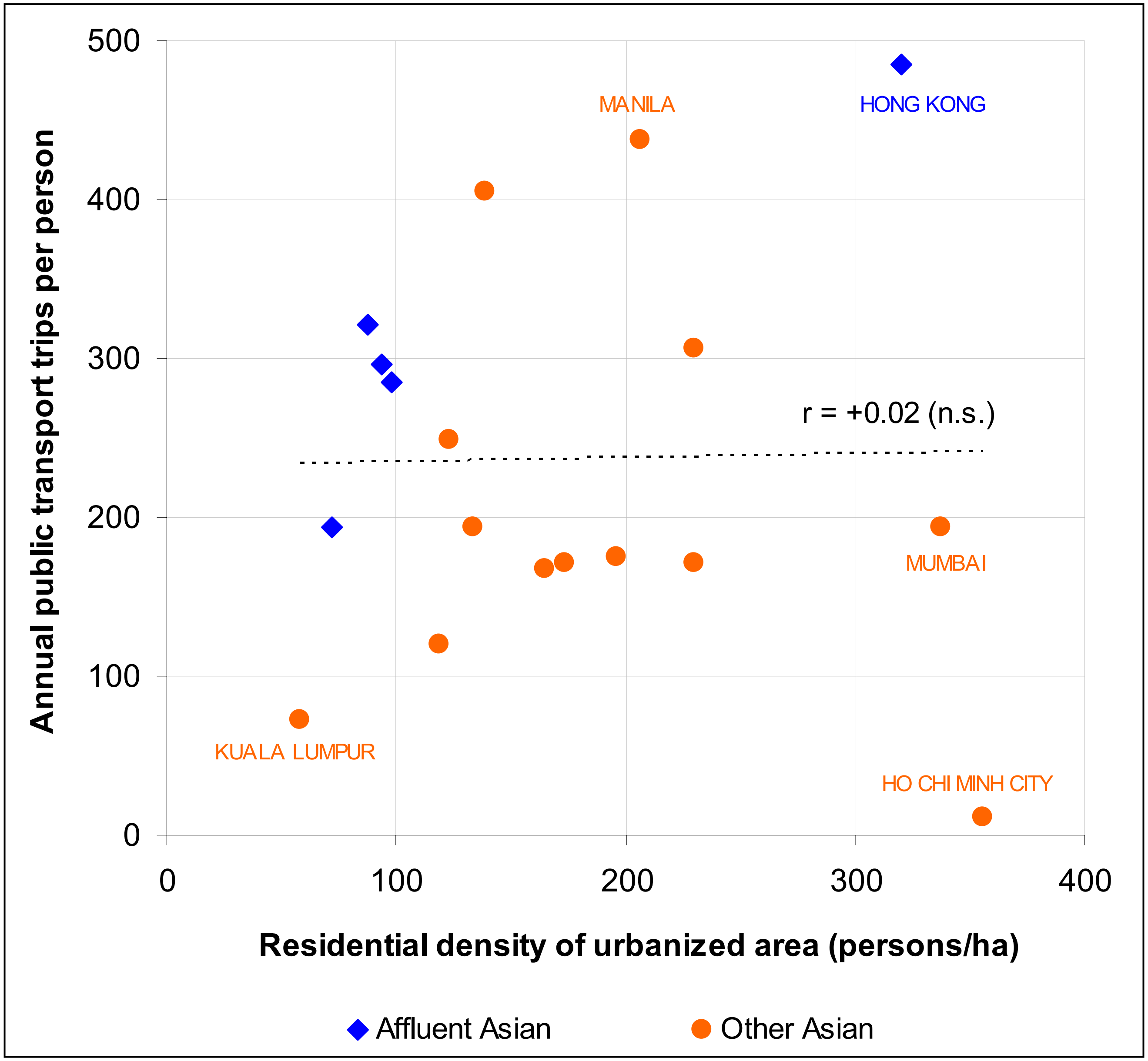
2.2. Hong Kong: the urban region in Asia

As well as being one of the world's affluent cities, Hong Kong is an *Asian* city. It is useful to examine the key features of urban density, car use, and public transport use in that context.

No suggestion that Hong Kong is more 'at home' in a grouping of Asian as opposed to affluent cities

Box 6 shows public transport trips in relation to residential densities for the 18 Asian urban regions in the UITP database. There is no evident relation between the two variables, and no suggestion that Hong Kong is more 'at home' in a grouping of Asian as opposed to affluent cities. There is certainly not among these Asian regions the strong positive association between density and public transport use illustrated for affluent regions in Box 2. Indeed, according to the *Database*, the densest Asian urban region, Ho Chi Minh City (356 persons per developed hectare), is also the region with the lowest use of public transport.

Box 6
Public transport use and residential density for 18 Asian urban regions, showing trend line and correlation coefficient (not significant in this case)



Hong Kong ranks third among these Asian cities in residential density. The variation in density among these urban regions is large, with a six-fold difference between the least dense (Kuala Lumpur, 58 persons per developed hectare) and Ho Chi Minh City. (Kuala Lumpur, although the least dense of these Asian urban regions, is denser than two thirds of the affluent urban regions represented in Box 2.)

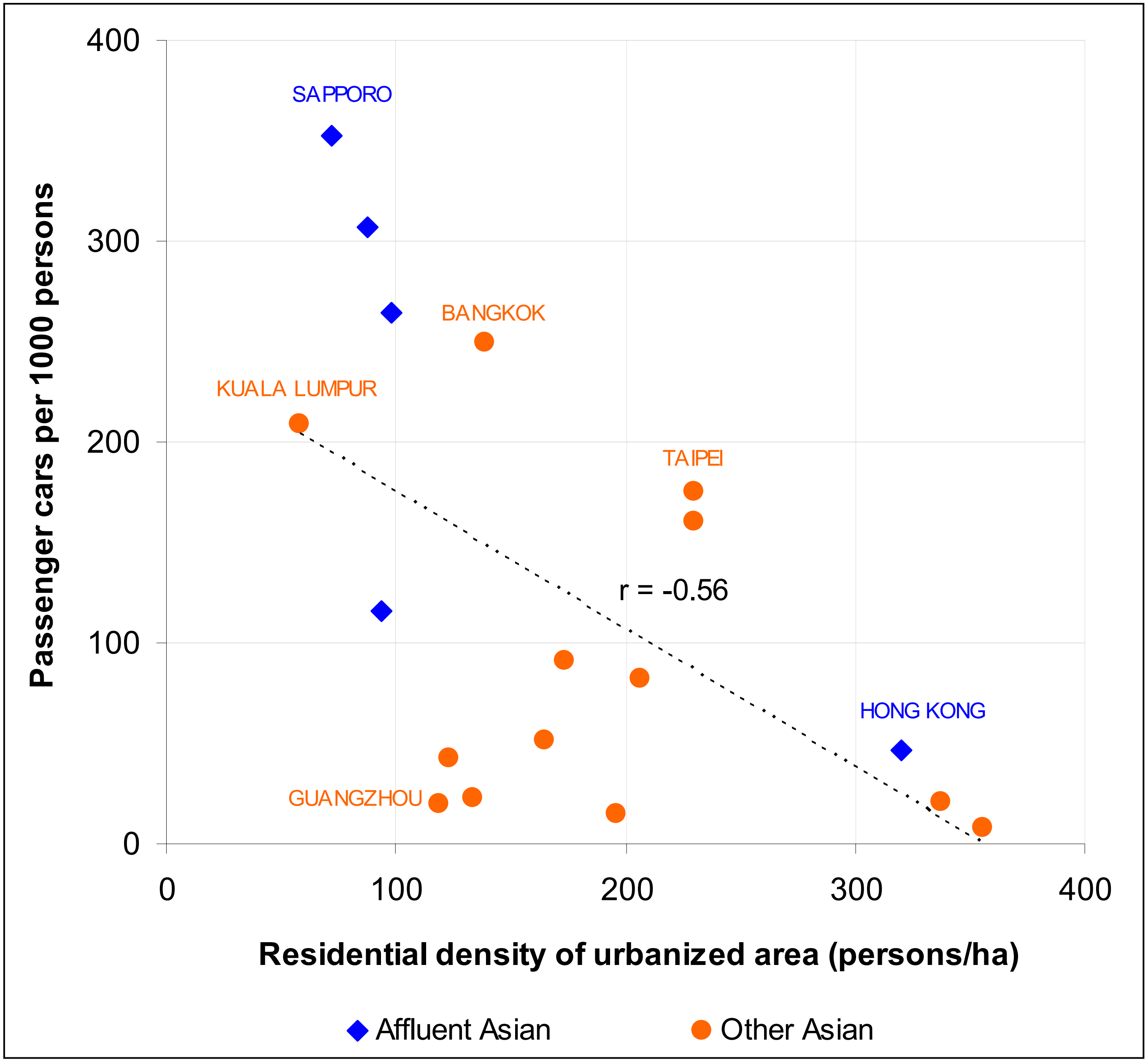
The negative correlation between car ownership and density apparent for affluent urban regions in Box 3 also appears to apply for Asian urban regions, as shown in Box 7, although it is less strong.[28] In this case, Hong Kong does seem to fit in just about as well with a set of Asian cities as with a set of affluent cities. This is perhaps only because the same relationship applies to the two sets of regions (i.e., higher residential density is associated with lower car ownership).

Further insight is available from Box 8, which shows that car ownership varies strongly with regional GDP for the less affluent Asian cities, but that Hong Kong's position in this respect is more in line with the pattern for affluent Asian cities.[29]

The proper positioning of Hong Kong

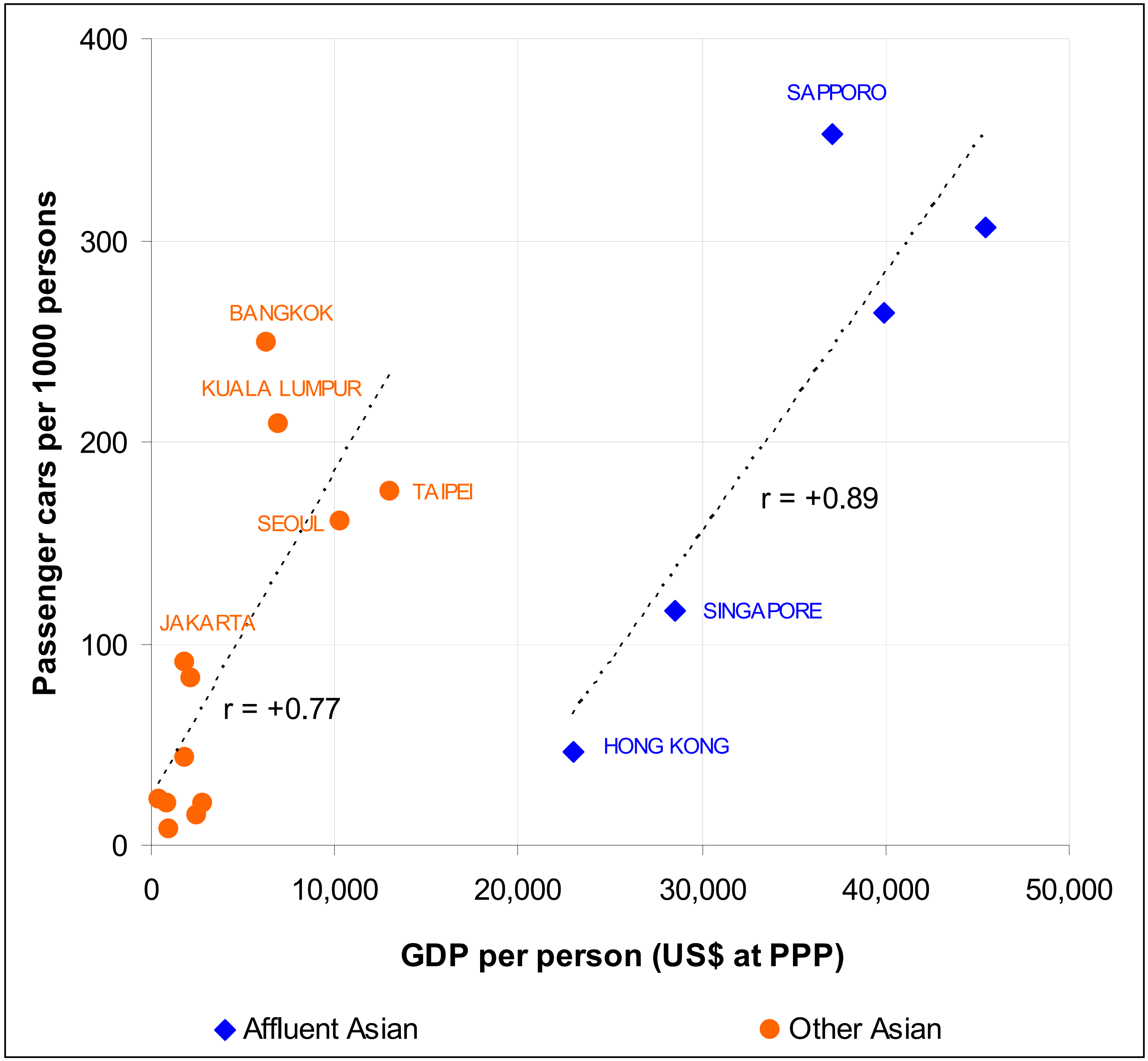
Thus, the proper positioning of Hong Kong is as an affluent urban region that happens to have an unusually high density of development, rather than as an Asian urban region that happens to be affluent.

Box 7
Car ownership and residential density for 18 Asian urban regions, showing trend line and correlation coefficient



What this means in practice is that the trends and practices of other affluent urban regions are relevant rather than those of other Asian urban regions. Moreover, lessons from Hong Kong, which could be numerous, may be more likely to be applicable to other affluent urban regions than to other Asian regions.

Box 8
Car ownership and affluence for 18 Asian urban regions, 1995, showing. separate trend lines and correlations (r) for the affluent and the other regions.



3. Land use and transport activity in Hong Kong

3.1. Settlement density

Here, the focus is on *changes* in Hong Kong over the last decade or so

Hong Kong's pre-eminence as the affluent urban region with the highest settlement density was noted in Chapter 2. The comparisons with other urban regions in Chapter 2 refer to one point in time, the year 1995. Important changes in several places could have occurred since then. Here, the focus is on changes *in Hong Kong* in settlement density and other variables since 1995 and before, with the aim of assessing whether or not the trends are in the general direction of sustainable transport.

Three interrelated features—high settlement density, high public transport use, and low car use—are favourable in relation to sustainability because each of them is associated with low levels of energy use for passenger transport. Low levels of energy use almost invariably mean low levels of use of non-renewable fossil fuels and consequent low levels of emissions of greenhouse gases. Moreover, low energy use is usually associated with low levels of emissions of locally and regionally acting pollutants.

Low levels of energy use for transport mean potentially strong conformity with the definition of sustainable transport

The overall result is potentially strong conformity with the part of the definition of a sustainable transport system adopted by the EU ministers that speaks to "[limiting] emissions and waste within the planet's ability to absorb them, [and using] renewable resources at or below their rates of generation" (see Box 1). The conformity is stronger if *trends* are towards even higher density and public transport use, and even lower car use.

Settlement density is perhaps the most important of these variables, the one that may be responsible for Hong Kong's extraordinary features. Box 9 shows that there was a slight decline in settlement density (persons per developed hectare) during the 1990s.[30] Thus, during the 1990s the urbanised part of Hong Kong increased in area at a slightly higher rate than the population, i.e., in these terms Hong Kong experienced a small amount of urban sprawl.[31]

Box 9
Settlement densities in Hong Kong in 1990 and 1999

	1990	1999
Population (thousands)	5,705	6,721
Developed land (hectares)	14,800	18,400
Of which, transport uses	*2,400*	*4,600*
Of which, all other uses	*12,400*	*13,800*
Settlement density (persons/ha of developed land)	385	365
Settlement density (persons/ha, excluding land used for transport)	*460*	*487*

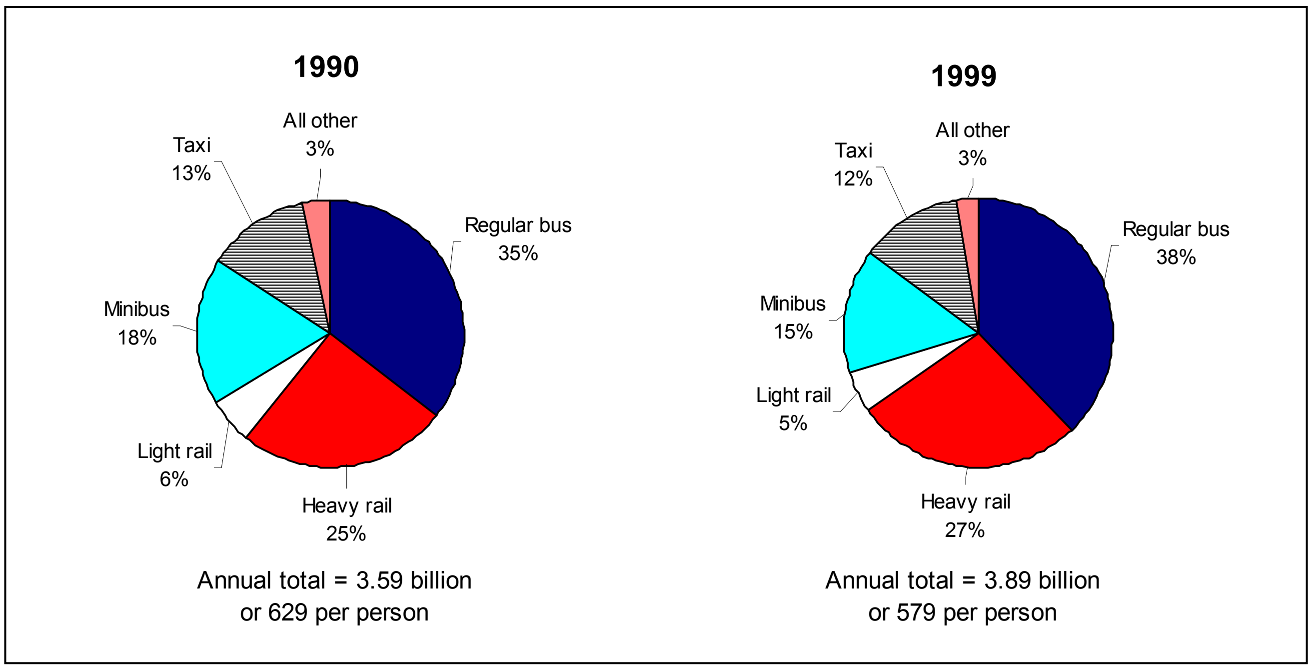
However, more than two thirds of the increase in the amount of developed land through the 1990s involved the development of land for transport purposes (chiefly but not exclusively associated with the development of Chek Lap Kok Airport). If land for transport is excluded, Hong Kong's settlement densities *increased* during the 1990s (see the bottom row of Box 9).

Because of the noted strong association between settlement density and features favourable to attainment of sustainable transport, Hong Kong's recent trends in this respect can thus possibly be regarded as favourable.

Current policies maintain high densities

Current government policies and actions concerning the provision of land for development suggest that the increase in settlement intensity could continue. Only 536 hectares is to be released for development during the period 2001-2006.[32] This represents an annual rate of growth in the amount of developed land for other than transport purposes of 0.7 per cent, well below the likely rate of population increase and well below the rate of 1.2 per cent that occurred during 1990-1999. Hong Kong seems set to remain the densest urban region in the world for many years to come.

Box 10
Trips by public transport in Hong Kong, by mode (pie charts), total, and per capita, 1990 and 1999



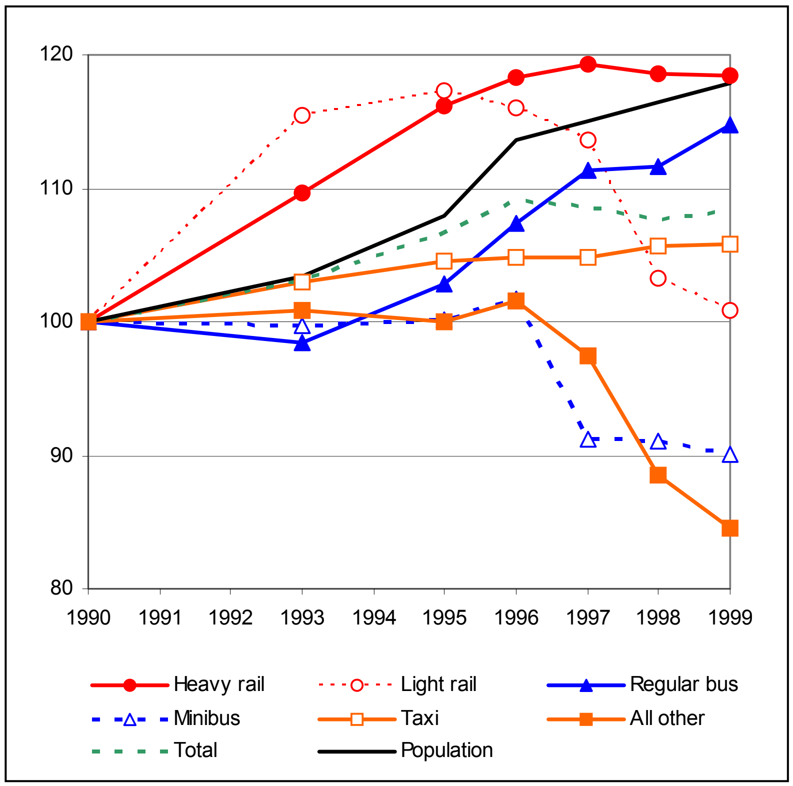
3.2. Recent transport trends

3.2.1. Use of public transport

Public transport use has not kept up with population growth

Public transport use was another factor related to sustainability in which Hong Kong was pre-eminent in the comparisons with other urban regions reported in Chapter 2. Recent trends in the use of public transport are shown in Box 10 and Box 11.[33] Overall there has been an increase in use. However, the rate of increase was below the rate of population growth; thus there has been a decline in *per capita* use of public transport (Box 10).[34] Box 11 shows that the overall increase occurred mostly before 1996. Since then, heavy rail[35] use has declined a little, light rail[36] use and minibus use have declined more, and regular bus[37] use has increased. Heavy rail and regular bus increased their shares of total ridership during the 1990s (Box 10).

Box 11
Trends in population and in public transport trips by mode, 1990-1999 (1990 = 100)



Thus, although the overall increase in public transport can be considered positive, there are

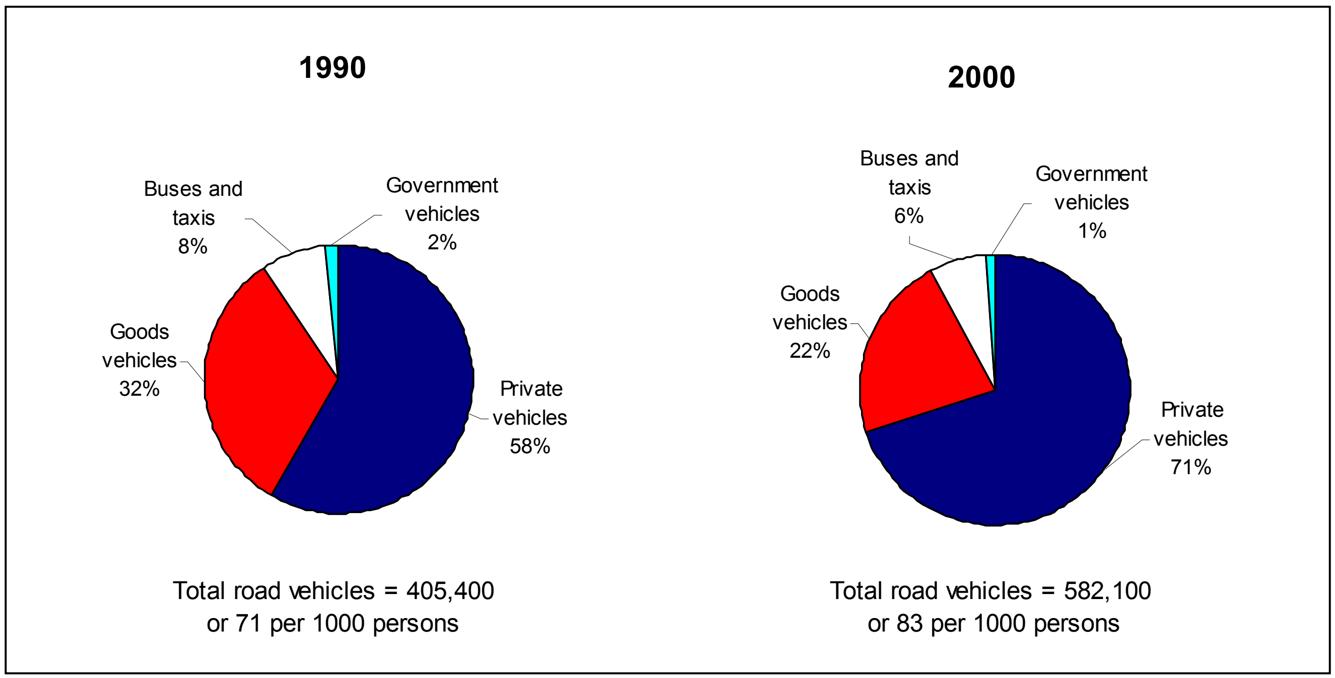
Recently, use of regular buses has grown at the expense of travel by rail

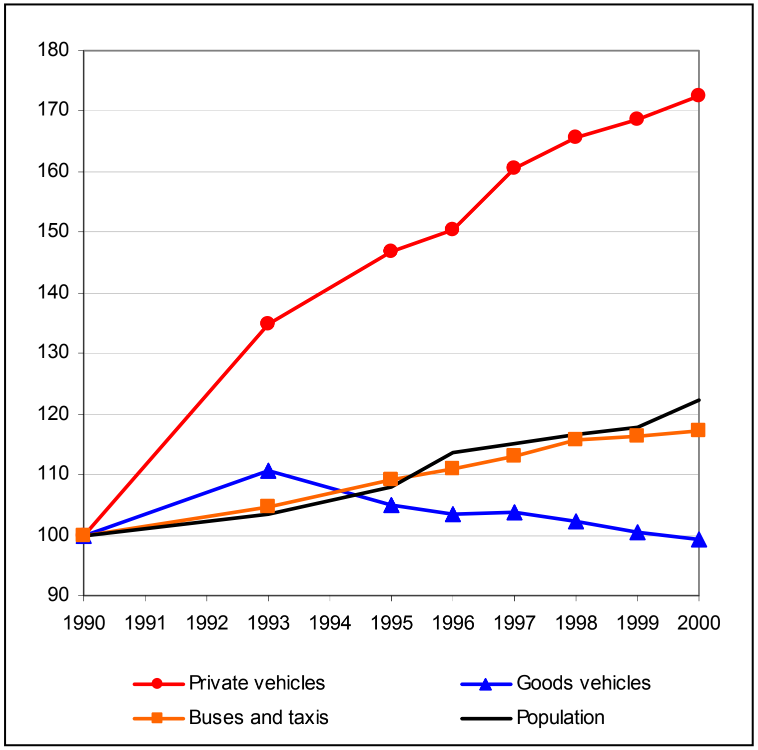
several negative features. These include the decline in *per capita* use, the accentuation of this decline in more recent years, and the relative growth in use of the more polluting and energy-intensive regular buses at the apparent expense of heavy rail systems.

3.2.2. Road vehicle fleet

The third of the three interrelated factors highlighted in Chapter 2 was car ownership. Again, Hong Kong was extreme in a direction consistent with sustainability; among affluent urban regions its ownership rate was the lowest. Low rates of car ownership are associated with consequent low rates of car use, fossil fuel use, and emissions of all kinds.

Box 12
Road vehicle fleets by type (pie charts), total, and per capita, Hong Kong, 1990 and 2000





Box 13
Trends in the road vehicle fleet and in population, 1990-2000

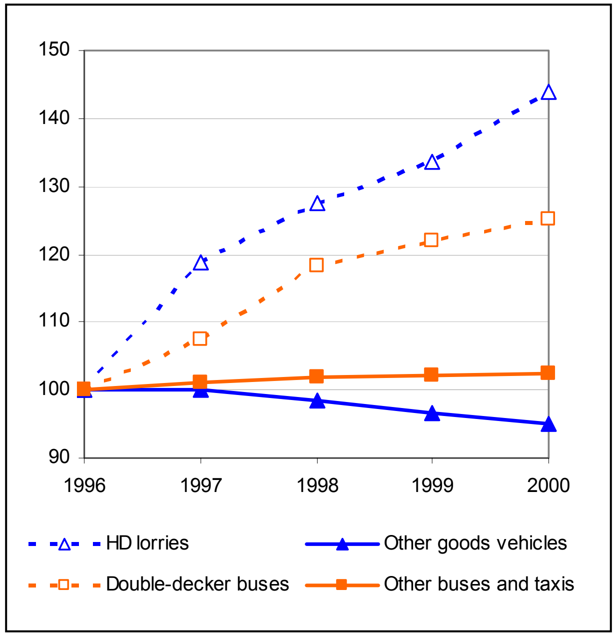
The total road vehicle fleets in 1990 and 2000 are shown in Box 12,[38] together with breakdowns by vehicle type. The overall fleet increased by 44 per cent. Most of this increase comprised growth in private vehicles (cars and motorcycles), whose numbers increased by 73 per cent, as illustrated in Box 13. Per capita ownership of private vehicles increased by 41 per cent, from 41 to 58 per 1000 residents.[39] These high rates of growth are in the opposite direction to what is required for sustainability.

Box 12 and Box 13 are a somewhat misleading in respect of buses and goods vehicles. This is because of changes in the balances within these categories between large and small vehicles. The overall number of goods vehicles on Hong Kong roads declined slightly between 1990 and 2000 (Box 13). However, the number of heavy-duty lorries increased by more than 40 per cent (Box 14). Also shown in Box 14 is how the number of double-decker buses increased at a higher rate than the number of other public transport vehicles on the road.

3.2.3. Trends in road traffic

There have been corresponding increases in road traffic, except in recent years. Box 15 shows how the total number of vehicle-kilometres performed has grown,

Box 14
Trends in the numbers of large lorries and large buses, Hong Kong, 1990-2000 (1990 = 100)



by 90 per cent during the period 1986-1999; it shows as well annual totals of vehicles on the road. Breakdowns by type of road vehicle are not available.

The amount of road traffic levelled off in the late 1990s, in part because of a decline in the number of smaller commercial vehicles on the road

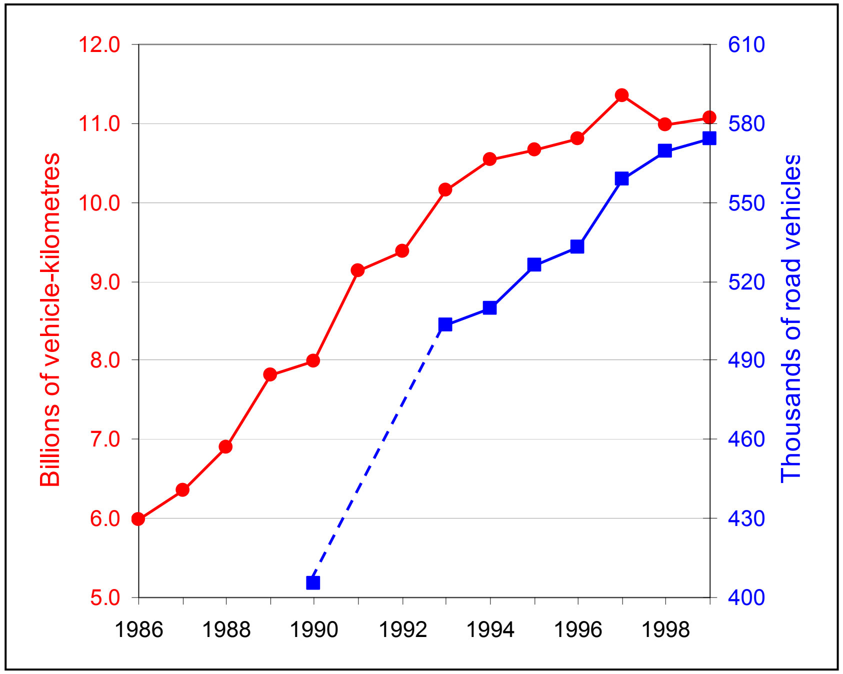
In the absence of pertinent data, it may be reasonable to conclude that the levelling off of traffic volumes between 1997 and 1999 could have been due to the decline in the number of goods vehicles on the road, especially smaller goods vehicles (see Box 13 and Box 14), itself perhaps a consequence of economic recession. The number of private vehicles continued to grow during this period (Box 12), and it is likely that the number of vehicle-kilometres performed by this type of vehicle grew proportionately.[40]

Whatever the cause, the overall levelling off of road traffic in the late 1990s is in a direction consistent with progress towards sustainable transport.

3.2.4. Trends in air and marine freight activity

Air and marine passengers have little relative impact on transport within Hong Kong, but the effects of air and particularly marine freight can be substantial.

Box 15
Totals of road vehicle kilometres (left scale) and road vehicles (right scale), Hong Kong, 1986-1999 and 1990-1999



Volumes of air freight and sea freight handled in Hong Kong have shown extraordinary increases during the last two decades.

In 2000, Hong Kong had the world's busiest port and (for freight traffic) second busiest airport

Air freight grew from about 250,000 tonnes in 1980 to 2.3 million tonnes in 2000, putting Chek Lap Kok airport second in the world in tonnage handled. Sea freight volume grew from 1.5 million to 17.8 million container units between 1980 and 2000, putting Hong Kong's port facilities first in the world in amounts handled.[41] Much of the growth in road freight traffic may have been associated with these large increases in air and sea freight transport activity.

3.3. Transport projections

3.3.1. Public transport infrastructure

Revival of growth in rail

Recent actions by the Hong Kong SAR government may revive the growth in use of heavy rail experienced during the early 1990s (see Box 11). The *Rail Development Strategy 2000* speaks to completion of six new rail lines by 2005, increasing the total length of the heavy rail network from 146 kilometres in 1999 to over 200 kilometres in 2006.[42]

3.3.2. Road vehicle fleet

The Hong Kong Government's transport strategy is based in part on the Third Comprehensive Transport Study (CTS-3), based in turn on the assumptions and set out in Box 16.[43] Even in the '2016 low' scenario, the road vehicle fleet and road traffic are projected to rise at higher rates than population. In the '2016 high (2)' scenario, the annual rate of growth in the road vehicle fleet over the study period is projected to be more than twice the rate of population growth (6.0 vs. 2.4 per cent).

Box 16
Projections of totals of vehicles on the road in Hong Kong in four CTS-3 scenarios

Scenario	GDP growth 1997-2016	Population (growth)	Private vehicles (growth)	Goods vehicles (growth)	Cross-boundary traffic (growth)	Growth in vehicle-km travelled
1997 baseline		6,425,000	327,000	117,000	30,000	
2016 low	57%	8,184,000 (27%)	455,000 (39%)	141,000 (21%)	85,000 (183%)	45%
2016 medium	127%	8,934,000 (39%)	618,000 (89%)	185,000 (58%)	120,000 (300%)	79%
2016 high (1)	127%	8,934,000 (39%)	960,000 (194%)	262,000 (124%)	120,000 (300%)	120%
2016 high (2)	148%	10,130,000 (58%)	1,084,000 (231%)	262,000 (124%)	164,000 (447%)	148%

3.3.3. Transport activity

Motorised transport activity is projected to increase at a higher rate than population

The CTS-3 projected transport activity, based on committed road and rail infrastructure projects and the '2016 high (1)' scenario illustrated in Box 16. Some of the results of the projections are in Box 17.[44] Three things stand out. The first is that motorised transport activity is projected to increase at a higher rate than population. The second is that travel by car is expected to increase at a higher rate than travel by public transport, and will just about double in total amount during the indicated 19-year period. The third is that travel by rail modes is set to increase by the largest amount, absolutely and relatively, in response to the investment in the rail network described in Section 3.3.1.

The same source projected a 125-per-cent increase in road goods vehicle journeys over the 19-year period, from 709,000 to 1,590,000 trips, and a 300-per-cent increase in cross-boundary trips, from 30,000 to 120,000 journeys. This potential growth is touched on again in Section 4.7 in discussion of transport's economic impacts.

Box 17
Projections of motorised movement of people in Hong Kong in 2016; daily trips by various modes compared with 1997
▼

Trip mode	1997		2016		Increase
	Trips	Per cent	Trips	Per cent	
Private vehicles	934,000	8%	1,800,000	9%	93%
Passenger rail	3,579,000	30%	9,825,000	47%	175%
Other public transport	7,280,000	62%	9,332,000	45%	28%
Total trips	11,793,000	100%	20,957,000	100%	78%
Trips/person	*1.84*		*2.35*		*28%*

The projected 45- to 148-per-cent increase in road transport activity between 1997 and 2016 (see Box 16) can be compared with the 89-per-cent increase that occurred over the shorter period from 1986 to 1997 (see Box 15). Even if the lowest increase comes about—the '2016 low' scenario—it would nevertheless be a large increase. To the extent it would come with associated adverse impacts, it would be in the direction contrary to that required for progress towards sustainable transport.

3.4. Concluding remarks

The first conclusion to be drawn from this chapter is that the trends in Hong Kong's settlement density are consistent with attainment of sustainable transport. Hong Kong is the densest affluent urban region in the world and appears set to remain so. High density is associated with high public transport use and low car use, which in turn—as will be demonstrated in Chapter 4—are associated with low energy use and low levels of emissions. Settlement density in Hong Kong is not increasing and is not set to increase in the near future.

There are disturbing trends in transport activity and transport-related variables

The second conclusion is that, notwithstanding the continued high settlement density, there are disturbing trends in transport activity and transport-related variables. Of the latter, the most important may be the rapid growth in car ownership. This probably translates into a rapidly growing rate of travel by car, although the available data on this point are insufficient to draw firm conclusions as to exactly what has been happening.

Car ownership is set to increase substantially over the next 15 years, and the rate of increase in travel by car is projected to rise at a higher rate than is travel by public transport, although at a lower rate than at which car travel has increased in recent years. The second conclusion thus points to changes that are inconsistent with attainment of sustainable transport.

The third conclusion concerns the balance of public transport activity, which accounts for more than 90 per cent of motorised passenger transport today and likely will beyond 2016. In the early 1990s, travel by rail increased much more rapidly than travel by bus, but this trend—which is highly favourable for the environment, as will be explained below—was reversed in the late 1990s. The next 15 years are set to see a resurgence of rail. This will be to the point that slightly more public transport trips will be made by rail, which accounts today for only about a third of such trips.

Unless policies change, most motorised movement of people in 2016 will still be by road and will still involve polluting fossil fuels

The third conclusion points to a situation that will be highly favourable in regard to attainment of sustainable transport. Nevertheless, there are two qualifications. One is that, unless policies change, most motorised movement of people in 2016 will still be by road and will still involve polluting fossil fuels (assuming these fuels are available). The other is that, unless policies change, most electrified transport will rely on highly polluting generation using coal.

4. Effects of transport in Hong Kong

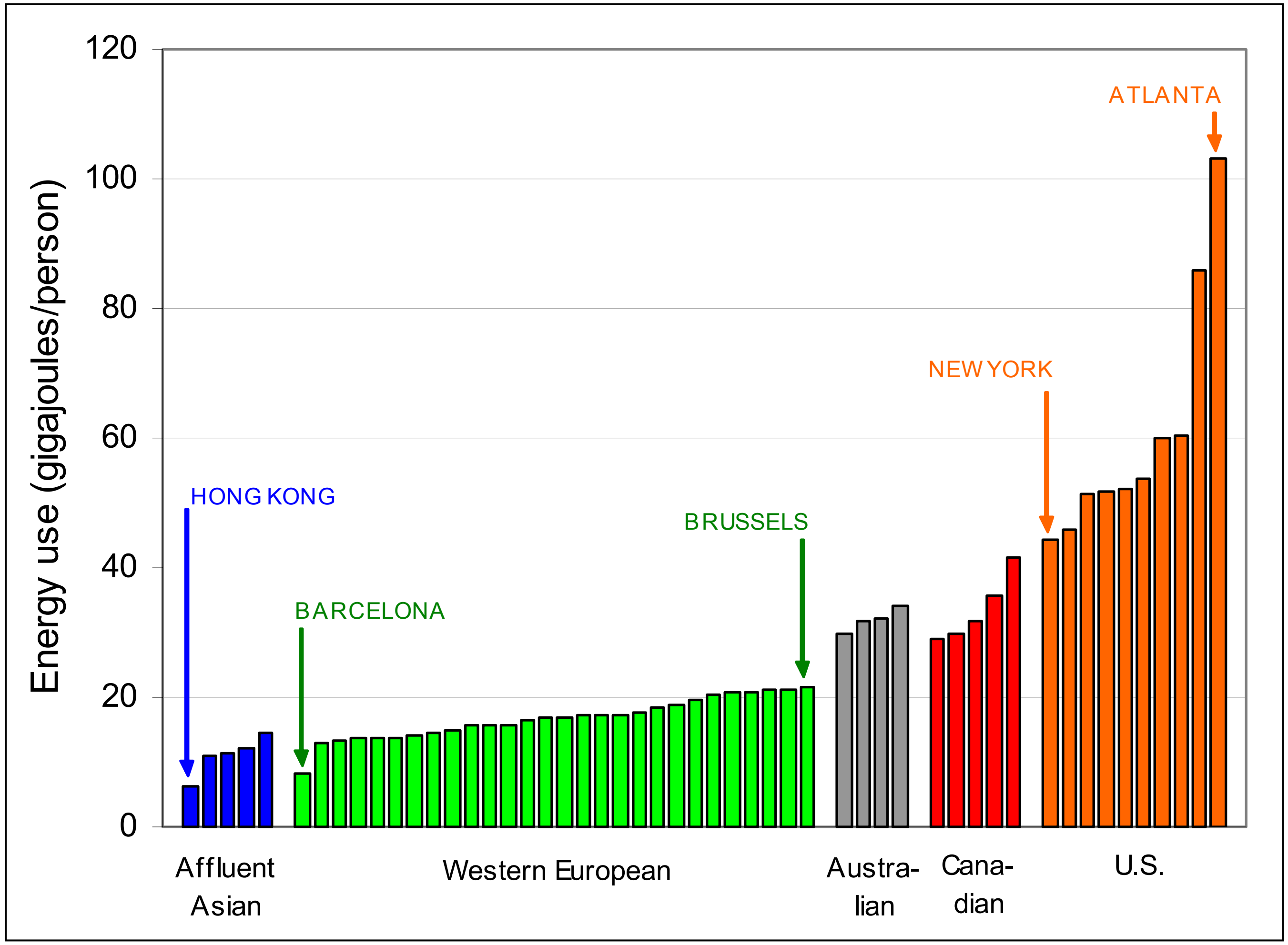
4.1. Energy use

The burning of fossil fuels causes most of transport's environmental impacts

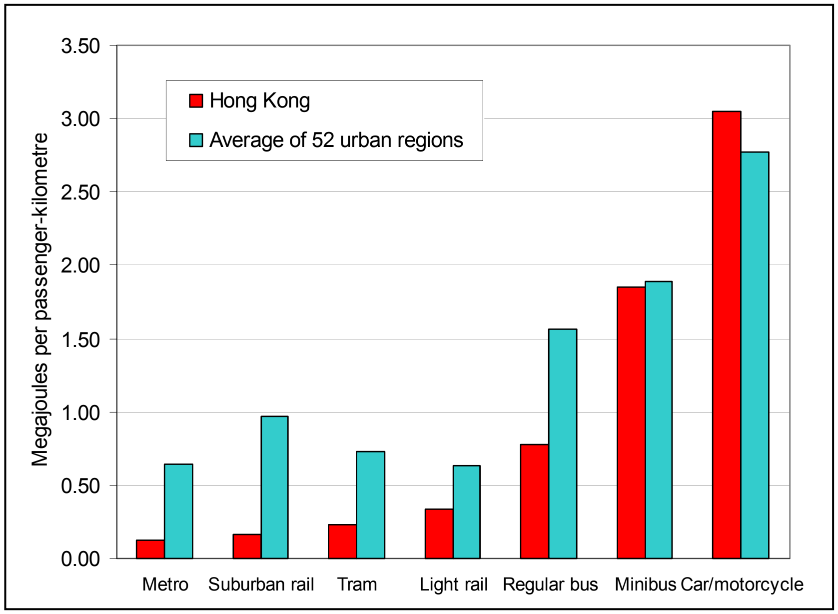
Almost all transport relies on the burning of fossil fuel. In energy terms, well over 90 per cent of the total, in Hong Kong and elsewhere, comes from oil products—petrol and diesel oil—but there is also some use of natural gas and coal, particularly for generating electricity used by trains and trams. It is the burning of fossil fuels that causes most of transport's environmental impacts, whether global impacts such as climate change from emissions of greenhouse gases or more local impacts such as urban smog.

Hong Kong's very high settlement density and consequent high proportion of public transport use give it the lowest energy use per capita among affluent urban regions, as shown in Box 18.[45] There is a 16-fold difference between Hong Kong (6.5 gigajoules per person) and the urban region with the highest energy use, Atlanta (103.3 gigajoules per person).

Box 18
Energy use for passenger transport in 52 urban regions, 1995



An additional factor is illustrated in Box 19,[46] which suggests that for most passenger transport modes Hong Kong's systems use energy more efficiently than those of other affluent urban regions. At least in part, this is because of the high occupancy levels of trains, trams, and buses.

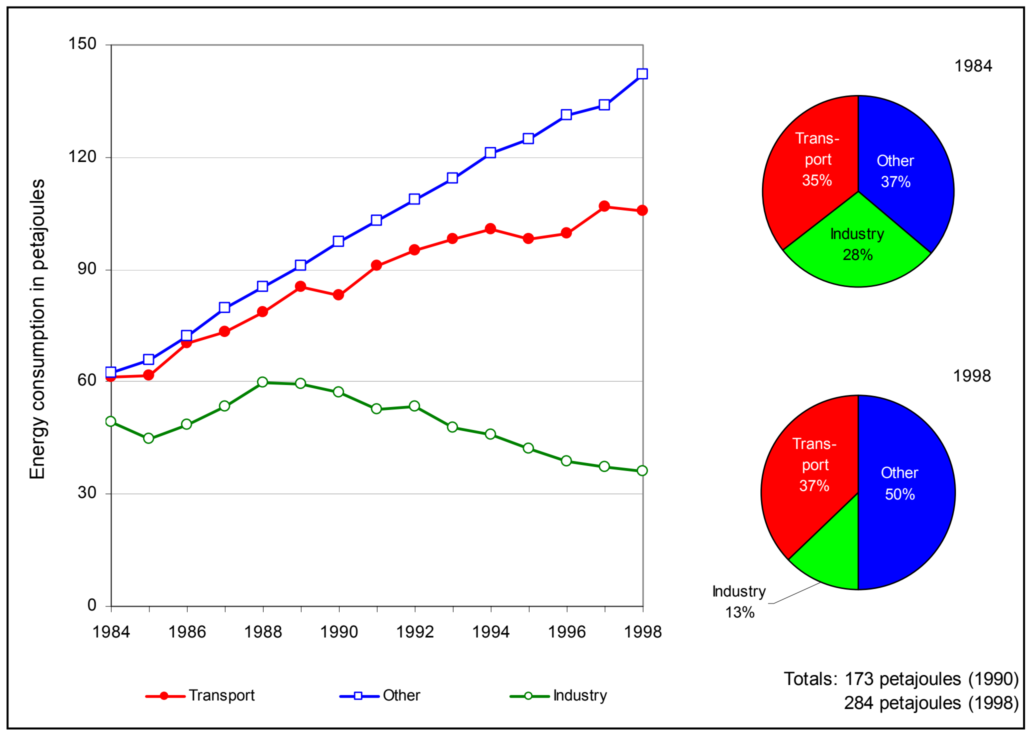


For strict comparison with the modes using diesel fuel or petrol, the energy use for modes using electric power in Box 19 should be multiplied by a factor of about three to compensate for generation and distribution losses. Taking this into account, it can be estimated that in Hong Kong travel by metro (MTR) and suburban rail (KCR) requires only about half the energy involved in travel by regular bus, which in turn requires only about a quarter of the energy use involved in travel by car.

Box 20 shows that energy use for all purposes except in-

Box 19
End energy use by land passenger transport modes, Hong Kong and 52 urban regions, 1995

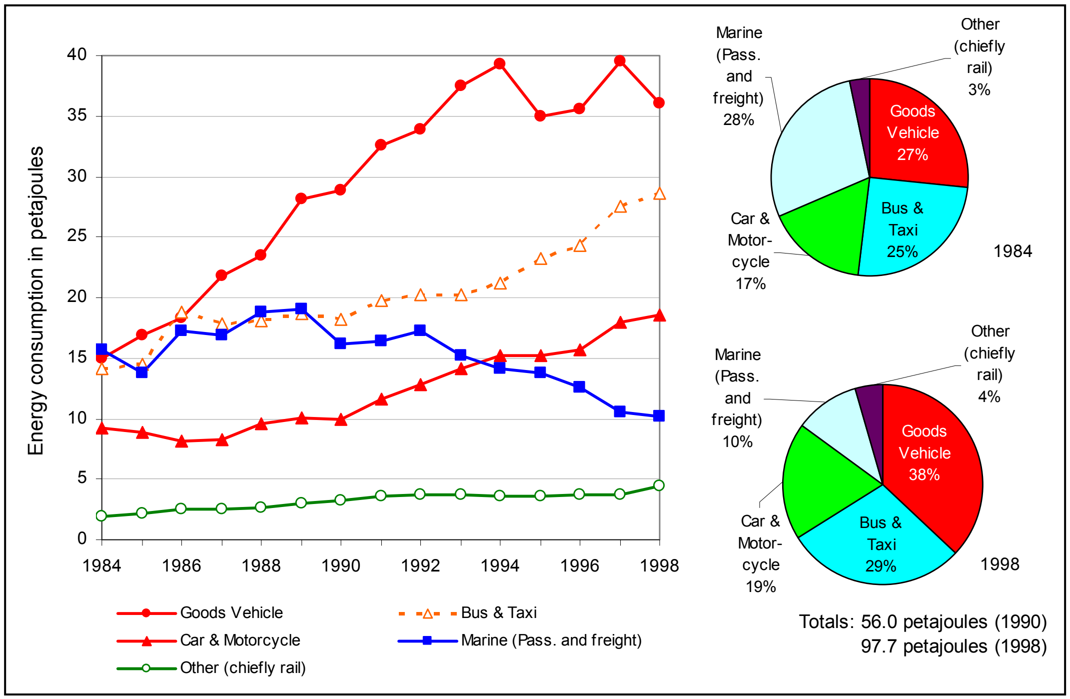
Box 20
Transport energy use in relation to other energy use, Hong Kong, 1984-1998



dustry has increased steadily over the last 15 years.[47] Energy use for purposes other than transport and industry—e.g., space heating and cooling, lighting, cooking, etc.—increased at a higher rate than that for transport, which nevertheless increased by 74 per cent between 1984 and 1998.

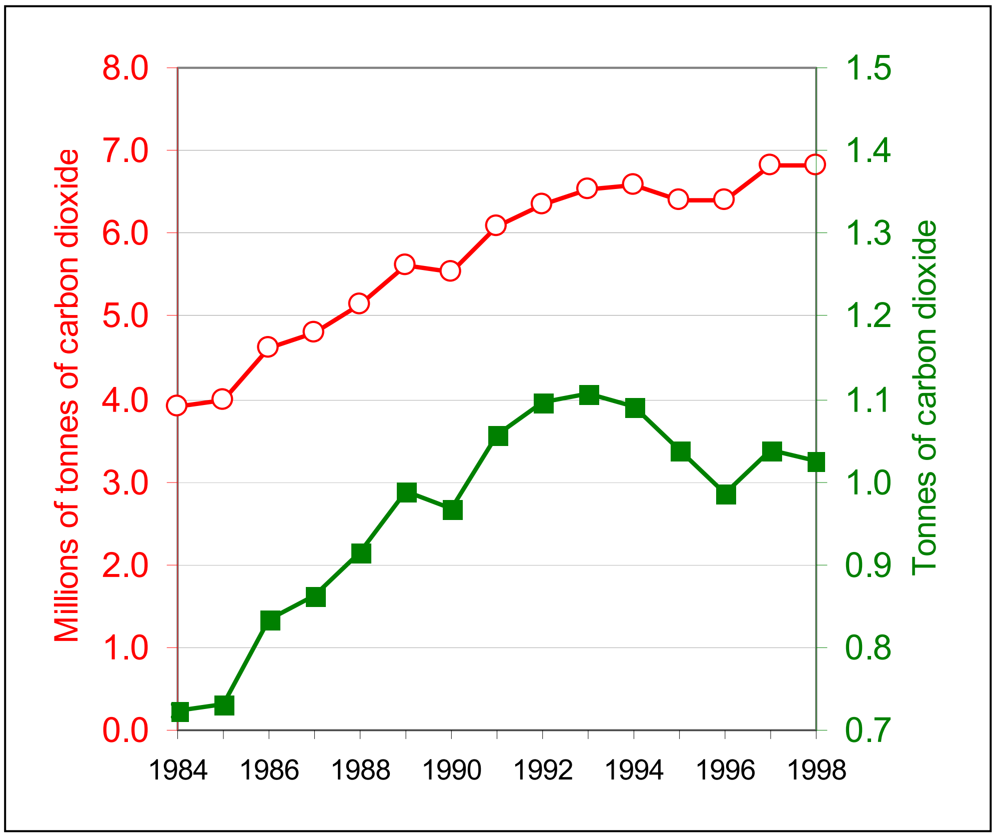
Within the transport sector, freight transport consumed the largest share and showed the largest rate of increase, although in the late 1990s this had levelled off and energy use by buses and taxis and by cars and motorcycles was still increasing (see Box 21). Marine transport of people and freight declined over this period. Energy use for rail—passenger rail including the MTR and trams, and freight rail—is hard to separate out from several miscellaneous transport uses (e.g., helicopters) in available data records. However, the low level of use by the 'other' category shown in Box 21 is consistent with the previously noted extremely high energy efficiency of Hong Kong's passenger rail systems (see Box 19).

Box 21
Energy use by transport modes, Hong Kong, 1984-1998



The few available data suggest there were slight *declines in energy efficiency* across all transport modes between 1991 and 1997. Energy use per vehicle kilometre *increased* by about five per cent in the case of cars and motorcycles, six per cent in the case of buses and taxes, and 16 per cent in the case of goods vehicles.[48] Some or all of the apparent worsening of energy efficiency could have been the result of increases in average vehicle size, particularly lorries. If this is the case, and the lorries were loaded efficiently, there could have been reductions in energy use per tonne of freight carried, which can be a better measure of energy efficiency.

Box 22
Carbon dioxide emissions from transport, total (circles, left-hand scale) and per capita (squares, right-hand scale)



4.2. Emissions of greenhouse gases

There seems to be almost no doubt the Earth's surface is warming and little doubt that it is the result of human activity. There are questions, however, as to the rate of warming and the importance of particular human activities. Most atmospheric scientists implicate emissions of the greenhouse gas carbon dioxide (CO_2) from fossil fuel use as the main human activity contributing to climate change.[49] Continuation of current rates of warming for several decades could have major adverse effects on the ecosystems on which humans depend.[50]

Few data seem to be available on CO_2 emissions from transport and other activities in Hong

Kong. The estimates in Box 22 are derived from the energy data presented in Box 21.[51] Total emissions of CO_2 have been rising, but recently at no more than the rate of population increase. As might be expected from the comparative energy use data in Box 18, the per capita emissions from transport of just over one tonne of CO_2 a year is low in comparison with other places. For example, the average across all OECD countries in 1997 was 3.0 tonnes, ranging from 1.0 tonnes (Mexico) to 6.2 tonnes (U.S.A.).[52]

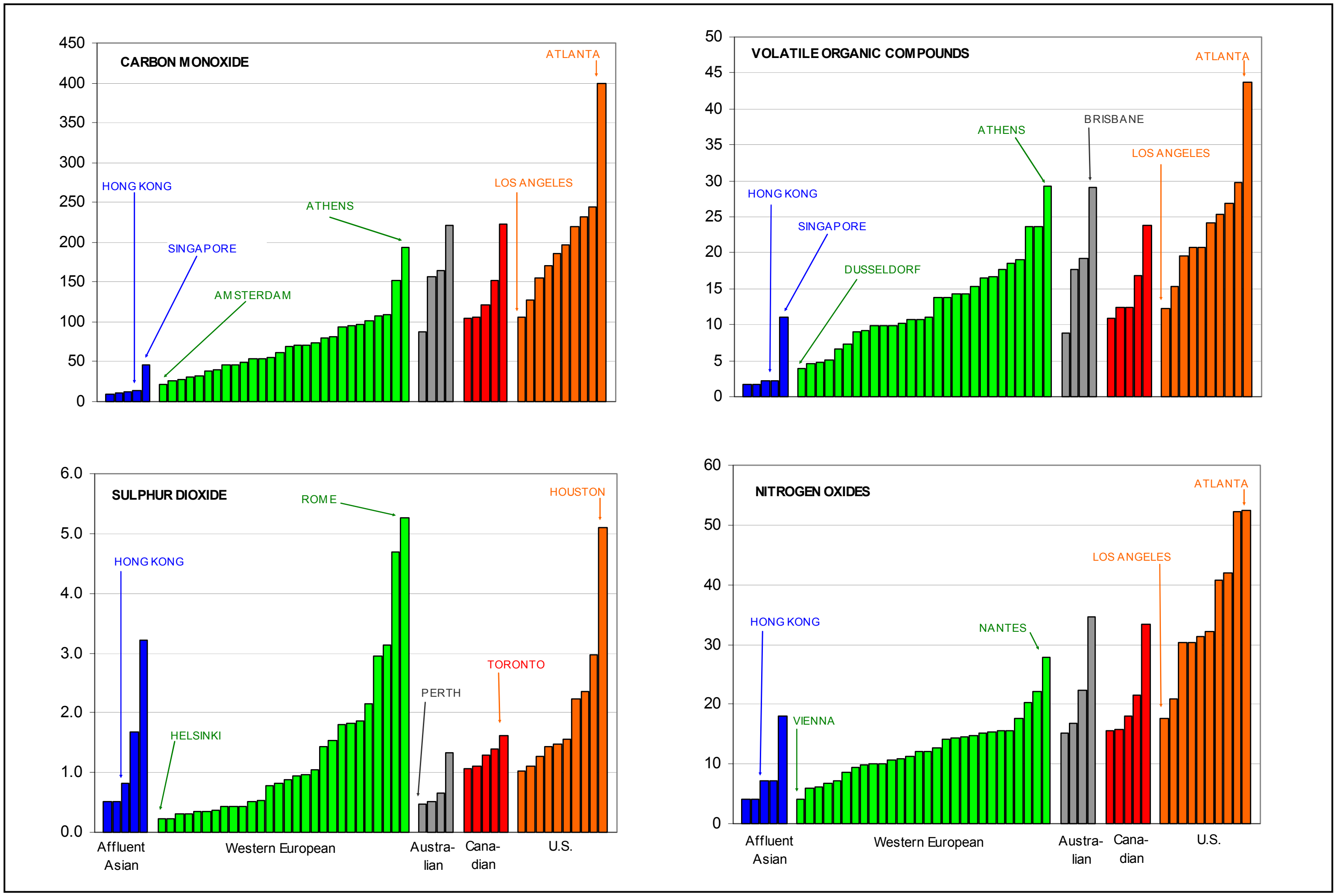
4.3. Emissions of other pollutants

4.3.1. Comparisons with other urban regions

Emissions of locally and regionally acting pollutants from transport arise for the most part from combustion of fossil fuels and are highly correlated with the amounts of fuel burned. However, emissions of specific pollutants also vary with the on-the-road effectiveness of pollution control devices such as three-way catalytic converters. Thus, there is more variation in the emission of these pollutants per unit of energy consumed than in the emission of carbon dioxide, the main greenhouse gas, which is largely unaffected by these devices.

For each local pollutant except sulphur dioxide, Hong Kong is among the urban regions with the lowest emission rates

Data on emissions from transport of four common pollutants are shown in Box 23. Hong Kong does not have the lowest rate of emissions from passenger transport for any of these pollutants, but in each case except sulphur dioxide it is among the urban regions with the lowest rates.[53]

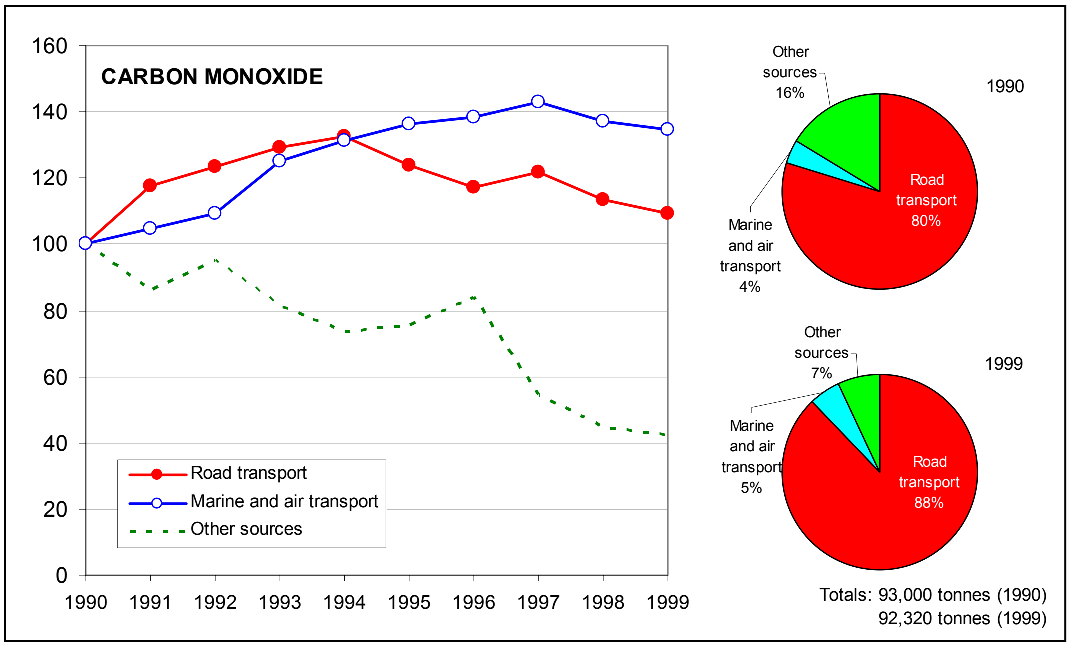


Box 23
Emissions of pollutants from passenger transport in 52 urban regions, 1995

4.3.2. Trends in emissions

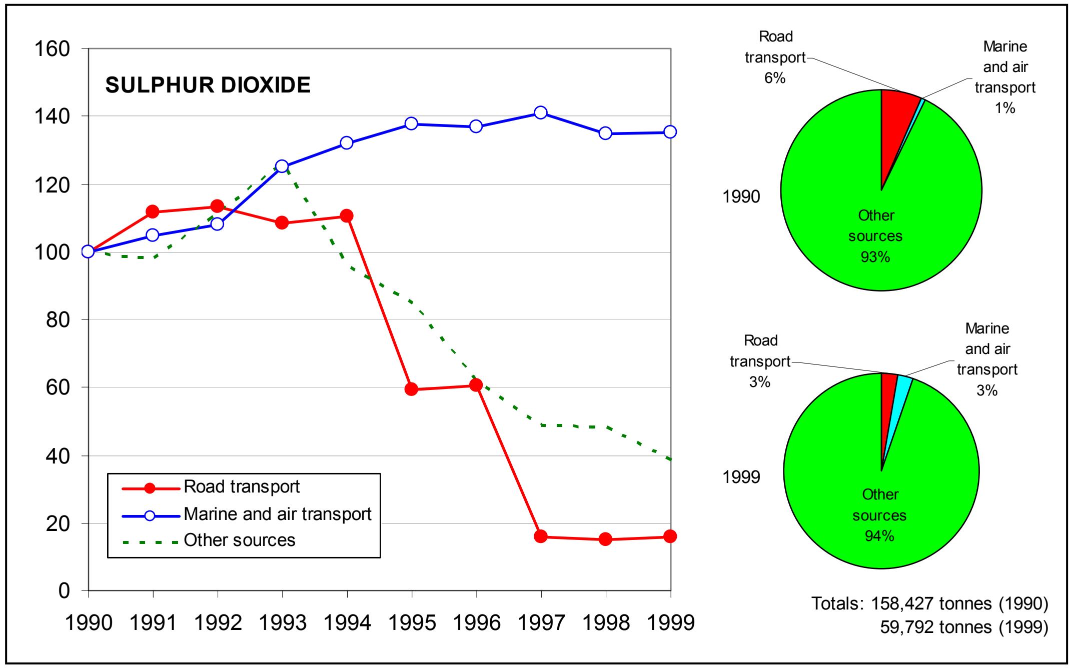
Carbon monoxide (CO) is a poisonous colourless gas that results from incomplete combustion of carbon-containing compounds such as petrol, diesel oil, and coal.[54] CO emissions from fossil fuel use in Hong Kong remained relatively constant during the 1990s, but the amounts and proportions from transport increased as emissions control were implemented at other sources (Box 24).[55] Petrol engines are a more important source of CO than diesel engines, in which combustion tends to be more complete overall. A particularly worrisome aspect of CO is the extent to which it can accumulate in confined spaces. Measurements of CO levels *within vehicles* in Hong Kong suggest that the guideline for all-day exposure may be being regularly exceeded, thereby putting professional drivers at risk and perhaps pointing to hazardous accumulations in other confined spaces near traffic.[56]

Box 24
Emissions of carbon monoxide from mobile and other sources, Hong Kong, 1990-1999
▼



Sulphur dioxide (SO_2) results from the combustion of fuel from which naturally occurring sulphur has not been removed, at the oil refinery or, in the case of coal, at the furnace. SO_2 in the air damages living materials and also building materials, and results in acid rain that alters water-based ecosystems. It causes breathing problems and damage to the respiratory tract.[57]

Box 25
Emissions of sulphur dioxide from mobile and other sources, Hong Kong, 1990-1999



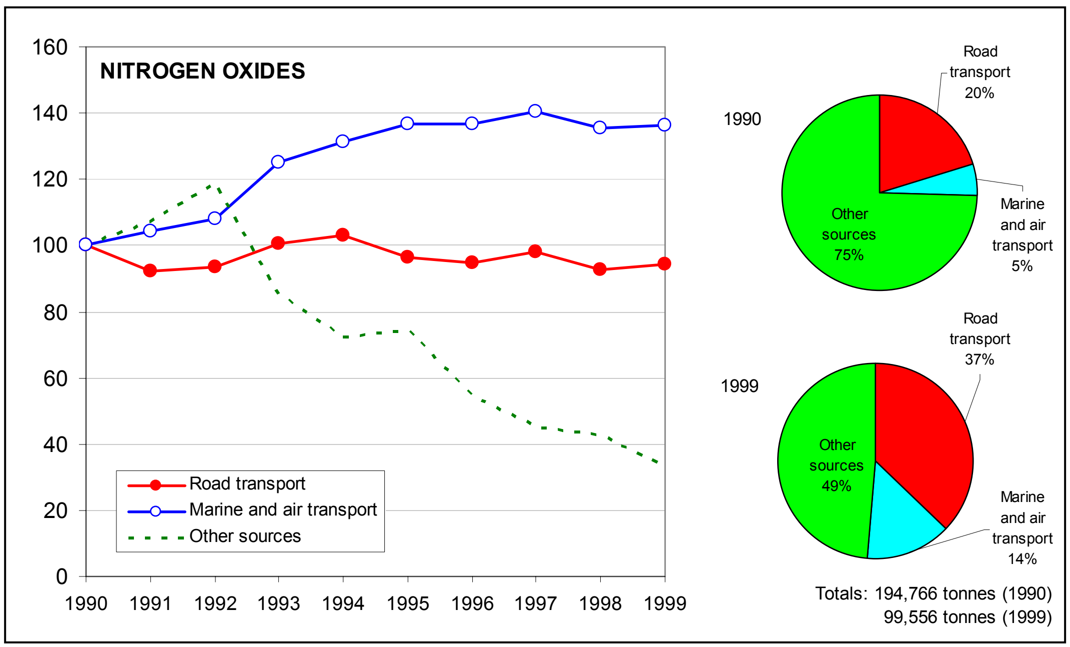
SO_2 was the pollutant for which Hong Kong compared a little less favourably with other affluent urban regions among those represented in Box 23. Nevertheless, by 1995—the year of that assessment—Hong Kong's SO_2 emissions from *road* transport had fallen steeply and were to fall steeply again, as illustrated in Box 25. By contrast, levels from marine transport have been increasing.

Transport's direct contribution to total sulphur dioxide emissions is small

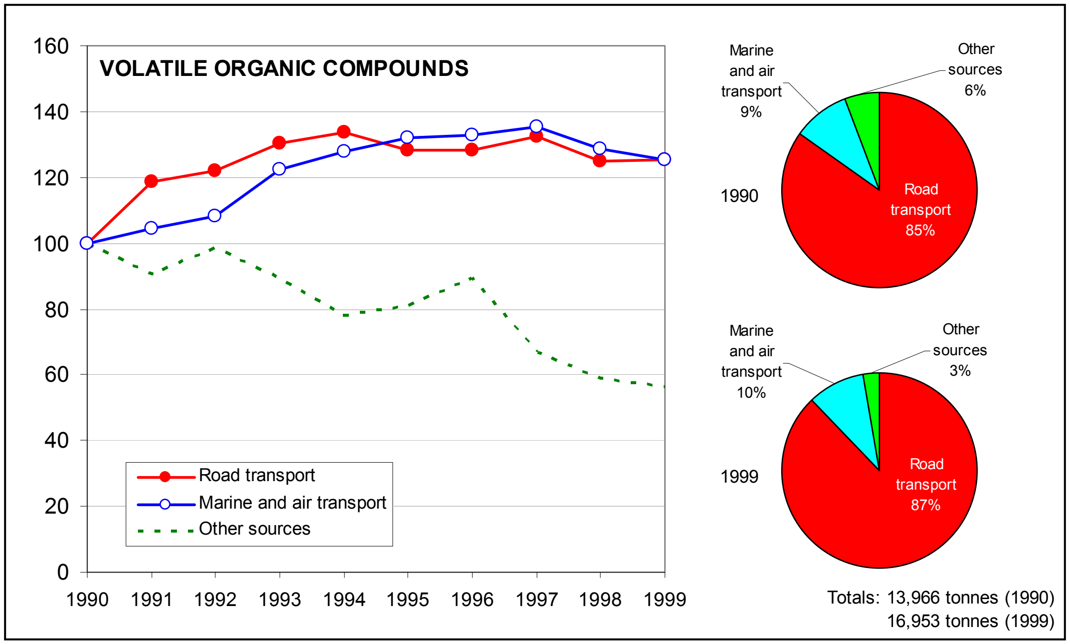
The reduced SO_2 emissions shown in Box 25 were the result of requirements to lower the amount of sulphur in petrol and in diesel fuel.[58] Lesser requirements applied to fuel for aviation and, particularly, marine engines, and thus there was no corresponding decline in SO2 emissions from these sources. Box 25 indicates that transport's contribution to all SO2 emissions is small: seven per cent of Hong Kong sources in 1999. However, reduction in the sulphur content of fuel is a key factor in achieving reductions in other pollutants; low-sulphur fuel is required to ensure proper operation of catalytic converters and other on-board pollution control devices.

Nitrogen oxides (NO_x) give polluted air its brown tinge. They are formed from air's two main constituents, nitrogen and oxygen, whenever there is combustion in air. These compounds damage living materials and building materials, result in acid rain that alters water-based ecosystems, and cause breathing problems and damage to the respiratory tract. Moreover, NO_x are a key ingredient in the formation of ground-level ozone (see Section 4.4).[59]

Box 26
Emissions of nitrogen oxides from mobile and other sources, Hong Kong, 1990-1999



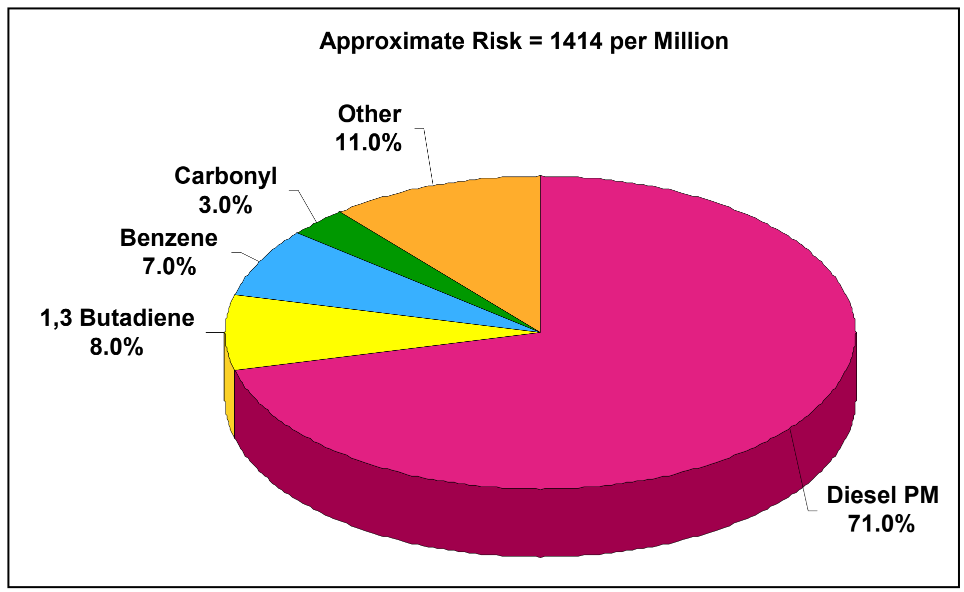
Emissions of NO_x from fossil fuel use fell overall by about 50 per cent during the 1990s, but emissions from mobile sources increased. Mobile sources accounted for a quarter of NO_x emissions in 1990, but more than half in 1999 (Box 26). Diesel engines accounted for more than three-quarters of NO_x emissions from road vehicles, although this proportion will likely decline a little with the conversion of the taxi fleet to use of LPG fuel.[60]



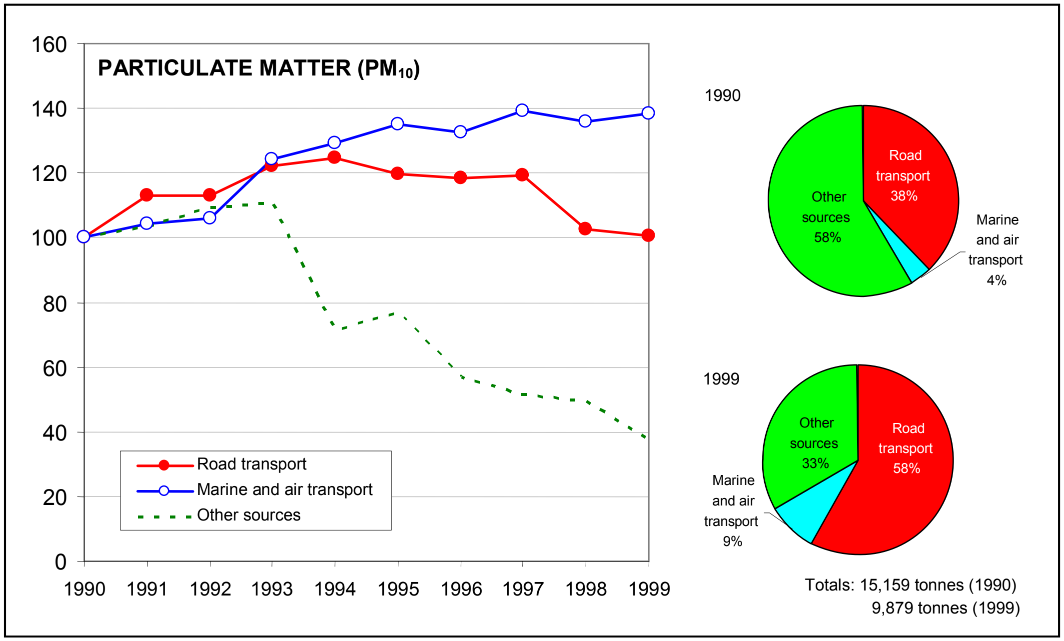
Box 27
Emissions of volatile organic compounds from mobile and other sources, Hong Kong, 1990-1999

Volatile organic compounds (VOCs) also result from incomplete combustion, but they mostly reach the atmosphere through fuel evaporation. Like CO, they are associated more with the operation of petrol than diesel engines.[61] They are hazardous in their own right—many are known carcinogens, e.g., benzene—and also serve as a key ingredient in the formation of ground-level ozone (see Section 4.4).

Emissions of VOCs from Hong Kong sources increased during the 1990s, entirely



Box 28
Apportionment of cancer risk in the Los Angeles Basin



Box 29
Emissions of particulate matter from mobile and other sources, Hong Kong, 1990-1999

due to increases associated with transport, which in 1999 accounted for 97 per cent of the total (Box 27).

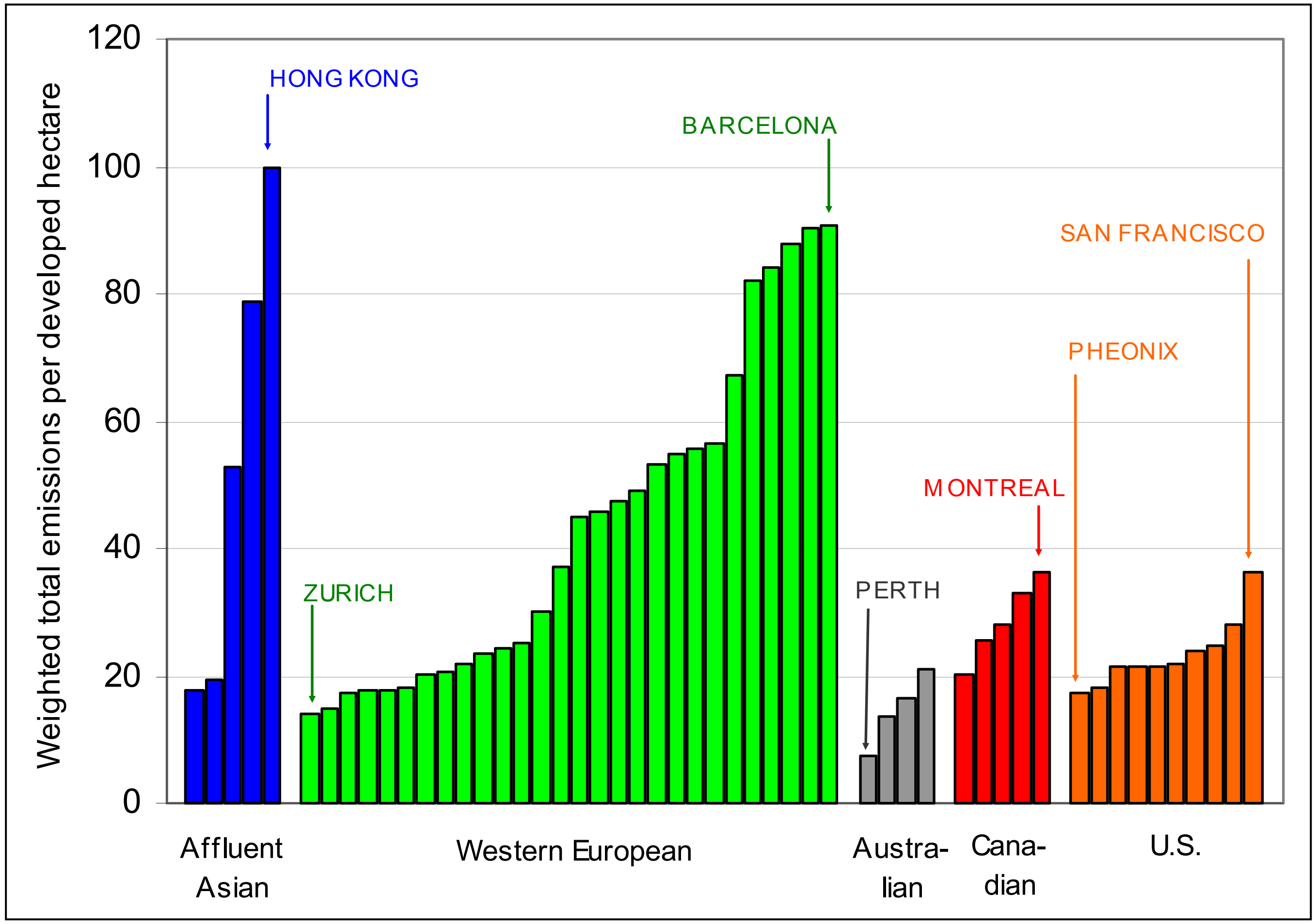
Particulate matter is also formed from incomplete combustion, but of a kind that is more likely to occur in diesel engines.[62] Small-diameter particulates, especially from the burning of diesel fuel, can be inhaled deep into the respiratory tract where they can cause lung and other cancers, and other respiratory conditions. The special importance of particulate matter is illustrated in Box 28, which suggests that diesel particulates are responsible for more than 70 per cent of the incidence of cancer associated with residence in the Los Angeles Basin.[63]

Box 29 shows that transport, particularly road transport, is the major source of respirable particulate matter in Hong Kong.[64] There has been some decline in the amount of particulate matter from road transport since the peak year of 1994, but in 1999 the total was still a little higher than the 1990 total and emissions from other transport sources continued to grow.

4.3.3. Spatial intensity of emissions

Among affluent urban regions, Hong Kong has the highest spatial intensity of emissions of local pollutants

As noted in Section 4.3.1, the total emissions per capita of transport-related pollutants in Hong Kong is low compared with most other affluent urban regions. However, what is important for local air quality is the spatial intensity with which they are emitted (i.e., how much per hectare). Box 30 shows that among affluent



Box 30
Spatial intensity of weighted average emissions of CO, NO_x, VOCs, and PM_{10}, 52 affluent urban regions, 1995

urban regions Hong Kong has the *highest* spatial intensity of emissions of these pollutants.[65] Indeed, this intensity is more than twice that of some other affluent Asian cities, most European cities, and all Australian, Canadian, and U.S. cities.

The essential paradox of Hong Kong

It is the extraordinarily high spatial intensity of emissions that causes the essential paradox of Hong Kong. The paradox is this. On the face of it, Hong Kong's transport is more sustainable than that of any other affluent urban region, and yet Hong Kong residents suffer from poor air quality, most of which is caused by Hong Kong's transport.

4.3.4. Projections of emissions from transport

Emissions fell in 2000

The data set that provides the basis for the discussion of emissions trends in Section 4.3.2 extends only until 1999. According to the Hong Kong Government, emissions of air pollutants from diesel road vehicles—responsible for about 70 per cent of vehicle-kilometres driven—fell by six to eight per cent in 2000 compared with 1999. This was said to be the result of the start of implementation of a plan to reduce these emissions by 30-80 per cent by 2005.[66] No details have been given so far of emissions of individual pollutants during 2000.

The Third Comprehensive Transport Study (CTS-3, see Section 3.3.2) included a Strategic Environmental Assessment (SEA) that involved estimation of the emissions from road transport associated with the various scenarios for 2016. The estimates are in Box 31, together with the projected changes in the road vehicle fleet and in vehicle-kilometres travelled.[67] The emissions estimates assume substantial reductions in emissions per vehicle-kilometre, in the order of 50 per cent for NO_x, 45 per cent for VOCs, and 35-50 per cent in the case of respirable particulates. Even then, according to the authors of the SEA, emissions of these three pollutants could well be higher in 2016 than in 1997, with correspondingly poorer air quality.

Measures have been proposed to reduce air pollution, but usually without estimates of how effective they are expected to be

CTS-3 recommended mitigation measures that could improve air quality, and several more measures have been proposed since the issuance of that report and the associated *Transport Strategy* document. For the most part, estimates of specific reductions in emissions or improvements in air quality have not been associated with implementation of these measures. The exception is the just-noted set of measures for reducing pollution from diesel, which aim to achieve emissions reductions of 30-80 per cent between 1999 and 2005.[68]

The increases in vehicle-kilometres travelled will likely result in commensurate increases in energy use and greenhouse gas emissions, less whatever improvements in the fuel efficiency of vehi-

▶ Box 31
Percentage changes in vehicles, vehicle-kilometres, and vehicle emissions, CTS-3 projections for Hong Kong, 1997-2016

Scenario	Road vehicles	Vehicle-kilometres travelled	Nitrogen oxides (NO_x)	Volatile organic compounds (VOCs)	Respirable particulates (PM_{10})
2016 low	+34%	+45%	-24%	-20%	-8%
2016 medium	+81%	+79%	-8%	-1%	+11%
2016 high (1)	+175%	+120%	+7%	+20%	+25%
2016 high (2)	+203%	+148%	+14%	+34%	+28%

Fuel use and greenhouse gas emissions from road transport could be as much as 2.5 times higher in 2016 than in 1997

cles will be realised. The record of the 1990s suggests that energy efficiency improvements may not occur (see Section 4.1). Thus, fuel use and greenhouse gas emissions from road transport could be as much as 2.5 times higher in 2016 than in 1997. Such trends would be clearly in the opposite direction from those required for sustainability.

Added to the CO_2 emissions from road transport could be a further burden from increased use of rail. Although the actual use of energy by rail is relatively low (see Section 4.1), total CO_2 emissions associated with rail travel may today be similar to those from travel by car because there is much more travel by rail and because most of Hong Kong's electricity is generated from coal, which is particularly CO_2-intensive. The proposed almost threefold increase in rail travel (see Box 17) could thus add a considerable amount to Hong Kong's greenhouse gas emissions from transport (unless, of course, there is less reliance on coal, and especially if there is less reliance on fossil fuels of any kind.)

4.4. Air quality

The two pollutants of most concern are nitrogen oxides and respirable particulates, chiefly because air quality guidelines for these pollutants are regularly exceeded

The result of emitting pollutants into the atmosphere from transport or other activities is poor air quality, which in turn causes most of transport's adverse effects. The extent of the poor air quality depends on the amounts emitted and their spatial concentrations, and also on what is otherwise in the air from other polluting sources near or distant. Of the pollutants emitted from transport discussed above, the two of most concern are nitrogen oxides and respirable particulates, chiefly because air quality guidelines for these pollutants are regularly exceeded.

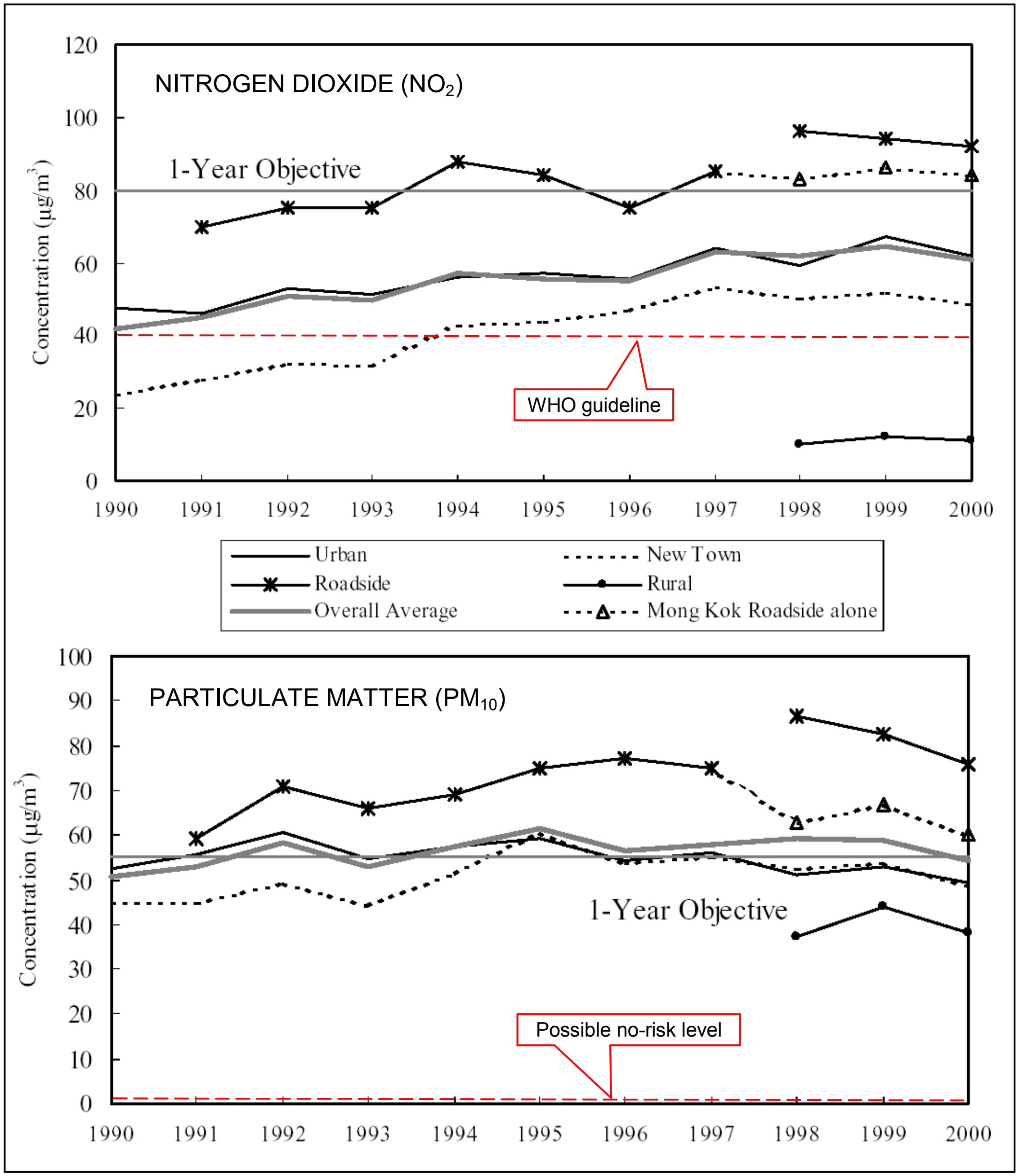
The upper panel of Box 32 shows atmospheric concentrations of **nitrogen dioxide** (NO_2), the main oxide of nitrogen in urban air.[69] Hong Kong's one-year Air Quality Objective (AQO) for this pollutant of 80 micrograms per cubic metre ($\mu g/m^3$) was exceeded at roadside monitoring stations for most years of the 1990s, although not at other stations.

For nitrogen dioxide and particulates, Hong Kong's Air Quality Objectives are too lax

The World Health Organization proposes the much lower guideline for NO_2 of 40 $\mu g/m^3$, shown in Box 32.[70] **If this guideline had been the Hong Kong standard during the 1990s, Hong Kong as a whole would not have been in compliance for any part of this period.** According to WHO, "… available results most clearly suggest respiratory effects in children at annual average NO_2 concentrations in the range of 50-75 $\mu g/m^3$ …".[71]

The lower panel of Box 32 shows atmospheric levels of **respirable particulates** (PM_{10}) in relation to Hong Kong's 1-year AQO of 55 $\mu g/m^3$. On average, this AQO was exceeded in the 1990s, substantially so in the case of concentrations at roadside stations. The World Health Organization has been unable to define a threshold below which no effects occur. Accordingly, a WHO guideline for PM_{10} has not been set. Available data suggest that reductions in life expectancy can be expected with adult exposure to long-term average concentrations of PM_{10} as low as 20 $\mu g/m^3$.

Box 32
Annual average concentrations of nitrogen dioxide and respirable particulate matter, Hong Kong, 1990-2000



The no-risk level for children and other vulnerable people may in effect be zero, as shown in Box 32.[72] It may be noted that the 1-year U.S. standard is 50 μg/m^3 (arithmetic mean), and that for California is 30 μg/m^3 (geometric mean).

Levels of other pollutants have been well within Hong Kong's Air Quality Objectives

Levels of two of the other pollutants discussed above—**carbon monoxide** (CO) and **sulphur dioxide** (SO_2) have been well within Hong Kong's respective AQOs. Because of the nature of CO poisoning, there are only short-term AQOs for CO (1-hour and 8-hour). These are identical to the corresponding WHO guidelines. For SO_2, the 1-year WHO guideline is substantially below the corresponding Hong Kong AQO (50 vs. 80 μg/m^3). However, even the more stringent WHO guideline for SO_2 has not been exceeded at Hong Kong monitoring stations since 1994, including roadside monitoring stations.[73]

Hong Kong does not have an AQO for **volatile organic compounds** (VOCs). The World Health Organization treats components of VOCs individually. Guidelines are set for several of these compounds, notably benzene, a constituent of petrol. The level of this carcinogen in Hong Kong's air in 2000 was well below the WHO guideline. For other such compounds, e.g., the carcinogen 1,3 butadiene, a constituent of vehicle exhaust, no WHO guideline has been developed.

Ground-level ozone is a transport-related pollutant of particular concern

A transport-related pollutant of particular importance for its adverse effects on human health and ecosystems is **ground-level ozone**.[74] Ozone—a form of oxygen—is an extremely reactive substance that damages all biological materials. It impairs respiratory function and also impairs the body's defences against disease.

It damages most plant life. Ground-level ozone is the main constituent of what is known commonly as smog. Ozone is not an emission from transport but is formed by the action of sunlight on two of transport's key emissions, NO_x and VOCs.

There is evidence that harm may occur at all detectable levels of ground-level ozone

Hong Kong has a 1-hour AQO for ozone of 240 $\mu g/m^3$. This was exceeded 10 times in 2000, all at monitoring stations away from the main population and traffic concentrations, a phenomenon discussed below. There used to be a corresponding WHO guideline for ozone of 150-200 $\mu g/m^3$, but this has been superseded by an 8-hour guideline of 120 $\mu g/m^3$. Annual average levels of ozone in Hong Kong's air appear have been rising gradually over the last decade, which may be related to the rising NO_2 trend illustrated in Box 32. Because of evidence that harm may occur at all detectable levels of ground-level ozone, this trend could be of concern. Specifically, increases in hospitalizations have been noted at ozone levels as low as 25 $\mu g/m^3$, which is below the annual average level recorded at Hong Kong's monitoring stations. **Thus, on average, ozone levels in Hong Kong could be such as to cause or exacerbate disease**.[75]

The highest ozone levels occur downwind from the source

Unlike other pollutants, the highest ozone levels occur downwind from where the constituents of ozone are emitted. This is because ozone formation is inhibited by the initial products of combustion,[76] and because the reactions requiring sunlight take time. In Hong Kong, there is an additional factor: often sunlight is not available at the source of emissions because of shadowing of roads by large buildings.

Moreover, ozone levels in high traffic areas are at their lowest during peak traffic periods. By contrast, levels of NO_x and PM_{10} show peaks corresponding to the highest traffic flows.[77]

4.5. Noise

More than half of Hong Kong's population could be adversely affected by traffic noise

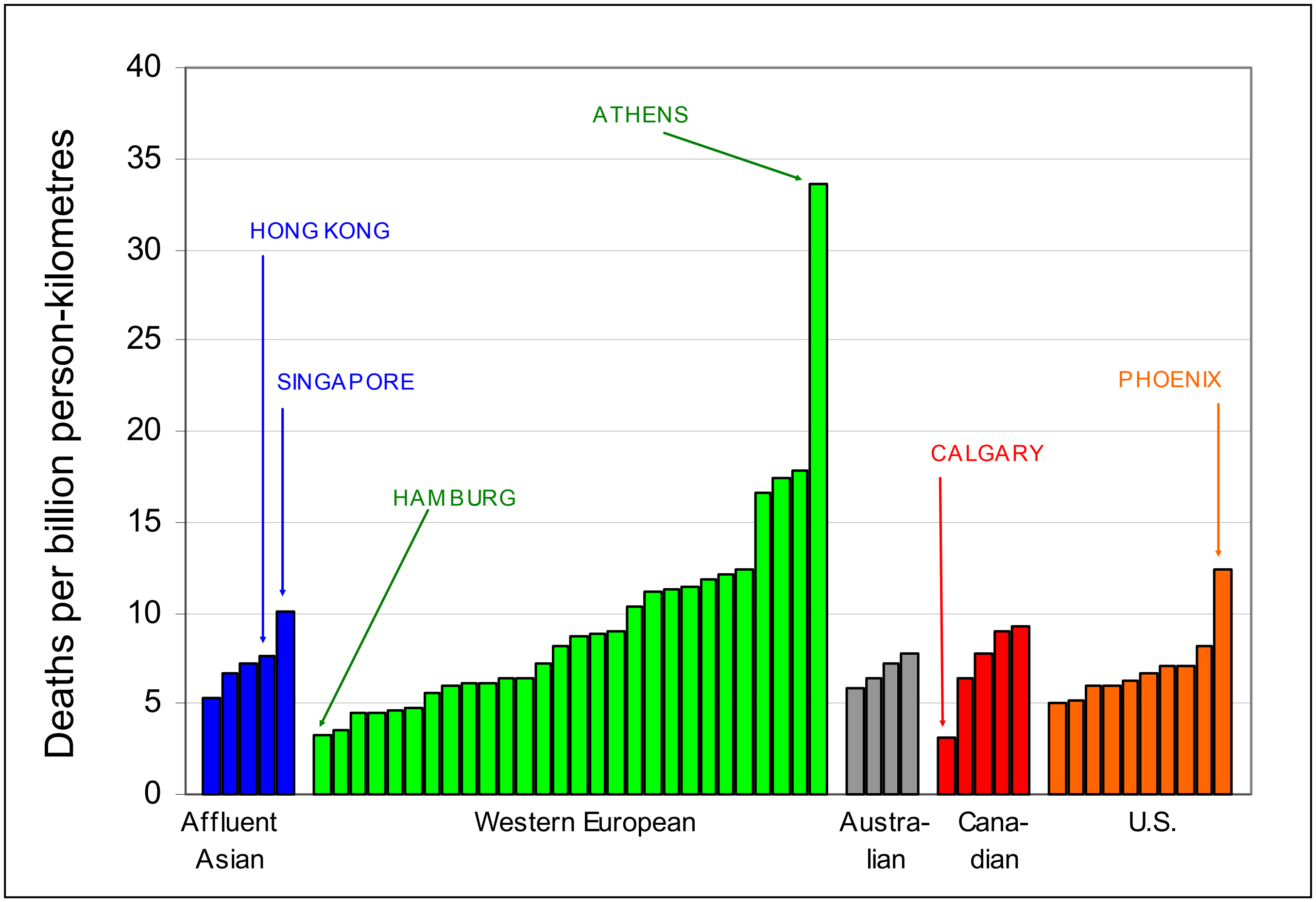
Hong Kong's high settlement density makes noise a potential major concern. Traffic noise is said to affect of one million people in Hong Kong in that this is the number estimated to have significant exposure to traffic noise above 70 decibels (dB).[78] The World Health Organization has suggested much more stringent guidelines of 55 dB (day) and 45 dB (night),[79] which could mean that more than half of Hong Kong's population would be affected.[80]

Complaints about noise do not suggest that transport noise is presently a major concern. After air quality, noise is the major reason for complaints received by the Environment Protection Department. However, only about four per cent of complaints about noise in 2000 concerned traffic or other transport sources.[81] If traffic does increase to the extent anticipated in CTS-3 (see Box 31), noise could well become a major concern.[82] Moreover, it could already be an under-appreciated source of ill-health and discomfort.[83]

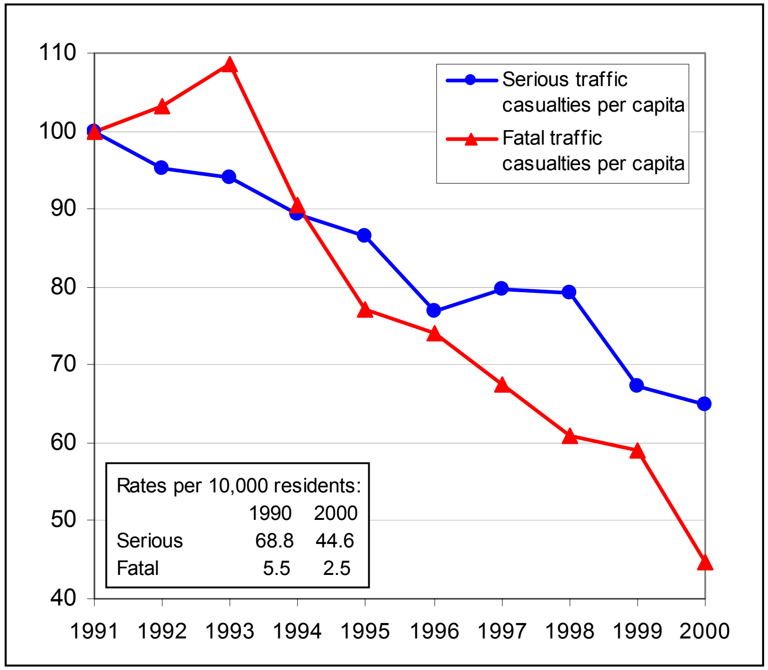
4.6. Casualties

Safety is a feature of the major definition of sustainable transport (see Section 1.3); accordingly, low rates of injuries and fatalities are desirable and sharp declines in rate indicate progress towards sustainability.

Box 33
Transport-related fatalities, 52 affluent urban regions, 1995



Box 34
Trends in serious and fatal casualties from traffic collisions, Hong Kong, 1991-2000 (1991 = 100)



Box 33 shows that in 1995 Hong Kong had a slightly lower than average number of transport-related fatalities *per person-kilometre travelled*.[84] If the fatality data had been shown *per capita*, Hong Kong would have been seen to have had the fifth lowest rate, which mostly reflects the relatively small amount of travelling done by Hong Kong residents.

Box 34 shows trends in road vehicle casualties for Hong Kong. Serious and fatal casualties from road vehicle collisions fell per capita by 35 and 55 per cent respectively between 1991 and 2001.[85]

4.7. Economic impacts

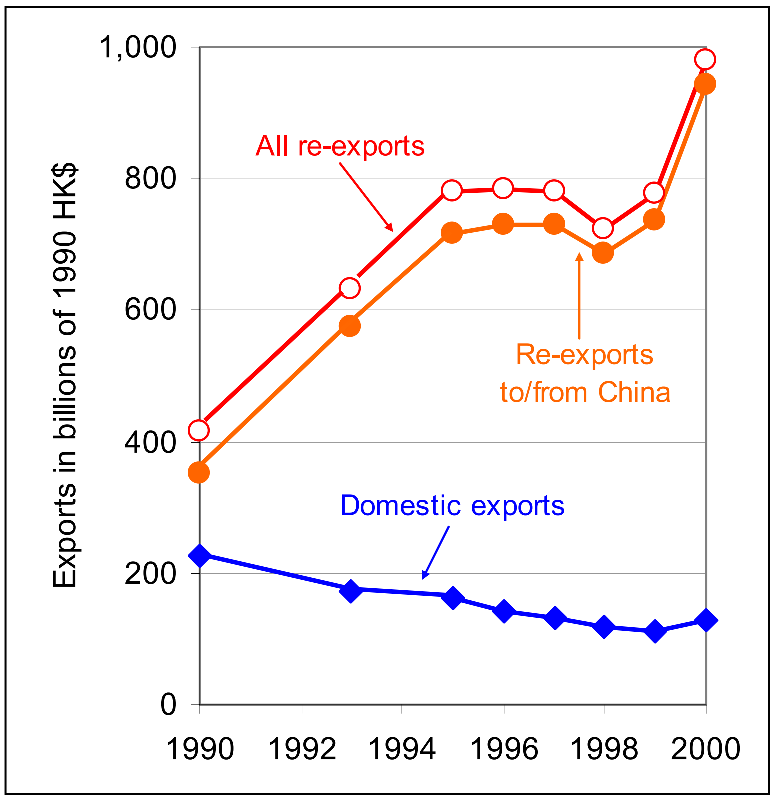
Hong Kong thrives on trade and on the transport services that underpin it

Hong Kong's business is transport. As one of the world's leading trading centres, with the busiest port and among the busiest airports, Hong Kong thrives on trade and on the transport services that underpin it. Among members of the Asia-Pacific Economic Cooperation Forum (APEC), only Singapore records trade as a higher proportion of its GDP.[86] For Hong Kong, exports were 136 per cent of GDP in 1999; of the exports, 87 per cent were re-exports. Almost all the re-exports by value involved goods transhipped to or from mainland China.[87]

Hong Kong's domestic exports fell by almost half during the 1990s, while re-exports involving China almost tripled in value,

Trends in domestic exports (produced in Hong Kong) and re-exports are shown in Box 35.[88] The former declined in real terms by 44 per cent between 1990 and 2000, whereas the real value of re-exports grew by 137 per cent. Re-exports involving China grew by 168 per cent, from 85 to 96 per cent of all re-exports. Thus, during the 1990s, Hong Kong's economy became substantially reoriented towards providing a transhipment function for trade between mainland China and elsewhere. This transformation has involved provision of financial and other services as well as transport. The growth in freight transport to and from the border, mostly by rail, may account for much of the growth in use of heavy lorries illustrated in Box 14 and in energy use for transport illustrated in Box 21.

Box 35
Exports from Hong Kong: domestic products and re-exports, showing re-exports to and from mainland China, 1990-2000



Moreover, the growth in freight activity is expected to continue. Port activity is expected to more than double between 2000 and

2020.[89] Air freight is expected to more than quadruple, although the time period over which this will occur is unclear.[90]

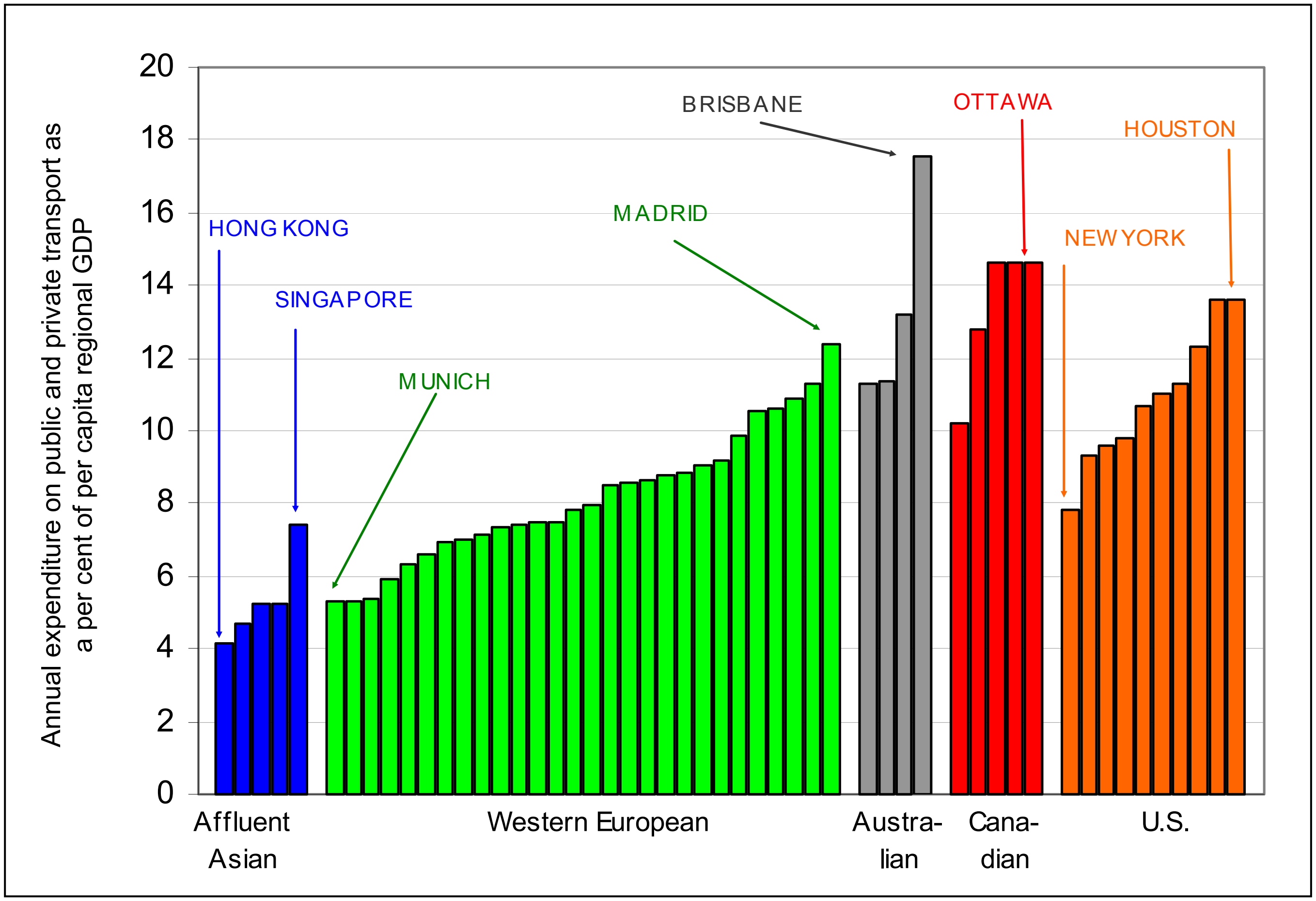
China's accession to the WTO could mean short-term growth and longer-term decline in Hong Kong's trade

China's accession to the World Trade Organization in December 2001 will likely mean an increase in China's share of world trade that in turn could have potentially opposing implications for Hong Kong. On the one hand, Hong Kong's seaport and airport could share in the increased trade. On the other hand, the greater ease of doing business directly with China could reinforce the growth in use of mainland skills and facilities, including Shenzhen's container ports.[91] An outcome of the play of these factors could be short-term growth in Hong Kong's trade with mainland China—i.e., for 5-10 years—and longer-term decline.[92] It follows that the port could continue to be of profound significance to Hong Kong's economy for many years, and most of the port's activity could continue to involve transhipment of mainland China's international trade. Thus, provision of effective transport arrangements to and from the border should be a key consideration in the planning for future transport facilities.

The effectiveness of Hong Kong as a business centre depends in part on the excellence of its transport arrangements

As well as the essential work of serving international trade, transport in Hong Kong supports just about all other economic activity. The effectiveness of Hong Kong as a business centre depends in part on the excellence of its transport arrangements and specifically the precision with which meetings, deliveries, and pick-ups can be scheduled. Relevant analysis does not seem to be available but it seems likely that the input cost of transport across the spectrum of economic activity is relatively low for Hong Kong compared with other urban regions.[93]

Box 36
Amounts individuals spent on transport of all kinds, 52 urban regions, 1995



The benefits of transport to Hong Kong's economy appear to outweigh the costs by a large margin

Thus, transport provides economic benefits and costs to Hong Kong. The benefits appear to outweigh the costs by a large margin, but it should not be forgotten that there are costs that can be reduced. Hong Kong imports all the transport fuel it uses and just about every manufactured item involved in transport (there is a small amount of shipbuilding). Thus, increases in transport activity mean a worsening of Hong Kong's trade balance. Reductions in transport activity, or substitution of transport-related imports by local production, would result in an improvement in the balance.

The above considerations apply particularly to business, but it is also worth noting that Hong Kong residents spend relatively less on transport than residents of other affluent urban regions (see Box 36).[94] There is a more than fourfold difference between the urban region with the highest transport cost (Brisbane, at 17.6 per cent of per-capita regional GDP, and Hong Kong (at 4.2 per cent). Relatively speaking, Hong Kong residents have more money to spend than Brisbane residents because they are spending much less on transport.

4.8. Social impacts

Most of the reported social ills associated with transport in affluent urban areas concern the perils of excessive motorisation; the term 'hypermobility' has been used.[95] Participants in the Environmentally Sustainable Transport (EST) project of the Organisation for Economic Cooperation and Development (OECD) reached the following conclusion: Continuation of present trends in OECD countries, particularly growth in road vehicle traffic, "…will result in growing social disparity and alienation, less street life, more anonymity, and more car dependence, resulting in loss of independent mobility for many, especially children." With less road traffic and more use of public transport, non-motorised modes, and rail freight,

"… life would become more egalitarian, convivial, and child-friendly".[96] (The EST project is discussed more generally in Chapter 5.1.)

Consider adverse social consequences of increased motorisation when discussing policies to increase levels of car ownership and road freight traffic

In respect of car use particularly, the transport situation in Hong Kong is so far removed from what holds in most urban regions in OECD countries it is difficult to make valid comparisons. Nevertheless, the possible adverse social consequences of increased motorisation may be worth bearing in mind when policies are discussed that would increase levels of car ownership (and also road freight traffic).

In the meantime, it may be appropriate to note Hong Kong's housing situation, which underlies the extraordinarily high settlement density. Hong Kong residents appear to have low amounts of residential floor space per person compared with residents of other affluent urban areas.[97] This raises the question as to whether there are adverse consequences of the high densities.

Adverse consequences of crowding?

Several adverse consequences of crowding were identified recently by the Director of Planning of the Hong Kong SAR Government, as well as several advantages.[98] Crowding was not considered to have adverse effects; indeed, it was said to "encourage social and economic interaction". The health effects of crowding were not addressed; they can be considerable, especially for children.[99] However, only Sweden has lower infant and child mortality rates than Hong Kong.[100]

Adverse impacts of transport sometimes considered as 'social' include those associated with personal health and safety. Transport-related emissions and air pollution matters were discussed in Chapter 4. Assessing their contribution to ill-health is challenging. One Hong Kong Government estimate appears to have concluded that the annual costs of air pollution to Hong Kong in terms of medical expenses and lost productivity total HK$3.8 billion,[101] perhaps half of which can be attributed to transport in Hong Kong.

Transport's 'external' or 'social' costs

In comprehensive assessments of transport's so-called 'external' or 'social' costs (i.e., costs unpaid by the direct beneficiaries of transport), collisions are usually associated with the highest monetary costs.[102] As noted in Section 4.6, casualties from transport collisions have been declining rapidly in recent years.

Finally, mention should be made of a further possible social cost related to Hong Kong's transport situation, namely the relative absence of opportunity to own a car. Few inventions had a more profound influence during the 20th century. In many parts of the world, people came to express themselves and many of their aspirations through car ownership.[103] The high cost of car ownership in Hong Kong denies most Hong Kong residents this kind of opportunity for expression.

Many argue that this is no great loss. There are many less costly, less bothersome, and more environmentally friendly means of expression. People can grow up in Hong Kong relatively free from the pressures and costs of car culture.

4.9. Concluding remarks

Striking conclusion re. spatial intensity of emissions

The striking conclusion from this chapter is that although emissions from transport in Hong Kong are among the lowest of the world's affluent urban regions, they are emitted with the highest *spatial intensity* and result in high and in some cases worsening levels of air pollution.

Air quality standards in Hong Kong may be too lax

A related conclusion is that in respect of the three pollutants of greatest concern—the smog precursor nitrogen dioxide, ground-level ozone, and inhalable particulates—air quality *standards* in Hong Kong may be too lax.

Rising greenhouse gas emissions from transport

Hong Kong has very low levels of fuel use for transport, but these are rising, particularly on account of goods traffic. One result of this increase is a rise in emissions from transport of the greenhouse gas carbon dioxide at a time when local and international concern about the adverse impacts of climate change is growing.

Hong Kong's noise standards may be too lax

Noise from transport is perhaps less of a concern than it should be in Hong Kong, given the large and growing numbers exposed to high noise levels. Moreover, with respect to noise too, Hong Kong's standards may be too lax.

With implementation of current policies, things will get worse

Another striking conclusion is that with 'business as usual'—i.e., implementation of current policies—there will be worsening of all these already adverse outcomes of transport activity. Continuation of business as usual should not be acceptable.

There are important economic benefits from current transport activity in Hong Kong, and transport's adverse social impacts may be small compared with elsewhere

On the positive side, there are important economic benefits from current transport activity, the adverse social impacts may be small compared with elsewhere, and Hong Kong's transport systems are becoming evidently safer, notwithstanding the increase in traffic.

Current official projections speak to large increases in transport activity that could result in increases in fuel use and greenhouse gas emissions and no decline in emissions of locally and regionally acting pollutants. However, the component of transport activity projected to have the largest growth—cross-border goods traffic—is being put into question by ongoing changes in world trading arrangements.

5. Energy futures: a key factor in transport planning

5.1. The end of cheap oil (and natural gas)?

The ready availability of oil obscures the importance of thinking about fuels when planning for transport

Transport planning is essentially about the planning of *motorised* transport whose character is profoundly determined by the fuels that are available and used to power the motors. This point has become obscured by the ready availability of oil for transport for almost all of the last 100 years. We may be about to see the end of cheap oil.

Oil fuels more than 96 per cent of the world's motorised transport, which in turn accounts for more than 55% of oil consumption and in OECD countries is the only growing use of oil.[104]

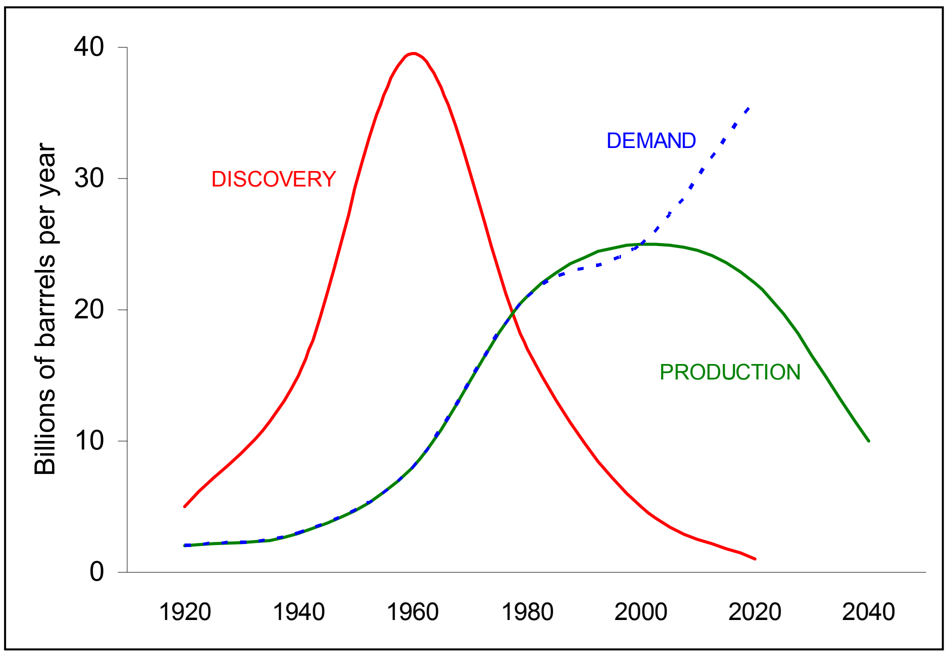
Petroleum liquids are just about perfect transport fuels

Setting aside environmental considerations, petroleum liquids, including petrol and diesel fuel, are just about perfect transport fuels. They have a high energy density, containing, for example, about 100 times as much energy as an equal weight of fully charged lead-acid battery.[105] They can be shipped, stored, and distributed with ease and comparative safety, and they are readily available at a remarkably low cost.

Two views of the availability of oil

There are basically two views of the availability of oil. One is that of the United States Geological Survey (USGS), which announced new estimates of worldwide reserves in March 2000 and said, "There is an abundance of oil and gas in the world."[106] The other view is most closely associated with geologists Colin Campbell and Jean Laherrère.[107] The latter author commented recently, "The USGS estimate implies a five-fold increase in discovery rate and reserve addition, for which no evidence is presented. Such an improvement in performance is utterly implausible."[108]

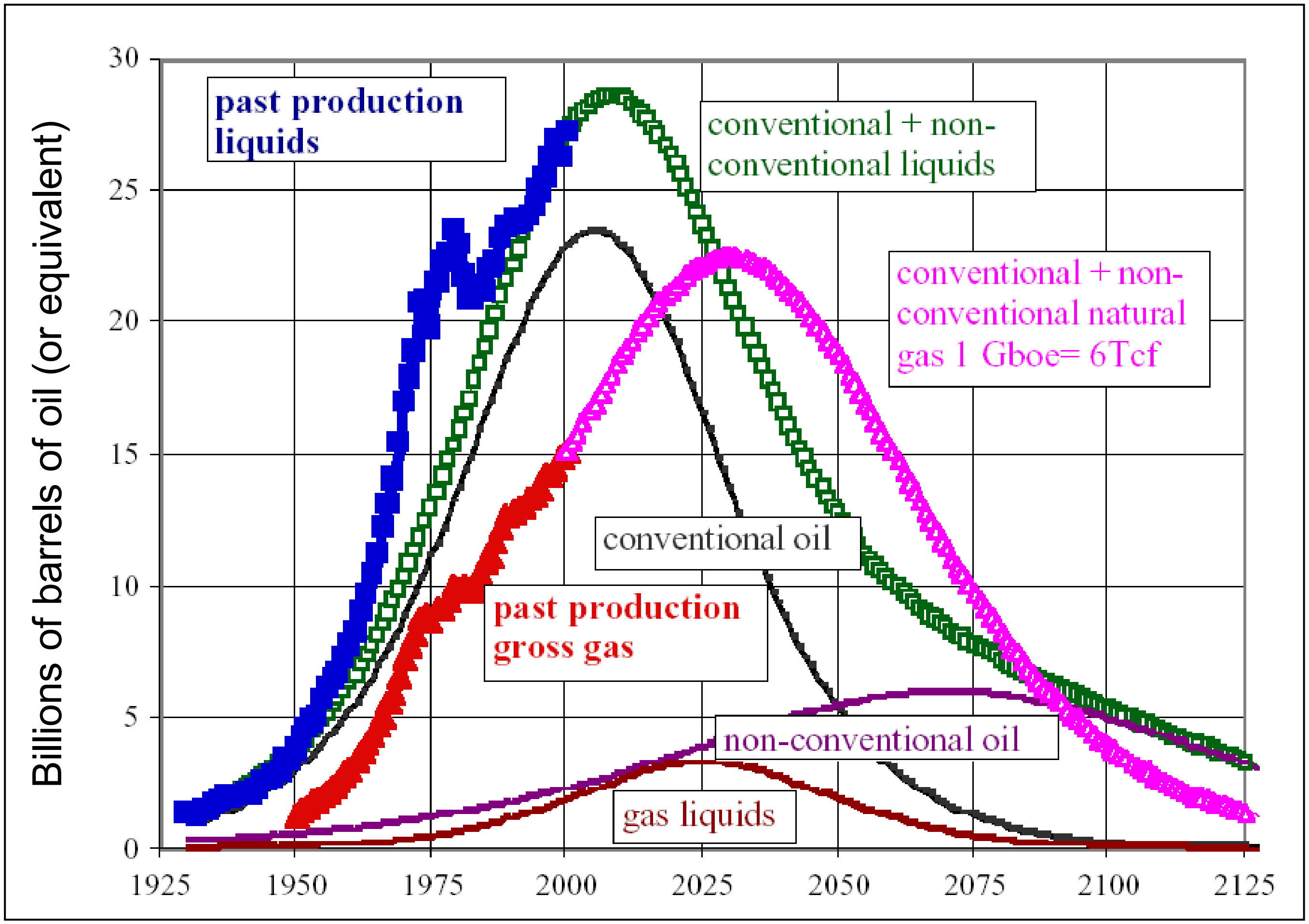
Box 37
Actual and projected worldwide discovery, extraction, and demand for conventional oil, 1920-2040



Campbell, Laherrère, and others[109] note that discoveries of conventional oil—i.e., "cheap oil" or oil that can be pumped from the ground, often under its own pressure—peaked in the 1960s and now amount annually to less than a third of oil production and use.

The peak of world oil production could occur in about 2005

They claim, moreover, that 90 per cent of readily extractable oil has been discovered, as opposed to the 50 per cent estimated by the USGS. Noting that aggregate production from a large number of wells typically begins to decline when half of the total they contain has been extracted, these commentators have concluded that the peak of world oil *production* will occur in about 2005, and will inevitably



Box 38
Worldwide annual production of petroleum liquids and natural gas, 1925-2125

fall thereafter. Demand for oil will continue to increase.

A divergence in demand and supply that will result in a massive increase in oil prices

The relationships among discovery, extraction of oil, and demand are shown schematically in Box 37.[110] To the extent these relationships apply, it follows that the latter part of this decade will see a divergence in the demand for and supply of oil that will result in a massive increase in oil prices.

The USGS does not appear to accept officially either the production model illustrated in Box 37 or, as noted, the estimate of reserves on which it is based. The model appears to have been accepted by the International Energy Agency, a governmental organization charged with predicting energy availability. IEA seems to prefer a larger estimate of reserves and has predicted a later divergence of demand and supply.[111]

Box 39
Life-cycle emissions from coal and natural-gas-fuelled electricity generating plants

	Coal	Natural gas	Ratio
Nitrogen oxides (g/kWh)	3.4	0.8	4.5
Sulphur oxides (g/kWh)	6.7	0.3	20.7
Particulates (g/kWh)	9.2	0.1	69.3
Greenhouse gases (kg CO_2-equ./kWh)	1.0	0.5	2.1

The actual production projections of Jean Laherrère and his colleagues are shown in Box 38.[112] Also included are projections for natural gas. The projections suggest a production peak for oil before 2010, and also a production peak for natural gas before about 2030.

Coal is also important for transport in Hong Kong, because it fuels the largest part of the generation of electricity used by public transport vehicles.[113] There is little doubt about its continued availability throughout the period until 2032.[114] However, as oil becomes substantially more expensive, so could coal, because oil fuels most of the equipment and transport used in getting coal from the underground seam to the generating station.

Coal is the dirtiest of fuels

Moreover, there should be hesitation about expanded use of coal because of the environmental impacts. Coal is the dirtiest of fuels. Box 39 presents a typical comparison of life-cycle emissions when coal or natural gas are used as fuels to produce electric power.[115] Use of coal results in many times the amounts of locally and regionally acting emissions and more than twice the amount of greenhouse gases.

5.2. Moving towards sustainable energy use

Given the uncertainties around oil supplies, and the authority and reputation of those who predict an early decline in production capacity, it is prudent to consider the possibility of large increases in crude oil prices within a decade. This would not occur because oil would be literally running out, but more because production could not keep up with demand. Similar considerations may apply to natural gas, with an inevitable decline in production happening in the third decade of this century rather than the first.

Avoidance of use of oil and natural gas would be a reasonable requirement for sustainability

Thus, a reasonable additional requirement for sustainability—as well as those set out in Section 6.1—would be avoidance of use of oil and natural gas, to the extent possible. This would be done above all to ensure economic and social sustainability for Hong Kong. If the forecasted severe constraints on production of these fuels occur during the next 30 years, and Hong Kong remains almost entirely dependent on them for transport, the impact of the constraints on Hong Kong's economic and social welfare will be severe. If a large measure of independence from these fuels has been achieved, Hong Kong will be relatively unaffected by the constraints. Moreover, if Hong Kong becomes a leader in attainment of such independence, it will thrive as an urban region while others struggle.

Hong Kong would benefit from avoiding use of fossil fuels as long this did not reduce its competitive advantage

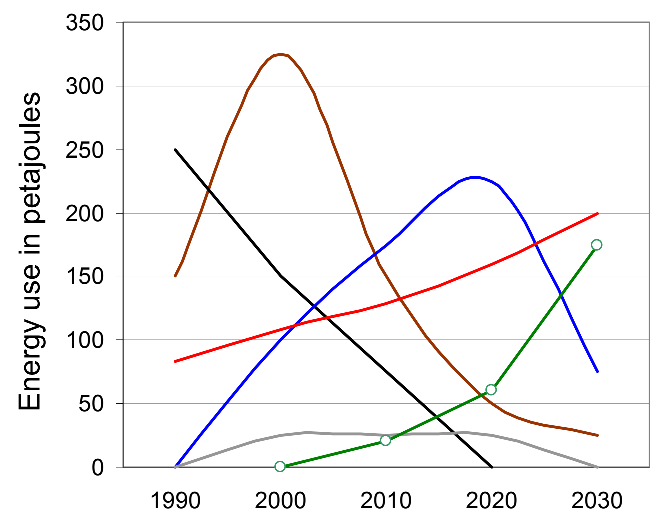
If the forecasted constraints on supply of oil and natural gas do not occur, Hong Kong could still benefit from reducing dependence on these fuels for transport. Hong Kong would benefit as long as avoidance of the use of these fuels did not reduce its competitive advantage in relation to other urban regions.

Competitive advantage could be lost if Hong Kong's transport became less effective and efficient, or if business were otherwise lost because of fuel use practices. On the other hand, competitive advantage could be gained if Hong Kong became a leader in the development of more sustainable fuel sources and transport systems.

Because transport-related emissions arise almost entirely from the burning of fossil fuels, any avoidance of use of fossil fuels could help with achievement of the proposed emissions targets.

5.3. Sustainable energy for Hong Kong

A sustainable energy system is one that involves use of renewable energy only. Candidate systems can be based on energy from the wind, sun (thermal and photovoltaic), tides, and ground (geothermal), and also from biomass.



	1990	2000	2010	2020	2030
Oil	150	325	150	50	25
Coal	250	150	75	0	0
Natural gas	0	100	175	225	75
Nuclear	0	25	25	25	0
Renewables	0	0	20	60	175
Electricity generated (pJ)	83	108	128	160	200
Primary energy supply (pJ)	400	600	445	360	275
NO_x (thousands of tonnes)	289	283	163	66	25
GHGs (megatonnes CO_2)	32	38	24	14	5

Box 40
Actual and proposed energy use and corresponding emissions from energy use.

Proposed milestones for primary energy use[116] for a transformation of Hong Kong's energy supply to one based largely on renewable sources are shown in Box 40.[117] Oil and oil derivatives—which are now the main source of primary energy—would be almost completely phased out by 2030. The ongoing decline in coal use would continue, and coal would be phased out completely by 2020. Initially, coal would be replaced by natural gas (from additional supplies piped to Hong Kong from Hainan and perhaps elsewhere), but use of natural gas too would decline rapidly after 2020 and would be almost phased out by 2030. Nuclear generation of electricity (imported from Guangdong) would stay at about its present level until after 2020.

The large increase in supply would come from renewables

The large increase in supply would come from renewables. Their present contribution is negligible, but their use would increase to provide for about 16 per cent of electricity generation by 2010,[118] and would triple in amount in each decade after that, i.e., their use would increase at the rate of 11-12 per cent per year.

Total primary energy use would fall by more than half, and by a population that could be at least 40 per cent higher than today if recent growth continues. However, this decline is offset in considerable measure by the growth in use of electric power, a high-grade type of energy that can be used with high efficiency (see below).

Box 40 shows that if the proposed milestones were to be met, total primary energy use in Hong Kong would fall by more than half between 2000 and 2030, NO_x emissions from fuel use would fall by more than 90 per cent, and emissions of greenhouse gases (GHGs) would fall by more than 85 per cent.

Electricity would become by far the most important end use of energy in Hong Kong

A significant feature of the scenario set out in Box 40 is that electricity becomes by far the most important end use of energy in Hong Kong. The data in Box 40 suggest that electricity presently comprises roughly a quarter of *end* energy uses in

Why this report is entitled *Electrifying Hong Kong*

Hong Kong.[119] The proposed scenario would have electricity providing more than three-quarters of end energy uses. Hence the title of this report *Electrifying Hong Kong*.

Electricity is an appropriate energy source for most purposes requiring additional energy in Hong Kong. It is a high-grade source, meaning that it can be used for almost any purpose, and thus can be readily replaced by a low-grade source such as solar heating or waste heat—e.g., for domestic hot water and space warming—when such a source is available.

Electricity is problematic as an energy source for driving vehicles, a matter that will be returned to in the next chapter. Ideally, to function independently, vehicles need a liquid or compressed gas that has high energy density (kilowatt-hours/kilogram) and can be safely and conveniently handled.

Two candidate transport fuels were rejected for the scenario: biomass fuels and hudrogen

Two candidate transport fuels were provisionally rejected for the scenario. One is fuel from biomass, probably ethanol or methanol, for use in internal combustion or fuel-cell systems. This was rejected because of the large amount of land required for cultivation and because their production may well require a larger energy input than can be yielded by the resulting fuel, i.e., their production processes are energy sinks rather than energy sources.[120]

The other provisionally rejected fuel is hydrogen. Most fuel cells require this fuel.[121] It can be stored on board vehicles (although with difficulty) and also produced by an on-board 'reformer' from a fossil fuel such as methanol or gasoline. The automotive industry has been developing systems making use of reformers. General Motors favours using gasoline as the feedstock, to take advantage of existing refuelling arrangements. DaimlerChrysler and Ford appear to prefer methanol because reforming it is more environmentally sound, and because this feedstock could potentially come from renewable sources (although see the comments on biomass fuels in the previous paragraph).[122] Recently, the U.S. government initiated a programme that will focus on developing hydrogen distribution and storage systems.[123]

Hydrogen manufactured from gasoline or methanol would not necessarily be sustainable (methanol is presently manufactured from natural gas). Moreover, fuel-cell vehicles using these fuels may not use less fossil fuel than vehicles with internal combustion engines. Systems in which hydrogen is manufactured from natural gas are more fuel efficient, but here the reforming cannot readily be done on the vehicle itself, raising the tricky question of on-board storage of hydrogen. The only sure way of producing hydrogen sustainably is to produce it by electrolysis using electricity that was in turn produced sustainably.[124]

Producing and using hydrogen sustainably involves major energy losses; it's better to use electricity directly

Here is the nub of the problem with hydrogen made using electricity. By the time you have made the hydrogen, compressed it, stored it, and then generated electricity from it in a fuel cell, more than 60 per cent of the original electrical energy will have been lost.[125] It would be better, if possible, to use the original electricity to drive the motor (or perform another function). It would be very much better to do this if energy is scarce and expensive.

Thus, in what follows, there is a very strong preference for systems that use renewably generated electricity to drive electric motors directly.

Presently, wind energy is the most promising means of generating electricity sustainably

As to the options for producing renewably generated electricity, presently the most promising appears to be wind energy. According to Lester Brown of the U.S. Worldwatch Institute, "Advances in wind turbine technology, drawing heavily on the aerospace industry, have lowered the cost of wind power from 38¢ per kilowatt-hour in the early 1980s to less than 4¢ in prime wind sites in 2001. In some locations, wind is already cheaper than oil or natural-gas-fired power."[126] He noted that Germany is the leader in terms of installed wind turbine capacity, with some parts of northern Germany producing 75 per cent of their electric power from wind. Denmark is the relative leader—i.e., the highest proportion of its electricity is generated from wind, already 15 per cent.

Denmark has transformed its interest in wind power into a solid economic base

Denmark has transformed its interest in wind power into a solid economic base. It has more than half of the global wind turbine market, amounting now to about a quarter of its exports, including the world's largest producer, Vestas Wind Turbines. In 2000, this company was 'promoted' to the London *Financial Times* Eurotop 300, i.e., it is considered to be one of the best 300 companies in Europe from the perspective of shareholder value. In the first six months of 2001, its turnover was twice that in the same period in 2000.[127]

Interest in offshore wind power in Ireland and China

In January 2002, the Irish Government announced development of the largest ever off-shore wind farm in the Irish Sea, larger than the total of all the present such installations worldwide.[128] This could be prudent policy for a small economy that imports all of its energy. It could also represent a bid to harness Ireland's technology powerhouse to the business of displacing Denmark as the leading exporter of wind power technology.

China is developing a major interest in wind power. The promise of a "wind-powered Olympics" was part of China's successful bid for the 2008 Games. Shi Pengfei of the State Power Company said in April 2000 that off China's east coast there is potential for development of offshore wind farms with a capacity of 750 gigawatts.[129] China's currently installed generating capacity is about 300 gigawatts; Hong Kong's is about 11 gigawatts.[130]

Box 41
Wind farm in the North Sea off the coast of Blythe, UK ▼

Offshore wind power seems to confer several advantages. The winds are stronger and steadier. Barriers to development of wind generation are lower, chiefly arising from turbine noise and aesthetics. Offshore development can, however, cost more than land-based development unless land prices are high, and it may be feasible only where water is shallower than about 20 metres. Box 41 shows a current wind farm.

The continental shelf off Hong Kong may be well suited to the development of wind farms, as appears to be the rest of China's east coast (see above).[131] There is room in Hong Kong waters for more than 100 gigawatts of generating capacity without interfering with shipping lanes and other requirements,[132] and only about 20-25 gigawatts of capacity may be required.[133]

There is room in Hong Kong waters and the wind speed is right

Moreover, the wind speed is right. Whereas, on land Hong Kong's wind speeds tend to be low, readings from the wind meter at Wagman's Island—more typical of offshore Hong Kong—indicate much higher speeds. There, in no month does the average fall below 5.3 m/sec (19.2 km/hour), and the yearly average is 6.3 m/sec.[134] This translates into an effective wind speed at turbine height of 7.3 m/sec, which in turn translates into just below optimum electric power output for the large turbines currently being manufactured.[135]

Transformation of Hong Kong's electricity generating capacity from coal and natural gas to wind would, if implemented over 30 years, result in sufficiently large production runs to justify manufacture of turbines tuned to Hong Kong's offshore conditions (and produced in Hong Kong). Their power peak would occur at slightly lower speeds than, say, for the Irish Sea, and they would be able to protect themselves during typhoons.

Wind power is the most promising among several promising energy sources for renewable generation of electricity

Wind power is merely the most promising among several promising energy sources for renewable generation of electricity.[136] The focus here on wind power is not meant to exclude interest in these other sources. An unpredictable mix of technological advances, investment decisions, and other factors will decide what is to be the mix of renewable energy sources that produces the 2030 output indicated in Box 40.

What seems clear at this point is that such a focus on renewables will be required. By 2030, the age of cheap oil and natural gas will have passed, and the use of coal will be unacceptable. And yet demand for electricity will be much higher.

6. Moving towards sustainable transport in Hong Kong

6.1. Requirements for sustainable transport

Criteria for the attainment of environmentally sustainable transport were based on internationally agreed goals, guidelines, and standards

The Organisation for Economic Cooperation and Development (OECD) considered the requirements for sustainable transport at length in a five-year-long undertaking known as the Environmentally Sustainable Transport (EST) project.[137] Criteria for attainment of EST were developed. They were based on internationally agreed goals, guidelines, and standards. These included the critical levels and loads defined by the World Health Organization (WHO) and adopted as part of the UN ECE Convention on Long-range Transboundary Air Pollution,[138] and those proposed within the UN Framework Convention on Climate Change.[139]

Six EST criteria were considered to be the minimum number required to address the wide range of health and environmental impacts from transport. They concerned noise, local air quality, regional acidification and eutrophication, tropospheric ozone, global climate change, and land use.

The most onerous of the EST criteria concerned emissions of greenhouse gases, which were to be reduced to and maintained at no more than 20 per cent of 1990 levels.[140] Other criteria spoke to reductions in other emissions—NO_x, VOCs, particulates—by 90 per cent or more; attainment of WHO noise guidelines (see Section 4.5); and land use changes consistent with the foregoing.

These may be the only quantified criteria for sustainable transport that have been established. They were developed for the mostly affluent OECD member countries and thus may be particularly applicable to Hong Kong. Although Hong Kong's transport and land features are often extreme, it is clearly on the continuum of affluent urban regions, as concluded here in Chapter 2.

In the OECD work, relative rather than absolute criteria were set for emissions to take into account the differing circumstances of OECD members. Thus, the resulting emissions guidelines spoke to percentage reductions below 1990 levels rather than to attainment of specific targets. Hong Kong's extremely low emission levels (see Section 4.3.1) could argue for lesser reductions. However, the high spatial intensity of emissions (see Section 4.3.3) and the resulting poor air quality (see Section 4.4) argue against any such relaxation.

A reasonable goal for Hong Kong could be to avoid emissions at road vehicles altogether

Indeed, given Hong Kong's extraordinarily high settlement density, and the high spatial intensity of emissions in Hong Kong, **a reasonable goal could be to avoid emissions at road vehicles altogether**, and to reduce emissions resulting from transport elsewhere—e.g., at electricity generating stations—so they meet the

OECD criteria, namely, an 80-per-cent reduction in CO_2 emissions and reductions of 90 per cent or more in emissions of locally and regionally acting pollutants.

The goal of avoiding emissions at vehicles altogether is exactly in line with the energy strategy proposed herre

Achieving the zero-emissions target would require use of electric motors for road vehicles as well as encouragement of non-motorised movement of people and freight. Thus, the goal of avoiding emissions at vehicles altogether is exactly in line with the energy strategy proposed in Chapter 5.

Noise levels from transport would likely fall as the number of electric vehicles grew, but additional steps could be required to meet WHO guidelines.

The OECD target date for attainment of sustainable transport was set at 2030 as being sufficiently near to avoid major impacts from inaction, but sufficiently distant to allow for the implementation of effective strategies. Arguments were made for extension to 2050 on the grounds of potential economic hardship, but these did not prevail.

The strategy proposed here also assumes an implementation time frame of about three decades. This corresponds closely to the current 2030 horizon for long-term planning in Hong Kong for transport facilities, land uses, and environmental issues.[141]

6.2. Transport in Hong Kong is not on a sustainable trajectory

Hong Kong's transport system may now be among the closest to sustainability; but it is becoming less sustainable

Among the transport systems in affluent urban regions, Hong Kong's system may be among the closest to sustainability; but in many respects it is becoming less sustainable. Here are particular features of its unsustainability:

Road-vehicle traffic is expected to increase substantially during the period until 2016 (See Section 3.3.3). If the present projections are extended beyond 2016 there would by 2032 be an increase of between 63 and 168 per cent over *today's* traffic levels.[142] Unless trends in energy use and energy efficiency change, there could be commensurate increases in fuel use and greenhouse gas emissions. Current levels are about 16 per cent above 1990 levels.[143] Thus, projected 2032 levels are *between 9 and 16 times higher* than the targetted sustainability level of 80 per cent below the 1990 level.

Emissions of locally and regionally acting pollutants would not rise far above present levels—an increase of 34 per cent is the highest projected in Box 31—and they could well be lower than present levels. However, even in the most optimistic case, they would be far above what has been proposed here as the sustainability target, namely *zero emissions at the vehicle* and 80 per cent or more below 1990 levels.[144]

Noise levels from transport are presently sufficiently high that half of Hong Kong's population may be exposed to levels above the WHO guidelines, and present trends are towards more exposure (see Section 4.5). Dramatic reductions in traffic noise, beyond any sound-proofing effort, could be required to ensure that the number of people exposed becomes very low.

Thus, much about transport in Hong Kong needs to be changed to move it towards sustainability.

6.3. Meeting the sustainability requirements

6.3.1. Overall considerations

As set out in Section 6.1, the challenge over the next three decades is to transform Hong Kong's transport system for people and freight into one that uses less than 20 per cent of current fossil fuel use (less than 10 per cent of the projected use in 2032), produces essentially no emissions in settled areas and few elsewhere, and results in noise levels within WHO guidelines.

The challenge for the next three decades would be met by implementing the proposed energy scenario and optimising transport

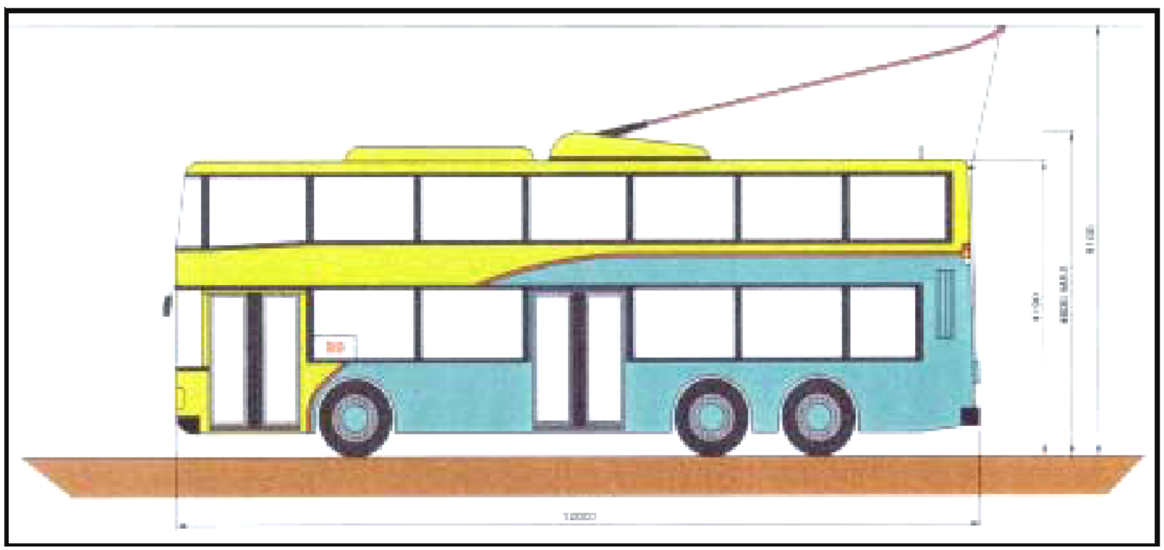
As it happens, this challenge would be met for Hong Kong as a whole by implementation of the energy scenario outlined in Chapter 5. As noted in Section 5.3, that scenario would be associated with reductions in greenhouse gas emissions by more than 85 per cent and by reductions in locally and regionally acting emissions—nitrogen oxides were uses as the example—by more than 90 per cent.

Thus the challenge becomes that of adapting Hong Kong's transport system to the energy scenario and optimising transport activity within the scenario.

More specifically, if for planning purposes it seems reasonable to assume that approximately half of end use electrical energy will be available for transport in 2032, the challenge becomes that of making the best economic and social use of that energy.

The strategy proposed here is to make the greatest possible use of wire-fed or trolley vehicles, known here as *tethered* vehicles. Presently in Hong Kong, the MTR and KCR rail systems, KCR's light rail system, and the tramway system comprise tethered vehicles and their associated infrastructure. The vehicles (trains, trams, etc.) receive their electricity supply from a fixed cable through a trolley arrangement. Tethering could be extended to buses (see Box 42[145]) and lorries,[146] and even to smaller vehicles.

Box 42
Consultant's preferred trolleybus for Hong Kong: low-floor, air-conditioned, up to 12 metres long



The fundamental point about tethered systems has been made in Chapter 5. They require much less energy overall than fuel-cell systems. This is not a matter of presently inadequate technology so much as the laws of thermodynamics, which require energy losses as processes multiply. Energy is of necessity lost when hydrogen is made, stored, and processed

Trolley systems will always provide for more transport activity for a given energy input

into electricity in a fuel cell compared with direct application to a motor. A reasonable assumption is that trolley systems will always provide for three times or more transport activity for the input of a given amount of electric power.[147]

The efficiency of use of electric power by battery systems can be higher. However, they suffer from low power density and the consequent need for frequent recharging. Also, battery vehicles are heavy, which results in reduced transport efficiency. Finally, end-of-life management of battery systems poses special environmental problems.

Nevertheless, fuel-cell and battery systems will likely each have a place in Hong Kong's all-electric transport system

Nevertheless, fuel-cell and battery systems will likely each have a place in Hong Kong's all-electric transport system. It will not be possible to run trains and trams everywhere, or even overhead wires for trolleybuses and other trolley vehicles. Also, some users will want to pay the very high cost of owning and operating untethered personal vehicles.

A further point about tethered systems is that they have an extremely high onboard power/weight ratio, adding considerably to the overall efficiency. Quite small electric motors can move large buses and lorries. Moreover, because of superior torque at low speed, such systems provide better acceleration and hill-climbing performance.

6.3.2. Moving people

Tethered vehicles will be the workhorses of Hong Kong's all-electric passenger transport system

The workhorses of Hong Kong's all-electric passenger transport system in 2032 will be tethered vehicles. The largest number of people will be carried in trains. Most of the remainder will be carried in trams and trolley buses. The proposed daily trip scenario is set out in Box 43.[148] Here are the assumptions underlying the scenario:

Population: The recent growth of about a million persons a decade is expected to continue until 2032.

Box 43
Scenario for 2032 showing mix of daily trips compared with the current mix ▼

	2002		2032	
	Trips (millions)	Per cent of total	Trips (millions)	Per cent of total
Motorised trips by:				
Personal vehicles	1.1	8%	1.0	4%
Taxis	1.3	10%	1.0	4%
Buses	6.5	47%	7.4	32%
Rail	4.7	35%	14.1	60%
Total motorised trips	13.6	100%	23.5	100%
Population (millions)	7.0		10.0	
Trips/person	1.95		2.35	

Trips by personal vehicles and taxis: These are expected to remain about the same as now, but decline substantially in proportion to the total in response to the higher relative costs of this kind of travel. All of these trips would be made by electric vehicles powered by batteries or fuel cells.

Trips by heavy and light rail: The large increases in rail use proposed by the Government until 2016 are expected to continue beyond 2016, but at a lower rate. (If the increase until 2016 set out in Box 17 were to be continued at the same rate, there would be 23 million trips by these modes in 2032, i.e., 98 per cent of the total of trips in 2032 proposed in Box 43.)

Assumptions underlying the proposed transport scenario for 2032

Trips by bus: These are expected to increase absolutely but show a sharp relative decline. The significant change here would be that all of these trips would be made by electric vehicles, notably large and small trolley buses.

Trips by tethered vehicles: As indicated by the rose-coloured cells in Box 43, these trips amount to 35 per cent of all motorized trips in 2002 and are set to amount to 92 per cent of all such trips in 2030.

Trips/person: The number of motorised daily trips per person is projected to be the same in 2032 as has been projected for 2016, i.e., a 28-per-cent increase over 1997 (see Box 17). Further growth in this number is not anticipated because of the higher cost of some elements of the transport system (personal vehicles and taxis) and the growth in amenity for pedestrians and bicycle users (see below).

In short, in 2032, Hong Kong residents will be making many more trips than now, almost entirely in tethered public transport vehicles fuelled by electricity produced from renewable sources.

6.3.3. Moving freight

As with the movement of people, the scenario proposed here for 2032 speaks to movement of essentially all goods by electric vehicles, mostly tethered vehicles. It is difficult to be as precise about goods movement because, in common with other jurisdictions, the Hong Kong SAR Government does appear to keep good relevant data. For example, there do not appear to be data on tonne-kilometres performed by road and by rail. What data are available suggest that presently less than three per cent of goods movement in Hong Kong is carried out by rail, and perhaps much less.[149]

Another special challenge regarding goods movement is that the anticipated growth in use of heavy road goods vehicles may be particularly large, especially in relation to cross-border traffic (see Box 14 and Box 16). This growth may be in doubt (see Section 4.7), but it would be foolish to plan as if it will not happen.

The freight strategy proposed here involves carrying as much as possible by rail and carrying the rest in electric road vehicles, including trolley lorries

What is proposed here is that the maximum amount that could be feasibly carried by rail be determined, in the light of evolving trade relationships with mainland China and technical opportunities from the transport perspective.[150] The balance of the freight would be carried by electric road vehicles.

Larger road goods vehicles would be tethered, either to the wires used by trolley buses, or to wires established for goods vehicle use, where there was no trolley-bus route or sharing was impracticable. For well-travelled routes, including new links with the mainland, one or more lanes for goods vehicles, served by trolley wires, could ensure efficient services.

Depending on what happens across the border, the tethered vehicles could be capable of operating independently on power from batteries or fuel cells, with even the possibility of use there of internal combustion engines. As noted above, one of the major advantages of tethered vehicles is that the on-board space requirements for drive systems are exceptionally low, leaving plenty of room for accommodation of another drive system.

Goods vehicles operating within Hong Kong could also be dual-mode, operating on wires when they are available and on fuel cells or batteries elsewhere. The incentive to operate with wires will be high, because of the energy losses involved in battery and especially fuel cell operation. There will also be a strong incentive to work only with wires, thereby avoiding the high capital and continuing costs of fuel cell and battery systems.

A more detailed proposal for sustainable freight transport would require work beyond the resources available for this report; making such a proposal is a matter of urgency

In short, it is not possible without further work to sketch out a scenario for freight movement in 2032 that corresponds to the one for the movement of people in Box 43. The broad outlines of the 2032 freight system can be set and have been proposed. Freight movement is essential to the well-being of Hong Kong and its people, perhaps more than passenger movement, and may pose more challenges for sustainability. Detailed work towards a strategy for the next few decades is a matter of urgency.

6.3.4. Non-motorised transport

There seem to be no data on the amount of non-motorised transport, but casual observation suggests there is a lot of it in Hong Kong, including some movement of goods in this way.

There is already concern in the Hong Kong Government about pedestrian amenity. For example, in a speech in January 2002 setting out some "preliminary thinking on the subject of Planning for Pedestrians", the Secretary for Planning and Lands said,

> "Most of you will agree that walking in the urban areas of Hong Kong, such as Mong Kok or Causeway Bay, is not the most pleasant experience. Quite a number of our footpaths and sidewalks are too narrow. We have large, sometimes unruly, crowds who are always in a hurry competing for the limited space. It is difficult to cross roads at the ground level. The competition between pedestrians and cars are fierce at certain junctions. Signage is often inadequate. There are also many barriers to pedestrian movement. The needs of the elderly and the disabled are not fully taken care of. There is no place to rest. There is inadequate protection from bad weather. Sometimes the footpaths are poorly maintained and that causes safety problems. Together with the noise and air pollution from road traffic … it is not difficult to understand why people choose to minimise walking opportunities."[151]

He went on to articulate four principles that have come out of an ongoing study also entitled "Planning for Pedestrians": linkage, safety, accessibility and comfort, and attractiveness and vibrancy.

Most of the components of the proposed energy and transport scenario will further facilitate and encourage pedestrian movement. The urban environment will be cleaner and quieter and contain fewer road vehicles. But more could certainly be done to increase the amount of walking and thereby reduce strains on the transport system as it evolves towards the 2032 targets.

The scope for some increase in the amount of functional—as opposed to recreational—cycling seems large

Cycling seems to be widely used as a means of personal transport in parts of the New Territories but it is rare in Kowloon and in most places on Hong Kong Island. Hilly terrain, high traffic flows, and lack of amenities for cyclists all serve to discourage cycling. The scope for some increase in the amount of functional—as opposed to recreational—cycling seems large.

Again, implementation of the proposed scenario will serve to help create a better environment for cyclists. An increase in cycling could facilitate implementation rates of the scenario.

A pre-requisite for further work on non-motorised modes is better data on them. A firm data base is needed to set targets, and assess performance in relation to them.

7. Implementing the all-electric option

7.1. Movement of people

The proposed energy scenario would be the main driver for the the proposed transport scenario

In what is proposed here, the implementation of the proposed energy scenario would be the main driver for the implementation of the proposed transport scenario. Both would involve what may be an unusual degree of intervention by government. Both would require a massive, effective public education programme to facilitate implementation. Before any action were taken in the directions proposed here, much further study would be required to ensure that there is adequate reason to move towards the scenarios, that the best possible strategies are available, and that detailed implementation plans are ready for use.

Moreover, what is proposed here concerns a 30-year planning horizon. Hong Kong has changed greatly since 1972 and there could be as much or more change by 2032. Whatever strategies are adopted must be capable of adaptation to new circumstances. Frequent review of progress will be essential.

What follows addresses implementation of the transport scenario more than the energy scenario. The basic assumption is made that the energy scenario will be implemented. Ideally, this report would have elaborated two or more energy scenarios and two or more transport scenarios for each energy scenario. The resources were not available for this. In any case, a report setting out several scenarios can lose some of its clarity of purpose.

The overriding targets and milestones are those of the energy scenario; the transport planners' job would be to develop optimal strategies consistent with these milestones

The essence of good long-range planning is the establishment of targets and of milestones towards those targets. In the present exercise, the overriding targets and milestones are those of the energy scenario. They are set out in Box 40. Their most important feature for transport is a reduction in oil use by more than 50 per cent during the present decade and by an even larger percentage during the period 2010-2020. For transport planners, how this would be achieved is relatively unimportant. The planners' main concerns would be to develop optimal strategies for transport that are consistent with the milestones of the energy scenario.

Current Government policy with respect to passenger rail is entirely consistent with what can be regarded as a sustainable trajectory

The passenger transport scenario in Box 43 sets out a framework for strategy development. Within that framework there is a key element that is already on course, namely rail services. Current Government policy with respect to passenger rail is entirely consistent with what can be regarded as a sustainable trajectory. All that is required is that present plans be implemented, and also that rail development continue beyond 2016, although at a lower intensity.

Bus services may present the greatest challenge

Bus services may present the greatest challenge. Two things are required for conformity with the transport scenario. One is to convert fleets to electric power, which essentially means replacing diesel buses with trolleybuses. The other is to reduce the rate of growth in bus traffic.[152]

What is required here is that within the framework of the energy scenario the Government work with the bus companies to set 5-year targets for the changeover to trolley buses. If a basic assumption of the energy scenario is correct—namely that diesel fuel prices will rise steeply before the end of the present decade—the Government will not have difficulty securing the cooperation of the bus companies as long as they can be persuaded that fossil fuel prices will rise.

There will have to be much detailed work as to trolleybus route selection and phasing

The issue here is trolleybus infrastructure: wires, poles, transformers, and so on. There will have to be much detailed work as to route selection and phasing.

The proposed reduction in the rate of growth in bus use of any kind may not need special treatment. Increased competition from rail, higher fuel prices, and the challenges of conversion may all help ensure that growth is moderated.

The proposed relative declines in private vehicle use and taxi use will likely occur without special intervention, brought on by increased fuel prices and competition from improved public transport. There may be some infrastructure issues here too, including the provision of public charging stations for battery vehicles, and perhaps hydrogen stations for fuel-cell vehicles.

Attention should also be given to matters that are not immediately addressed by the framework of the transport scenario, including noise and non-motorised movement.

7.2. Movement of freight

For reasons given in Section 6.3.3, the transport scenario for 2032 cannot be readily quantified with respect to freight both because data on present freight movement are poor and because there are large uncertainties about future cross-border traffic.

The broad outline of the required freight strategy is clear, but not the details

Nevertheless, the broad outline of the required strategy is clear. Over 30 years, freight transport within Hong Kong is to be transformed from almost total dependence on diesel fuel to almost total dependence on electric power.

An unknown portion of this transformation will involve expansion of rail freight services. When the parameters of the expansion become clear, Government will also have to play a role in ensuring use of the rail service. This could be done largely through direction as to how infrastructure is to be provided. However, at every step, consideration will have to be given to Hong Kong's best economic interests, particularly as they depend on the viability of the port.

A tricky element of the strategy will be transformation of the road vehicle fleet to one involving tethered lorries and vans

A trickier element of the strategy will be transformation of the road vehicle fleet to one involving tethered lorries and vans. Unlike with passenger transport, where users of overhead wires will be a few bus companies, there will be many freight transport users. The logistics will require much attention and sophisticated application of information technology.

Government will likely have to play a strong role in fostering the transformation, and certainly a strong role in providing the required infrastructure. This will have to be done on a common carrier basis. Multiple sets of wires on the same thoroughfare would be unthinkable.

Again, when better information is available, firm milestones should be set, progress monitored, and corrections made.

7.3. Aviation and marine transport issues

The above analyses have focussed on land transport within Hong Kong. The airport and the seaport are relevant to this focus because of the traffic they generate.

Hong Kong needs to prepare for the demise of aviation with the end of cheap oil

What may require special attention from the perspective of transport within Hong Kong is the demise of aviation with the end of cheap oil. Aviation uses the most fuel per person-kilometre and is the most sensitive to fuel price increases.

Over the last 30 years, fuel's share of operating expenses has varied in the range 10-30 per cent,[153] and the share may well go higher than this range during the next few decades. The result would be a major decline in aviation activity and corresponding changes in local transport activity.

Marine transport may experience increased international activity, even involving more passenger traffic

Marine transport is relatively fuel-efficient and thus may even experience increased international activity, possibly involving more carriage of passengers as well as freight. Again, changes in marine transport could have ramification for land transport within Hong Kong.

Marine transport is also part of the cross-border freight activity. Indeed, by tonnage, river freight activity to and from Hong Kong is similar in amount to road freight activity.[154] If rising fuel prices were to favour river freight, there could be serious competition with road and rail freight.

7.4. Paying the cost of it all

The principal challenges for Government in the implementation of the energy and transport scenarios would be these: (1) to ensure that implementation occurred in ways that enhanced the economy and had the support of Hong Kong residents; and (2) to ensure that appropriate investments were made with a fair allocation of costs.

The 'hands-off' approach of the Hong Kong Government could for the most part continue; there are adequate revenue streams for the required changes

On the second matter, there seems to be no reason why the historic 'hands-off' approach of the Hong Kong Government could not for the most part continue. Energy and transport both have revenue streams affecting just about all the population and they are both goods whose high usage may be inimical to society's interest. Thus the primary source of funding for the radical changes required for implementation of the scenarios can reasonably be energy and transport revenues.

However, fine-tuning may be required to avoid excessive hardship for poor residents and to avoid excess where the marketplace fails to restrain it. These strategies will be needed in whatever way energy prices increases are approached. They are not specific to what is proposed here.

An important role of government would be to support required research and development

What may require specific expenditure by Government on behalf of Hong Kong society as a whole is investment into research and development of the innovations proposed here, particularly regarding offshore wind power and tethered vehicles.

7.5. Better integration and cooperation

Another important role would be more hands-on direction of the transport system to ensure better integration and cooperation

What may also be required from Government is more hands-on direction of the transport system to ensure better integration and cooperation. A feature of the present system is fierce competition between modes, particularly rail and bus, and lack of integration between components of the whole system that feeds the competition and reduces passenger amenity.

The example of Britain is particularly instructive. Urban public transport systems in London and outside underwent deregulation in the mid-1980s but in very different ways. In London there was (and is) ‘competition for the road’; franchised routes are tendered in batches. Outside London there is ‘competition on the road’; any operator meeting safety standards and giving due notice can operate anywhere.

Competition among public transport operators can be destructive

The result has been that outside London there has been a fall in bus ridership and a large rise in car ownership and use. Inside London, there has been an increase in ridership and a much smaller increase in car ownership and use.[155] The circumstances of the UK are quite different from Hong Kong but the lesson to be drawn may be pertinent: competition among public transport operators can be destructive.

Hong Kong residents have one of the best public transport systems in the world. Nevertheless, it could be improved by better integration among services—e.g., more connecting points between rail systems—and higher cost-effectiveness through avoidance of unproductive competition.

7.6. Key steps for the next 10-15 years

The author of this report was asked to indicate "the two highest priority practical transport innovations for Hong Kong over the next 10-15 years and what are the specific practical steps Hong Kong should take to implement those innovations". This section deals in turn with two transport-related innovations. Each of them is set for an initial 5-year rather than 10- to 15-year time frame. The intention in each case would be to continue the kind of work proposed for 15 years and perhaps longer.

7.6.1. R&D capacity for tethered vehicles

If the proposed transport scenario is followed, Hong Kong will become an early major user of tethered vehicles. Widespread use of them throughout the world over the next several decades seems reasonably certain, with major market potential.

Early establishment of Tethered Vehicle Institute

What is proposed is early establishment of Tethered Vehicle Institute to enhance Hong Kong's research and development capacity in this area. The inception of the Institute could be funded directly by Government as an expression of public interest. However, it is unlikely that continued funding would be required because of the opportunities for revenue from Institute activities.

An appropriate endowment by Government would be HK$10 million for each of five years. The Institute could be located within one university but be a joint venture of more than one. It would have clear performance targets that ensured long-term value for the Government's investment.

The Tethered Vehicle Institute would be given responsibility for helping ensure that relevant parts of the proposed transport scenario be implemented, evaluated, and revised as may be required.

7.6.2. Education about the need for change

If further investigation supports the appropriateness of the strategies proposed here, there will be a massive need to educate Hong Kong citizens about the need for fundamental change in many aspects of energy use and particularly transport.

A campaign to support Hong Kong as a leader in the quest for sustainable transport

What is proposed here is that the Government consider launching such a campaign to support the positioning of Hong Kong as a social and market leader in the quest for sustainable transport.

The required investment by government could be several times larger than that for the Institute proposed above. The benefits in terms of an informed, supportive citizenry would be incalculable.

8. Concluding remarks

Hong Kong is a remarkable city that is already closer to having sustainable transport than almost any other part of the industrialised world. It is drifting in the direction away from sustainable transport, but not seriously so. Moreover, there are many positive features about current trends and proposals, notably the plans for much expanded passenger rail travel.

The special contribution of the present report is to make a strong link between energy planning and transport planning

What has not figured strongly in how Hong Kong approaches transport issues is the energy framework that makes motorised transport possible. The special contribution of the present report is to make that link strongly. This is done at a time when popular assumptions of essentially unlimited availability of fossil fuel are about to be challenged.

The flaw of the present report could be its reliance on a single energy scenario that drives a single transport scenario

The deep flaw of the present report could be its presentation of a single energy scenario that drives a single transport scenario. If the energy future for the world and for Hong Kong evolves in a substantially different way from what is assumed here, then the proposed transport scenario will not be driven in the manner indicated and the exercise could be entirely hypothetical.

With more time and more resources, multiple scenarios could have been developed, but then a central point of the present report, the strong link between transport and energy, could have been lost.

Further investigation may well conclude, however, that it is not the energy scenario as a whole that is wrong but only the detail of its timing. Then, almost all of what is proposed here would remain valid.

Hong Kong should embrace a strategy that rejects the internal combustion engine in favour of becoming the all-electric city

What is proposed here is that Hong Kong should embrace a strategy that rejects the internal combustion engine in favour of becoming the all-electric city. This would be partly a leap of faith and partly raw pragmatism. It would be a leap of faith because if would depend on a certain vision about the future. It would be pragmatic because it would protect Hong Kong from growing unavailability of the fossil fuels that underpin modern civilisation.

Becoming the all-electric city could give the Hong Kong economy an additional focus that builds on its present strengths

Becoming the all-electric city would be pragmatic also because it could give the Hong Kong economy an additional focus that builds on its present strengths. Being a leader in the use of particular technology often brings with it leadership in the market for that technology. The example of Denmark and wind power has been presented forcefully in this report. Hong Kong could readily become a leader in tethered vehicle technology, which promises to be a growth industry in the 21st century

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This version of the report may well have numerous errors and other inadequacies. I am responsible for all of them, and would appreciate knowing about them so that I can correct later versions. Here are my coordinates:

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End Notes

[1] The issues concerning use of non-renewable resources are more complex than those concerning cumulative damage to the environment. From one perspective, *any* use of non-renewable resources can be considered unsustainable in that it reduces the opportunities for future generations. However, because future generations would not be able to use these resources without becoming unsustainable, the opportunities that would be denied by their earlier use could be considered somewhat hypothetical.

Two points of view seem relevant. One is the argument that use of non-renewable resources is justifiable if through their use human knowledge is expanded in ways that enhance sustainability. The use of oil products in contraceptive applications would be an example, or in research and development towards wind-power generation of electricity. The other point of view is that of the incredulous young adult in 2030 who berates his baby-boomer grandparent with the rhetorical questions, “You burned it all? All of it? In your stupid cars and furnaces?”

[2] This quote is from Page 280 of Gray RH, Bebbington J, Walters D, *Accounting for the Environment*, London: Paul Chapman, 1993.

[3] This quote is from Page 139 of Hawken P, *The Ecology of Commerce*. New York: HarperCollins, 1993.

[4] This quote is from Page 43 of World Commission on Environment and Development (the Brundtland Commission), *Our Common Future*, Oxford University Press, New York, 1987.

[5] The definition appears in Box 5a (Page 21) of *Sustainable Development for the 21st Century: Executive Summary*, Environmental Resources Management, Planning Department, Government of the Hong Kong Special Administrative Region, August 2000.

[6] The full text of the 1997 five-volume report of Canada’s Royal Commission on Aboriginal Peoples, *For Seven Generations*, is available at <www.indigenous.bc.ca>.

[7] This quote appears in Chapter 3 (Section 1.2) of Volume 2 of the Royal Commission report detailed in Note 6. It is from *Kaswentha*, an unpublished 1995 research study conducted for the Royal Commission by Paul Williams and Curtis Nelson.

[8] The full text of *Agenda 21* is available at www.un.org/esa/sustdev/agenda21text.htm.

[9] 'Kyoto' here refers to the Third Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC), held in Kyoto, Japan, in December 1997. The Conference adopted the text of a Protocol to the UNFCCC concerning emissions of six greenhouse gases (GHGs). The Kyoto Protocol has been signed by 84 countries, including China, and ratified or similarly adopted so far by 43 of these countries, including none of the major producers of GHGs (see <www.unfccc.int/resource/kpstats.pdf>). The Protocol comes into effect when ratified by 55 countries responsible for 55% of GHGs emitted in 1990. The United States, responsible for about 25% of the world's GHG emissions of human origin, indicated in March 2001 that she will not ratify the Kyoto Protocol.

[10] According to Table 2.3B of *OECD Environmental Data Compendium*, Organisation for Economic Cooperation and Development, Paris, 1999, worldwide carbon dioxide emissions from transport increased by 41% between 1980 and 1997, rising from 20% to 23% of total CO_2 emissions. Emissions from 'energy conversion' mostly electricity generation increased by 45% rising from 36% to 42% of all emissions. Overall, CO_2 emissions increased by 25% during this period.

[11] The possible need to have a lower reduction from transport than from other sectors is being discussed within the European Union. A recent study conducted for the European Climate Change Program concluded that without special intervention greenhouse gases (GHGs) emissions from transport in the EU will increase the most among the major sectors between 1990 and 2010 (transport +31%, services +14%, energy +1%, household uses 0%, agriculture -5%, industry -15%, etc.). This increase takes into account an agreement with car manufacturers to improve the fuel economy of new cars by about 25% during this period. Notwithstanding transport's major increase, the study proposes that to meet the EU's Kyoto Protocol requirement transport be expected to provide the *lowest* reduction in GHG emissions from the 'business-as-usual' level (4%, vs. for example, 12% for industry). This, the study concludes, is because reducing emissions from transport is expensive; only a small reduction from this sector can be achieved within the targetted reduction cost of €20/tonne of CO_2 equivalent. (See at Blok K et al, *Economic evaluation of sectoral emission reduction objectives for climate change*, March 2001, at <europa.eu.int/comm/environment/enveco/climate_change/sectoral_objectives.htm>.)

[12] The quote is from *Definition and Vision of Sustainable Transportation*, Centre for Sustainable Transportation, 1997, available at <www.cstctd.org>.

[13] The definition in Box 1 appeared initially, in a slightly different form, in the source detailed in Note 12. The version in Box 1 was formally adopted as the European Union's definition by the EU Ministers of Transport and Communications at their meeting in Luxembourg in April 2001.

[14] The quote is from the document *Hong Kong Moving Ahead: A Transport Strategy for the Future*, Transport Bureau, HKSAR, 1999, available at <www.info.gov.hk/tb/press/ahead.htm>. The other four 'betters' are: (1) better integra-

tion of transport and land use; (2) better use of railways as the backbone of Hong Kong's passenger transport system; (3) better public transport services and facilities; and (4) better use of advanced technologies in transport management.

[15] The quote is from Wang LH, In search of a sustainable transport development strategy for Hong Kong, *Policy Bulletin*, Hong Kong Policy Research Institute, No. 5, 1998, available at <www.hkpri.org.hk/bulletin/5/l-h-wang.html>.

[16] The quote is from the presentation entitled "Indicators for Sustainable Transport Policy" by Wing-tat Hung to the Better Air Quality Motor Vehicle Control and Technology Workshop, Hong Kong Polytechnic University, 2000.

[17] The submission to the Legco Panel was on 12 January, 1999, by seven professional staff of the University of Hong Kong's Centre of Urban Planning and Environmental Management entitled "Fundamentals of a more sustainable transport system for Hong Kong".

[18] The *National Conference on Sustainable Development Indicators* was organised by Canada's National Round Table on the Environment and the Economy (NRTEE) and held on March 27, 2001, as part of the NRTEE's mission to develop a method of public accounting that takes into account changes in resource and human capital. The NRTEE is a federal agency reporting directly to the Prime Minister. Statistics Canada is a federal agency changed with collecting and providing information about Canada.

[19] The database is available on a CD-ROM and is referenced as Kenworthy J, Laube F, *The Millennium Cities Database for Sustainable Transport*, Union Internationale des transports publics (UITP), Brussels, Belgium, 2001. It comprises some 250 indicators of various kinds for the year 1995 for each of 100 urban regions, comprising 60 affluent regions (in Australasia, Western Europe, Japan, and North America, plus Hong Kong and Singapore) and 40 other regions (in Africa, Asia, Eastern Europe, the Middle East, and Latin America). See also Note 21.

[20] 'Passenger transport' here normally refers to the motorised movement of people, as distinguished from 'freight transport', which is the motorised movement of freight. 'Passenger transport' includes the movement of persons driving their own vehicles, even though the term 'passenger' literally does not refer to them. 'Passenger transport' does not include the movement of persons operating buses, etc. Where there is reference to the *non-motorised* movement of people or freight, this feature is specifically indicated.

[21] Box 2, Box 3, and similar boxes have been developed from the source detailed in Note 19. The presumed causal factor is usually shown as the abscissa (residential density in Box 2) and the other factor is shown as the ordinate (public transport use in Box 2). Note that data have been used from only 52 of the 60 affluent urban regions in the database. The five regions with populations less than 500,000 were excluded (Berne, Bologna, Geneva, Graz, and Wellington). Also excluded were three urban regions with unusually large numbers of missing data points (Lille, Lisbon,

and Turin). These exclusions may in any case be beneficial in that they reduce the influence of Western European regions, which are over-represented in the database. A point of interest about the database is that Hong Kong had by far the fewest missing data points: exactly one! This was for an obscure variable named "Car equivalents per number of park and ride spaces". The urban regions with the next fewest missing data points—13 in each case—were Amsterdam, Budapest, Rome, San Francisco, and Vienna. By contrast, Lille, Lisbon, and Turin had respectively 128, 221, and 189 missing data points. The completeness of Hong Kong's data is a testament to the diligence of the SAR's public servants and to the comprehensiveness of its transport arrangements.

[22] For correlations where there are 52 data points, as in Box 2 and similar boxes, correlations >+0.35 or <-0.35 are significant at the 1% level, and correlations >+0.27 and <-0.27 are significant at the 5% level.

[23] Without the Hong Kong point, the trend line in Box 2 would be slightly steeper. The correlation between public transport use and density would still be +0.70.

[24] The main 'special factor' restraining car use in Singapore is a rationing scheme involving a monthly auction of a quota of Certificates of Entitlement to own a vehicle. (For more information on this scheme, see, for example, Willoughby C, Singapore's motorization policies 1960-2000, *Transport Policy*, vol 8, pp. 125-139, 2001.)

[25] High residential densities can restrain car ownership partly by making it inconvenient (e.g., when parking places are few and therefore expensive) and partly by making it unnecessary (most of what a car would be used for can be achieved by walking of public transport). As well, a contributing special factor in Hong Kong may be the First Registration Tax, which adds 40-60% to the price of a new car.

[26] A surprising feature of automobile ownership and use is that for a given country the distance travelled per vehicle is relatively constant from year-to-year. Thus each additional vehicle on the road appears to result in a specific increase in the total number of vehicle-kilometres, suggesting that ownership is a strong determinant of use. (For a fuller discussion of this point see Gilbert R, Reduced car ownership as a route to clean transport, *World Transport Policy & Practice*, vol. 4(3), pp. 21-26, 1998.) Also see Note 45.

[27] For the source of the information in Box 4 and Box 5, see Note 21. In these boxes, GDP values for the urban regions are represented in terms of purchasing-power parity (PPP), i.e., they are weighted by living costs in the respective countries. In 1995, Hong Kong as a distinct economy had the fourth-highest per capita GDP (PPP) in the world, after Luxembourg, the United States, and Switzerland (The Economist, May 9, 1998). Hong Kong's relatively low ranking in Box 4 and Box 5 suggests that in other economies, particularly those of European countries, there were large differences in affluence between larger urban regions and other areas.

[28] In Box 6 and Box 7, which have 18 data points, correlations >+0.59 and <-0.59 are significant at the 1% level, and correlations >+0.47 and <-0.47 are significant at the 5% level.

29 In Box 8, the correlation among the five affluent urban regions is significant at the 5% level; the correlation among the other 13 urban regions is significant at the 1% level.

30 Data in the table in Box 9 are from Table 1.1 (mid-year population) and Table 16.11 (land usage) of *Hong Kong Annual Digest of Statistics*, Census and Statistics Department, Hong Kong SAR, October 2000. There is no ready explanation for the discrepancy between the density value for 1995 derived from this source (358 persons/ha) and that in the *Millennial Cities Database* (320 persons/ha; see Section 2.1 and Note 19).

31 'Urban sprawl' has been characterised as the condition where "the amount of urbanized land increases much more rapidly than the urbanized population" (Gilbert R, Wood H, Brugmann J, *Urban Land Management and Global Sustainability*. Paper prepared for the 8th session of the United Nations Commission on Sustainable Development, April-May, 2000).

32 The amount of land to be released for development comes from the 2001 policy statement of the Secretary for Planning and Lands, *Developing Hong Kong*, available at <www.policyaddress.gov.hk/pa01/pdf/deve.pdf>.

33 Box 10 and Box 11 are from Table 8.8 of *Hong Kong Annual Digest of Statistics*, detailed in Note 30. Population data are from Table 1.1 of this source.

34 The public transport use per capita data in Box 10 include taxi rides, whereas the corresponding data in Box 2, Box 4, and Box 6 do not. This difference accounts for most of the discrepancy between the indicated per capita rates of use.

35 'Heavy rail' includes the metro lines (run by the Mass Transit Railway Co., or MTR) and the suburban East Rail line (run by the Kowloon and Canton Railway Co., or KCR).

36 'Light rail' includes the tramway routes on Hong Kong Island and KCR's light-rail line in the New Territories.

37 In Box 10 and Box 11, 'regular buses'—also known as Franchised Buses—refer to large, mostly double-decker buses running on fixed routes and schedules. 'Minibuses'—also known as Public Light Buses—refer to small, 16-seater buses that may run on fixed routes (green minibuses) and may not (red minibuses).

38 The 1990-1999 data concerning vehicle fleets in Box 12, and also those in Box 13 and Box 14, are from Table 8.9 of the *Hong Kong Annual Digest of Statistics*, detailed in Note 30; population data for these years are from Table 1.1 of this source. Year 2000 vehicle data are from the Transport Department Web site at <www.info.gov.hk/td/eng/transport/tf_menu_index. html>. Year 2000 population data are from Table 1.1 of *Hong Kong Monthly Digest of Statistics*, Census and Statistics Department, Hong Kong SAR, June 2001. The vehicle data in each case are 'total registered' rather than 'total licensed'.

39 'Private vehicles' comprise cars, including SUVs, etc. (91% and 92% of the totals in 1990 and 2000) and motorcycles (9% and 8%). Car ownership rose from 38 per 1000 in 1990 to 54 per 1000 in 2000.

40 For a given jurisdiction, the number of kilometres driven *per car* tends to be constant from year to year. (See Note 26.) This phenomenon is evident from the few relevant data available for Hong Kong. According to information in Annex B of *Clean Air for Hong Kong*, Planning and Lands Bureau, Hong Kong SAR Government, June 1999 (at <www.info. gov.hk/efb/ link/cleanair>), the average number of kilometres driven per car was 11,284 in 1991 and a hardly different 11,652 in 1997.

41 Data on air and marine freight from 1980 to 1990 are in a copy of a PowerPoint presentation provided by Civic Exchange, which shows China's Civil Aviation Department and other sources for this information. Information about container traffic for 2000 is from the Web site of PECT Co. (Korea), which puts Hong Kong first in container throughput in 1999 and 2000 with a 9.8% increase between these years from 16.1 to 17.8 million TEU. About 73% of seaborne cargo handled in Hong Kong is containerised, including essentially all transhipment cargo. (see *Sea Transport*, Hong Kong Trade Development Council, May 2001, at <www.tdctrade.com/main/si/spseat.htm>.) Information about air freight for 2000 is from the Web site of Airports Council International, which puts Hong Kong second in total freight loaded and unloaded, declining to third for the first six months of 2001 after a fall of 6.7% compared with the same period in 2000. (See <www. airports.org>.) Provisional data from the Airport Authority Hong Kong suggest that the amount of freight handled during the 12 months of 2001 fell by 7.4% from 2.25 to 2.08 million tonnes (Press Release, January 13, 2002 at <www.hkairport.com/pr1/ pr20020113. htm>).

42 For the Government's rail expansion plans see the document *Rail Development Strategy 2000*, Transport Bureau, Hong Kong SAR Government, May 2000. See also the 2001 policy statement by the Secretary for Transport, *A Safe, Efficient, Reliable and Environmentally Friendly Transport System*, available at <www.policyaddress.gov.hk/ pa01/pdf/transe.pdf>. Six schemes comprise the "preferred railway expansion network" until 2006. A seventh, the Port Rail Line, is described as "potential" for this period. Further expansion is being considered for the period 2007-2016; it would increase the network length above 250 kilometres.

43 Box 16 is based on Table 2.2 in Transport Department Hong Kong SAR Government, Wilbur Smith Associates Ltd. et al, *Third Comprehensive Transport Study*, *Final Report*, Hong Kong, 1999. See also Transport Bureau, Hong Kong SAR Government, *Hong Kong Moving Ahead: A Transport Strategy for the Future*, Hong Kong, 1999, and Loo A, *Strategic Air Quality Assessment of the Third Comprehensive Transport Study*, presentation at the Better Air Quality Motor Vehicle Control and Technology Workshop held at Hong Kong Polytechnic University, September 2000 (at <www. cse.polyu.edu.hk/~activi/BAQ2000/frames.htm>).

44 Box 17 is based on Table 2.3 of the first source detailed in Note 43.

45 Box 18 concerning energy use is based on the source detailed in Note 19.

46 Box 19 concerning energy efficiency is based on the source detailed in Note 19. *End energy use* in this instance means the energy supplied to the vehicle, sometimes known as 'secondary energy use' distinguished from *primary energy use*, which would include the energy consumed in supplying the energy to the vehicle, e.g., the energy used in electricity generation. The expression 'tertiary energy use' is sometimes employed to describe the energy actually used, e.g., by a car.

47 Box 20 and Box 21 concerning trends in energy use in Hong Kong are based on data in *Hong Kong Energy End-Use Data*, Electrical and Mechanical Services Department, Hong Kong SAR Government, 2001 (at <www. emsd.gov.hk/emsd/nf_eng/pee/edata_1x.htm >). Please see the strong caution in Note 117 concerning differences between the data in this source and the data in another source.

48 The estimates of changes in transport's energy efficiency were based on the vehicle-kilometre data in Annex B of *Clean Air for Hong Kong*, detailed in Note 40 and the energy use data in the source detailed in Note 47.

49 According to the most recent report by the the Intergovernment Panel on Climate Change (IPCC), "There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities". These words are in the *Summary for Policymakers* prepared by the IPCC's Working Group 1 as part of the IPCC's *Third Assessment Report,* available at <www.usgcrp.gov/ipcc/wg1spm.pdf>. The IPCC is a panel of some 2,500 climatologists and other scientists convened by the UN and the World Meteorological Organization to provide assessment of climate issues. The most authoritative dissent from the IPCC position concerns the *mechanism* of warming, rather than whether it is occurring (see Hansen J et al. Global warming in the twenty-first century: An alternative scenario. *Proceedings of the National Academy of Sciences*, vol. 97(18), pp. 9875-9880, August 29, 2000). The difference lies in the relative historical importance of aerosols vs. carbon dioxide. Both accounts point to fossil fuel combustion as the main cause of warming and both point to the need to reduce carbon dioxide emissions in the future.

50 According to the recent report of the IPCC's Working Group 2 (see Note 49), likely effects of increased warming include inundation of low-lying coastal areas from sea-level rise, increased deaths from heat stress and disease, decreased crop yields, and damage to buildings. The *Summary for Policymakers* of this report is available at <www.usgcrp.gov/ipcc/wg2spm.pdf>.

51 Carbon dioxide emissions were derived by using the emission factors for diesel oil, petrol, coal, and natural gas proposed by the U.S. Energy Information Administration (at <www.eia. doe.gov/oiaf/1605/factors.html>) and applying them to the data represented in Box 21, assuming that all 'other' is electricity with 67% losses from generation and distribution. The electricity generation mix (coal, oil, natural gas, nuclear) is from the APEC Energy Database at <www.ieej.or.jp/apec/database/felectricity1.html>, with the additional assumption that 7,700 gigawatt-hours of energy from the Guangdong Daya Bay Nuclear Power Station has been

used in each year since 1994, as indicated by the China Light & Power Co. at <www.clpgroup.com>. Thus, the mix in 1998 is assumed to be roughly 60% coal, 30% natural gas, and 10% nuclear. (The small amount exported across the border is ignored.). Population data are from the first source detailed in Note 30.

52 These comparisons of CO_2 emissions are from the source detailed in Note 10. They concern whole jurisdictions, not just urban areas. Information about CO_2 emissions is not readily available from the database detailed in Note 19. In the source in Note 10, Luxembourg is actually reported as having the highest CO_2 emissions per capita from transport (10.6 tonnes per year), but this could be an artefact of the way the data are collected, and to the U.S. is considered here to have the highest rate.

53 The actual ranks of Hong Kong in emissions per capita in the 52 urban regions represented in Box 23 are: carbon monoxide, 49; sulphur dioxide, 34; volatile organic compounds, 49; nitrogen oxides, 46.

54 Health effects of transport-related pollutants are noted in *Clean Air for Hong Kong*, detailed in Note 40. An authoritative comprehensive account of the effects of these pollutants appears in Elsom D, *Smog Alert: Managing Urban Air Quality*, London (UK): Earthscan Publications, 1996. See also the source detailed in Note 70.

55 The emissions data in Box 24, Box 25, Box 26, Box 27, and Box 29 are taken from the Web site of the Environment and Food Bureau of the Hong Kong SAR Government (see <www. info. gov.hk/epd/air/emission/main.htm>).

56 See Chan LY, Chan CY, Qin Y, The effect of commuting microenvironment on commuter exposures to vehicular emission in Hong Kong. *Atmospheric Environment*, vol 33, pp. 1777-1787, 1999. These authors found that the average carbon monoxide level within cars in Hong Kong traffic was 11,700 micrograms per cubic metre ($\mu g/m^3$), which is above Hong Kong's 8-hour Air Quality Objective of 10,000 $\mu g/m^3$.

57 For health effects of transport-related pollutants, see the sources detailed in Notes 54 and 70.

58 Of particular importance in the reduction of SO_2 emissions were the imposition of limits to the sulphur content of diesel fuel of 2,000 parts per million in April 1995 and of 500 parts per million in April 1997.

59 The initial combustion product is nitric oxide (NO). This is oxidised by ozone to form nitrogen dioxide (NO_2), the main oxide of nitrogen in urban air. This process depletes ground-level ozone levels near traffic. Thus, higher ozone levels are often experienced some kilometres downwind of traffic. Another transport-related pollutant is nitrous oxide (N_2O)—also known as 'laughing gas'—one of the six greenhouse gases targetted by the Kyoto Protocol (see Note 9). Formation of N_2O is a by-product of the action of catalytic converters. See the book by Derek Elsom detailed in Note 54 for further details.

60 According to *Clean Air for Hong Kong*, detailed in Note 40, petrol-fuelled vehicles produced 24% of NO_x emissions from road vehicles in 1997, and taxis produced another 12%.

[61] According to *Clean Air for Hong Kong*, detailed in Note 40, petrol-fuelled vehicles produced 58% of emissions of VOCs from road vehicles in 1997.

[62] The process of particulate formation in gasoline and diesel engines is a major topic of current research, as is the investigation of health effects. What is clear is that per unit of energy released, diesel engines produce more than five times as much respirable particulate matter as petrol engines. Specifically, diesel is responsible for 5.4 times as much PM_{10}—particulate matter with a diameter of less than 10 microns—and 8.0 times as much $PM_{2.5}$—particulate matter with a diameter of less than 2.5 microns. (This information is derived from data in *National Transportation Statistics*, Bureau of Transportation Statistics, U.S. Department of Transportation, 2001, available at <www.bts.gov>.) Increasingly, concern about health effects is turning to the effects of ultrafine particulates ($PM_{2.5}$), but longer-term data for Hong Kong (and most other places) are available only for PM_{10}, which includes $PM_{2.5}$. Ultrafine particulates are particularly susceptible to diffusion to the upper floors of high-rise buildings lining street canyons as are common in Hong Kong. (See Chan LY, Kwok WS, Vertical dispersion of suspended particulates in urban area of Hong Kong, *Atmospheric Environment*, vol. 34, pp. 4403-4412, 2000.)

[63] Box 28 is from Walsh MP, *Global Trends in Diesel Emission Regulation, A 2001 Update*, Society of Automotive Engineers, 2001.

[64] As might be expected from the information in Note 62, diesel vehicles contribute the largest portion of particulate matter from road vehicles: 98% of the total in 1997 according to *Clean Air for Hong Kong*, detailed in Note 40.

[65] Box 30 is based on information from 52 affluent urban regions in the *Millennial Cities Database* detailed in Note 19. It represented emissions data already presented in Box 23. Emissions of each pollutant was weighted by the average emissions from the represented cities for that pollutant. This was done to avoid the over-representation of carbon monoxide that would occur if amounts of the four types of pollutant were merely summed for each urban region. Finally, the values were adjusted so that the highest value (that for Hong Kong) was equal to 100.

[66] The information about reductions in emissions from road vehicles during 2000 is from Environmental Protection Department, *Environment Hong Kong 2001,* Hong Kong SAR Government, 2001. The implementation plan includes the following: (i) replacing diesel taxis with vehicles using liquefied petroleum gas (LPG) by 2007 (one in four had switched by the end of 2000); (ii) introducing diesel fuel with a sulphur content below 50 parts per million in 2000; (iii) more stringent enforcement of smoky vehicles; (iv) encouragement of use of particulate traps or catalytic converters; and (v) introduction of Euro III emissions standards for new vehicles from 2001.

[67] Projections of the road vehicle fleet in Box 31 are a consolidation of those in Box 16. Projections of vehicle kilometres travelled and emissions are from the third source detailed in Note 43. These are derived from the Strategic Environmental Assessment of the Third Comprehensive Trans-

port Study (CTS-3), conducted by ERM Hong Kong Ltd. and produced under the title *SEA Technical Report.*

68 Measures to reduce diesel emissions are listed in Note 66.

69 Box 32 presents, with additions, charts in the source detailed in Note 40. See Note 59 for a brief discussion of oxides of nitrogen.

70 For the World Health Organization guideline for NO_2, see Page 31 of *Guidelines for Air Quality*, WHO, Geneva, 1999 (at <lhtee.meng.auth.gr/AIR-EIA/METHODS/AQGuide/AQGuide.htm>).

71 The quote concerning NO_2 is from Page 30 of the source detailed in Note 70.

72 On Page 37 of the source detailed in Note 70, the observation is made that, "… long-term average exposures to low PM levels, starting at about 10 μg/m^3 of fine particulate matter), were associated with a reduction in life expectancy". 'Fine particulate matter' is usually considered to comprise particles with an average diameter of less than 2.5 μg/m^3 (i.e., $PM_{2.5}$). WHO notes that, "… in general, $PM_{2.5}$ is a better predictor of health effects than PM_{10}" (Page 39 of the source in Note 70). Perhaps about half of PM_{10} consists of $PM_{2.5}$; in which case a long-term PM_{10} standard might reasonably be set at 20 μg/m^3.

73 Information in this paragraph comes from the sources detailed in Notes 40 and 70. Hong Kong's 24-hour AQO for SO_2 is also much less stringent than the WHO guideline (350 vs. 125 μg/m^3). However, this WHO guideline is also not now exceeded in Hong Kong.

74 Ground-level ozone is distinguished from stratospheric ozone (the 'ozone layer'), which blocks some of the sun's ultraviolet radiation and is damaged by CFCs and other halocarbons, including the hydrochlorofluorocarbons (HCFCs) now used in vehicle air conditioners.

75 See the discussion of guidelines for ground-level ozone on Pages 33-36 of the WHO document detailed in Note 70.

76 For inhibition of ozone formation, see the discussion of nitrogen oxides in Note 59.

77 The information about changes in pollution levels with time of day is from *Clean Air for Hong Kong*, detailed in Note 40.

78 The estimate of a million residents affected by noise is from *Environment Hong Kong 2001*, detailed in Note 66.

79 For WHO's noise guidelines see *Guidelines for Community Noise*, World Health Organization, Geneva, 1999 (at <www.who.int/peh/noise/guidelines2.html>).

80 This rough estimate of exposure to excessive noise is based on work showing that 40% of EU residents are exposed to noise above 55 dB and 20% to noise above 65 dB (Lambert J, Vallet M, *Study Related to the Preparation of a Communication on a Future EC Noise Policy*. INRETS LRN Report No. 9420, INRETS - Institut National de Recherche sur les Transports et leur Sécurité, Bron, France, 1994.) Thus, if 16% of Hong Kong residents are exposed to transport noise above 70dB, perhaps 50% are exposed to transport noise above 55 dB.

81 In 2000, 60% of all complaints concerned air quality; 29% concern noise. 72% of the air quality complaints concerned road traffic. Only 4% of the noise complaints concerned traffic. Data are from *Environment Hong Kong 2001*, detailed in Note 66.

82 The Strategic Environmental Assessment of CTS-3 (see Notes 43 and 67) concluded that maximum noise levels would rise, and the noise criterion would be exceeded for more hours a day. Heavy vehicles would be the main source of the increased noise. (See Page 6-5 of the SEA report.)

83 According to the source detailed in Note 79, adverse effects of noise include hearing impairment, interference with speech communication, sleep disturbance, cardiovascular and physiological effects, mental health effects, interference with cognitive task performance, and annoyance.

84 The data in Box 33 are from the source detailed in Notes 19 and 21. Hong Kong's transport-related fatality rate was 7.6 per billion passenger-kilometres; the average for the 52 represented urban regions was 8.4. Per capita, the rate was 38.4 deaths per million residents; the average was 81.1. Hong Kong residents travelled an average of 5,020 kilometres within Hong Kong. The average such distance travelled for the 52 urban regions was 9,600.

85 The accident data in Box 34 were provided by the Traffic Branch of the Hong Kong Police Force as a supplement to *Traffic Annual Report 2000*. Note that the rates in Box 34 only include road vehicle accidents; hence there is a slight discrepancy between Box 33 and Box 34 in 1995 data for Hong Kong.

86 Data on trade as a percentage of GDP is at <www.asia-inc.com/img/apeci_map.pdf>. Some percentages are Singapore 163%, Hong Kong 132%, Malaysia 125%, Chinese-Taipei 47%, Canada 42%, China, 22%, Japan 11%, U.S. 10%. Data are for 1998 or 1999.

87 The breakdown of exports is from Table 3.3 of the source first detailed in Note 38. Of the re-exports, 61% came from China and 34% was heading for China. Thus, 95% involved China one way or another.

88 The information in Box 35 is based on relevant tables in the two sources detailed in Note 38.

89 The projections of increases in port activity are in *Port Development Strategy Review*, Hong Kong Port and Maritime Board, September 2001 (summary at <www.info.gov.hk/pmb/eng/board/exec.pdf>).

90 Projections of growth in air freight handled at Hong Kong International Airport do not seem to be available. The ultimate capacity is 9 million tonnes per year. Airport officials have noted in 2000 that this would be reached by 2010 if recent growth rates continued, which would be unlikely (Airport Authority *Newsletter*, May/June 2000, at <www.hkairport.com/ news1/news200005.htm>). As indicated in Note 41, air freight activity fell by 7.4% in 2001; with most of the decline occurring *before* the events of September 11.

91 According to a January 14, 2002, report carried by Xinhua, the Government of China's news agency, Shenzhen be-

came one of the world's 10 busiest container ports during 2001, having experienced an annual average freight handling growth of 44.6% over five years. See also Finer J, "Ties that Bind", *Far Eastern Economic Review*, December 20, 2001. For an assessment of the evolution of the container business in the Pearl river Delta, see Wang JJ, Slack B, The evolution of a regional container port system: the pearl River Delta, *Journal of Transport Georgraphy*, vol. 8, pp. 263-275, 2000.

92 For a useful quick summary of what accession to the World Trade Organization (WTO) means and its potential impacts on Hong Kong see Cheng LK, *China's accession to the World Trade organization and its effects on the Chinese and Hong Kong economies*, paper prepared for the Summer Study Program of the Hong Kong University of Science and Technology Business School, 2001, available at <www.bm.ust.hk/ summer_camp/wto.htm>. Cheng concludes that "Hong Kong has no choice but to develop into a knowledge-based, technology-intensive economy". A potentially significant feature of China's WTO accession is the informal extension of the Multifibre Arrangement (MFA) from 2005 to 2008. The MFA sustains the largest component of mainland shipments and re-exports through Hong Kong. For a deeper analysis of this aspect, see Feenstra RC, Hanson GH, *Intermediaries in Entrepôt Trade: Hong Kong Re-Exports of Chinese Goods*, Department of Economics, University of California, Davis, December 2000, available at <www.ucdavis.edu/ faculty/fzfeens/pdf/markups7.pdf>.

93 Estimates of the costs of transport to business are relatively rare. They do not exist for Canada, although they do for the U.S. (See Gilbert R, Nadeau K, *Decoupling economic growth and transport demand: a requirement for sustainability*, presentation to be made at a conference organised by the U.S. Transportation Research Board entitled "Transport and Economic Development", to be held in Portland, Oregon, in May 2002 (available at <www.ted2001.com>). This paper draws attention to the U.S. Transportation Satellite Accounts (see Fang B, et al, *Survey of Current Business*, pp. 14-22, May 2000), and also to the critical importance of transport for much economic activity (see Baum H, Kurte J, Paper presented at Round Table 119 of the European Conference of Ministers of Transport, *Transport and Economic Development*, February 2001).

94 Box 36 is based on the source detailed in Notes 19 and 21.

95 For this usage of 'hypermobility' see Adams, JGU, *The Social Implications of Hypermobility*. ENV/EPOC/PPC/T(99)3, Paris: OECD, pp.75-113 (1999).

96 The quotes are from Chapter 3 of the report on Phase 3 of the EST project, available at <www.oecd.org/env/ccst/est>.

97 The only readily available international comparison of residential floor area per person seems to have inaccurate data on Hong Kong. It is at the Web site of the Department of Real Estate and Urban Land Economics of the University of Wisconsin (at <www.bus.wisc.edu/realestate/docs/inthsg2.pdf>, and suggests that residential floor area in Hong Kong was 7.1 square metres per person in 1993. Among the 16

affluent urban regions listed, Tokyo residents had the next lowest amount of floor area per person (15.8 m^2), those of Singapore had the third lowest at 20.0 m^2, and those of Washington DC had the highest at 68.7 m^2. The unweighted average for the 16 affluent urban areas was 32.4 m^2. The unweighted average for the 35 listed urban regions with 1995 GDP below US$10,000 was 11.8 m^2. What is almost certainly a more accurate source gives the average unit size as 47.9 m^2 in 1993 (Wong YCR, How severe is the housing shortage in Hong Kong? *Hong Kong Centre for Economic Research Letters,* vol. 42, January 1997, at <www.hku.hk/hkcer/articles/v42/wong.htm>). Taken with the estimate in that source of the number of units in that year (3.22 million) and the population estimate (5.90 million), this gives a floor area per resident of 26.1 m^2, almost four times that indicated in the earlier source! but still below the average indicated in that source. (This difference is much too large to be explained in terms of definitional differences as to what constitutes floor area. It is spelled out here to indicate the perils of relying on such international comparisons.) The last set of sources and calculations applied to the whole set of available data suggest that residential floor area per person in Hong Kong increased from 21.9 to 26.2 m^2 between 1983 and 1996. The best guess of several experts as to the current average floor area per resident of the Toronto region is 50 m^2.

98 See Fung BCK, *Planning for High-Density Development in Hong Kong*, presentation prepared for the Cities Summit 2001, Singapore, September 2001.

99 For a useful overview of the recent literature on crowding and health see Beggs PJ, Siciliano F, Spatial relationship between dwelling crowding and selected cases of morbilidy in Sydney, Australia, 1994-97, *Australian Geographer*, vol. 32(3), pp. 377-401, 2001.

100 For infant and child mortality rates see the United Nations Statistics Division, *Indicators on Health*, at <www.un.org/Depts/unsd/social/health.htm>.

101 This estimate is mentioned as being in the report known as "LegCo Paper CB(2)2073/99-00(01) 23/5/2000" referred to on Page 13 of *Clearing the Air*, Hong Kong Citizens Party, June 2000 (available at <http://www.legco.gov.hk/yr99-00/english/panels/tp/papers/2460e01.pdf>). A higher estimate (more than HK$12 billion) was noted in the Friends of the Earth's *Response to the Proposal to Introduce LPG Taxis*, submission to the Transport panel, Legco, November 1998 (available at <www.foe.org.hk/en/campaigns/images/98-11. doc>).

102 For a comprehensive estimate of the external, social or unpaid costs of transport see INFRAS (Zurich), *External costs of transport: Accident, environmental and congestion costs in western Europe*, prepared for the Union Internationale des Transports Publics, Brussels, March 2000.

103 For cars as means of expression, see, for example, Marsh P, Collett P, *Driving Passion: The Psychology of the Car*, London: Jonathan Cape, 1986.

104 For worldwide oil use, see *World Energy Outlook*, International Energy Agency, Paris, 2000. See also *BP Statistical*

Review of World Energy, June 2001, available at <www.bp.com/ downloads/702/ BPwebglobal.pdf>.

105 See MacCready PB, "Vehicle efficiency and the electric option", in Greene DL, Dantini DJ, *Transportation and Global Climate Change*. American Council for an Energy-Efficient Economy, Washington DC, 1993, pp. 147-158.

106 United States Geological Survey, *Press Release*, March 22, 2000.

107 See, for example, Campbell CJ, Laherrère JH, The End of Cheap Oil. *Scientific American*, pp. 78-83, March 1998. For an especially compelling overview of this perspective, see the presentation made by geologist Colin Campbell at the Technical University of Clausthal, Germany, in December 2000, available at <energycrisis.org/de/lecture.html> together with a video of the event. The whole matter has been reviewed in a recent book: Deffeyes, KS, *Hubbert's Peak: The Impending World Oil Shortage*, Princeton University Press, 2001. Deffeyes concluded, "This much is certain, no initiative put in place starting today can have a substantial effect on the peak production year. No Caspian Sea exploration, no drilling in the South China Sea, no SUV replacements, no renewable energy projects can be brought on at a sufficient rate to avoid a bidding war for the remaining oil. At least let's hope that the war is waged with cash instead of with nuclear warheads. … So when does world oil production peak and start downward? That's the big enchilada. … The mathematical peak falls at the year 2004.7; call it 2005. However, I'm not betting the farm that the actual year is 2005 and not 2003 or 2006. … There is nothing plausible that could postpone the peak until 2009. Get used to it." (pp. 149, 157-8).

108 See Laherrère J, *Is the USGS assessment reliable?* World Energy Council Cyberconference, May 19, 2000, at <energyresource2000.com>. Deffeyes (see Note 107) wrote the following on the USGS estimates: "…the 262-billion-barrel estimate issued by the U.S. Geological Survey in 2000 is way out in right field. To make the USGS estimate come true, there would have to be new U.S. oil discoveries that add up to the reserves of Kuwait. … The USGS estimate is again implausibly high. Its number, 3.012 trillion, requires discovering an additional amount of oil equivalent to the entire Middle East." (pp. 154-5, 157) It should be noted that the USGS does not speak with one voice. One of the strongest expositions of the position most identified with Campbell and Laherrère (see Note 107) is a poster prepared by LG Magoon of USGS, available at <geopubs.wr.usgs.gov/ open-file/of00-320>.

109 See, for example, Salameh MG, Can the oil price remain high? *Petroleum Review*. pp. 42-22, April 2000, and also Rubin J, Buchanan P, *Why oil prices will have to go higher*, Occasional Report #28, CIBC World Markets Inc., Toronto, Canada.

110 Box 37 is taken from *Sustainable Transportation Monitor* No. 2, February 1999, and from the sources indicated there (available at <www.cstctd.org>). This issue of the *Monitor* provides further discussion of the basis for Box 37.

111 IEA's 1998 *World Energy Outlook* was more explicit than the 2000 *WEO* (see Note 104 for the full reference) in its

endorsement of the kind of model proposed by Campbell and Laherrère (see Notes 107 and 108 and associated text). The 1998 *WEO*'s middle projection pointed to a peak in the production of conventional (i.e., cheap) oil in or near 2013.

[112] Box 38 is from a presentation by Jean Laherrère at an OPEC conference entitled *OPEC and the global energy balance: Towards a sustainable energy future*, held in Vienna in September 2001, available at <www.oilcrisis.com/laherrere/opec2000.pdf>.

[113] See Note 51 for the mix of fuels for electricity generation in Hong Kong.

[114] For coal availability, see the sources detailed in Note 104.

[115] The comparison in Box 39 of life-cycle emissions from electricity generation is based on Table 17 in Spath PL, Mann MK, *Life Cycle Assessment of a Natural Gas Combined-Cycle Power Generation System*, National Renewable energy Laboratory, U.S. Department of Energy, September 2000 (available at <www.nrel.gov/docs/fy00osti/27715.pdf>).

[116] See Note 46 for explanation of the differences among the different kinds of energy use, primary, secondary, etc.

[117] The information in Box 40 for 1990 and 2000 concerning primary energy use comes from the APEC source detailed in Note 51. There are rather large discrepancies between this information and that for end energy uses in Box 20 and Box 21. (Also see Notes 47 and 119.) Resolution of these discrepancies cannot be achieved at the time of writing, and so all these estimates should be treated with great caution. The emission factors used in Box 40 were these: for NO_x, 377, 930, and 208 grams per megajoule for oil, coal, and natural gas respectively. For GHGs, the corresponding factors were 63.0, 90.0, and 43.3 kilograms per megajoule. They are based on the information on which Box 26 and Box 39 are based (i.e., the sources detailed in Notes 55 and 115). These emission factors were assumed to hold until 2030 (i.e., total emissions at these levels of energy use could well be lower). The energy use data and projections have been rounded to make for a cleaner presentation.

[118] Denmark, the present leader in wind-powered electric power generation plans to produce 10% of its supply from wind turbines by 2005 and 20% by 2020. See Andersen PD, *Review of Historical and Modern Utilization of Wind Power.* Risø National Laboratory, Denmark, 1999 (at <www.risoe.dk/vea-wind/ history.htm>). The source in Note 126 suggests that already in 2001 as much as 15 per cent of Denmark's electricity may come from wind.

[119] The end use data in the source in Note 47 point to a higher current share of electric power in the end use energy mix, about 46% in 1998. As pointed out in Note 117, the discrepancy between that estimate and the one derived from the information in Box 40 cannot presently be resolved. The actual current mix would affect the details of the implementation strategy, but it does not affect the validity of the proposal to move towards almost exclusive reliance on electric power generated by renewable means.

[120] To understand how much land is required to produce biofuel for vehicles, it is worth considering the recent estimates of David Pimentel. He concluded that production of a year's supply of ethanol from corn for the typical car in the U.S. would require approximately one hectare of land, which can be compared with the 0.6 ha required per American for food production. Pimentel also noted that about 70% more energy is required to produce the corn than is available in the ethanol. (See Pimentel D, "Biomass Utilization, Limits of" in *Encyclopedia of Physical Sciences and Technology*, Third Edition, Volume 2, Academic Press, New York, in press, 2002, proof available at <www.academicpress.com/epst/biomass.pdf>.)

[121] The difference between a battery and a fuel cell is this. A battery is recharged by applying electricity, thereby reversing the chemical processes that depleted the electrolyte during the provision of electricity. A fuel cell is recharged by replenishing the electrolyte, which is usually a mixture of oxygen in air and supplied hydrogen. Some systems have the qualities of both, notably the zinc-air battery/fuel cell, which uses replaceable cassettes of zinc pellets in electrolyte as fuel. Conversion to zinc oxide produces usable electricity. Off-vehicle regeneration recharges the zinc oxide to zinc that can be used again.

[122] For the auto companies' strategies, see Crosse J, Fuel cell future. *Automotive World*, pp. 38-43 November 2000.

[123] The hydrogen infrastructure programme is misleadingly dubbed 'FreedomCAR'. It replaces an 8-year old program named Partnership for a New Generation of Vehicles that had the goal of quadrupling the energy efficiency of the average U.S. car by 2004. See the press release of the U.S. Department of Energy at <www.energy.gov/HQPress/releases02/janpr/pr02001.htm>.

[124] The various points in this paragraph concerning hydrogen are covered in more detail in *Cleaner Vehicles and Fuels: The Way Forward*, Civic Exchange, Hong Kong, July 2001, and also *Sustainable Transportation Monitor*, Issue No. 5, Centre for Sustainable Transportation, Toronto, Canada, November 2001, and in the sources cited in these documents.

[125] The estimate of a >60% loss was taken from the report by the Paul Scherrer Institute (Switzerland) for the International Energy Agency, at <www.eren.doe.gov/hydrogen/iea/pdfs/ chapter4.pdf>. This estimate includes only electrolysis and fuel-cell losses. Storage losses (including compression) can also be considerable. Moreover, the assessed system was stationary; mobile systems are generally less efficient.

[126] See Chapter 5 of Brown L, *Eco-Economy: Building an Economy for the Earth*, WW Norton & Co, New York, 2001.

[127] On Vestas, see Ward A, "Danish economy facing wind of change", *Financial Times (London)*, August 24, 2000. See also the Web page of the company at <www.vestas.com>.

[128] Information about the Irish Sea development is available at <www.ens-news.com/ens/jan2002/ 2002L-01-14-01.html)>.

[129] See Pengfei S, *Wind energy resource in China and planning of wind farm development*, presentation at U.S./China Renewable Energy Forum, April 2000, at <www.nrel.gov/international/china/pdfs/re_forum/china_wind_energy_resource.pdf>.

[130] For installed electricity generating capacity see the source detailed in Note 51.

[131] An excellent presentation of the potential for off-shore generation of electricity by wind turbines was made by Eric Walker of Friends of the Earth Hong Kong at the Business Environment Council's Annual Business and Environment Conference, Hong Kong, October 2001. Eric Walker noted that offshore turbines can exploit strong winds at lower heights using shorter towers at lower cost. He noted too that the shallow continental shelf off Hong Kong is ideal for offshore wind development. (This presentation is available at the Business Environment Council Web site at <www.bec.org>, but only with a password.)

[132] With 5-megawatt turbines spaced at 200 metres, about 800 square kilometres are required to install 100 gigawatts of capacity. Hong Kong's sea area is more than 1000 km^2.

[133] The estimate of the required electric power generating capacity is based on the scenario sketched out in Box 40, which assumes capacity in 2030 of about twice the present level of 11 megawatts.

[134] For a record of wind speeds at Wagman's Island, see <www.hko.gov.hk/wxinfo/climat/ normals.htm>).

[135] For analysis of the operating ranges of wind turbines, see <www.windpower.dk/tour/wres/ powdensi.htm>.

[136] See the book by Lester Brown detailed in Note 126.

[137] For details about and reports on the OECD's EST project see <www.oecd.org/env/ccst/est>.

[138] What is referred to here is also known as the *Protocol to Abate Acidification, Eutrophication and Ground-level Ozone* and is set out at <www.unece.org/env/lrtap/protocol/99multi.htm>.

[139] See the Convention Web site at <www. unfccc. int>.

[140] The criterion for reduction in emissions of GHGs from transport (chiefly carbon dioxide from the burning of fossil fuels in internal combustion engines) was derived from the work of the UN's Intergovernmental Panel on Climate Change (see Note 49). The IPCC's 1995 assessment had concluded that overall reductions in GHG emissions to at least 50% below 1990 levels would be required to present catastrophic climate change (Houghton JT et al, eds, *Climate Change 1995*. Cambridge University Press, 1996), a position reinforced by subsequent work (see <www.usgcrp.gov/ipcc/ wg1spm.pdf). Participants in the OECD's EST project concluded that for rich countries—such as those that comprise most of the membership of the OECD—reductions by at least 80% would be required to allow poorer countries greater opportunities for economic development than they might face with a blanket 80% cut. Thus the EST criterion for reduction in GHG emissions became attainment of absolute levels of GHG emissions that

would be no more than 20% of absolute 1990 levels. This line of thinking influenced the vision and definition developed by the Centre for Sustainable Transportation (see Note 12 and associated text).

141 See *Stage 1 Public Consultation Planning Objectives and Key Study Areas* concerning the proposed study *Hong Kong 2030: Planning vision and Strategy*, Hong Kong SAR Planning Department, at <www.info.gov.hk/hk2030/>.

142 The projections in CTS-3 (see Box 16) speak to at least a 45% increase in road traffic by 2016, and perhaps a 148% increase, both over 1997 levels. The 45% increase extrapolated to 2032 would amount to 63% increase over 2002 levels. Likewise, the 148% increase translates into a 168% increase over 2002 levels.

143 The estimate of transport energy in 2002 is derived from extrapolation of information in Box 20.

144 Put another way, current emission levels of these pollutants are similar today to what they were in 1990 and are projected to be similar again in 2016 and thus 2032. Accordingly, they are and will be 10 times or more above the sustainability target of 90% or more below 1990 levels.

145 Box 42 is Figure 2 of *Feasibility study of introducing a trolleybus system in Hong Kong*, prepared in May 2001 by Atkins China Ltd. for the Hong Kong SAR Transport Department. The report concluded that "Trolleybuses cost considerably more than motor buses and are less flexible in use, but they offer potential environmental benefits with respect to air quality and noise." Subsequently, the Transport Department has argued against the introduction of trolley buses in built-up areas although not in new development areas. The greater environmental benefits of trolley buses over diesel buses were not considered to be sufficient to justify their greater costs. There was no consideration in the assessment as to the role trolley buses could play in a transport system constrained by reduced availability of oil. For the June 2001 report by the Transport Department to the Legislative Council Panel on Transport see <www.legco.gov.hk/yr00-01/english/ panels/tp/papers/a1575e03.pdf>. For a more optimistic (and informative) view of trolleybuses see <www.tbus.org.uk/home.htm>.

146 Lorries powered through trolley arrangements are relatively unknown. A full exposition of dual-mode off-road systems was provided by Walter Koellner of Seimens Energy & Automation, Inc. at "Haulage 2001", held in Tucson, Arizona, March 2001 (see <www.sea.siemens.com/miningbu/docs/Haulage_2001_Presentation.PDF>. He argued that with 'trolley assist' a reduction in fuel consumption of 70-70% over the entire haul cycle is typical, more power can be provided, noise is low, emissions are negligible, and maintenance costs are greatly reduced. There appears to be at least one example in Russian of on-road trolley lorries and vans (see <www.oubeck.com/reports/russia/russia_1995.htm>).

147 This assumption is based on the source detailed in Note 125 and the discussion in that note.

148 The information concerning 2002 in Box 43 is based on that in Box 17.

149 The estimate that <3% of freight transport within Hong Kong involves rail is based on the following. According to Table 8.4 of the source first detailed in Note 38, about 1.2% of the freight other than livestock crossing the land border in 1999 went by rail. If all the livestock carried by the KCRC also went across the border (see Page 148 of KCRC's *AnnualReport 2000*) allowing 0.5 tonne/head, the percentage carried by rail is 2.7%. Because it seems extremely unlikely that a higher percentage of local freight movement within Hong Kong is carried by rail, this 2.7% could well be the upper bound. Hence the rounded use of 3%.

150 Special attention could be paid to proposals to link Singapore and London by rail via Guangzhou, also Guangzhou to Istanbul via New Delhi, and also Guangzhou to Tokyo via Beijing and Seoul (see Wehrfritz G, "The Orient Express", *Newsweek*, Special Issue, July-September 2001. This article notes that China is laying 600-1000 kilometres of new track as year, a rate higher than that of the U.S. at the height of its 19th-century rail boom. This frenzy of rail-directed activity could offer numerous opportunities to Hong Kong, as well as challenges to its port and airport. Strengthening of freight rail links between Hong Kong and Guangzhou would seem to be a pre-requisite to making the most of the opportunities.

151 The quote is from the speech by John C Tang at the Asian Institute of Intelligent Buildings dinner on January 14, 2002, available at <www. info.gov.hk/gia/general/200201/ 14/0114187.htm>.

152 The emphasis here on conventional rail and trolleybuses should not preclude investigation of alternative systems such as the elevated electric transit system proposed for the north shore of Hong Kong Island (see Eastham TR, Masada E, *Electric Urban Transit Technologies for the Reduction of Air Pollution in Cities*, paper prepared for the MAGLEV2000 conference, Rio de Janeiro, Brazil, September 2000.

153 For aviation's costs, see Figure 10-1 of the report on aviation of the Intergovernmental Panel on Climate Change: Penner JE et al. (eds.) *Aviation and the Global Atmosphere.* Cambridge University Press, Cambridge UK, 1999.

154 According to Table 8.4 of the source first detailed in Note 38, in 1999, 40.6 million tonnes was moved by river and 38.5 million tonnes by road. Note that over the 1990s, river freight grew more rapidly for movements out of Hong Kong (an increase by 7.0 vs. 2.9 times), whereas river freight grew less rapidly for movements into Hong Kong (an increase by 2.9 vs. 3.3 times).

155 See particularly Tables 5 and 21 of Bayliss D, *Buses in Great Britain: Privatisation, Deregulation and Competition*, paper presented at the World Bank conference "Transport Expo 99", Washington DC, April 1999, available at <www.worldbank.org/ transport/expopres/ bayliss1.doc>.