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

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

Table 2.1: World transport energy use by mode

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

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

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

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

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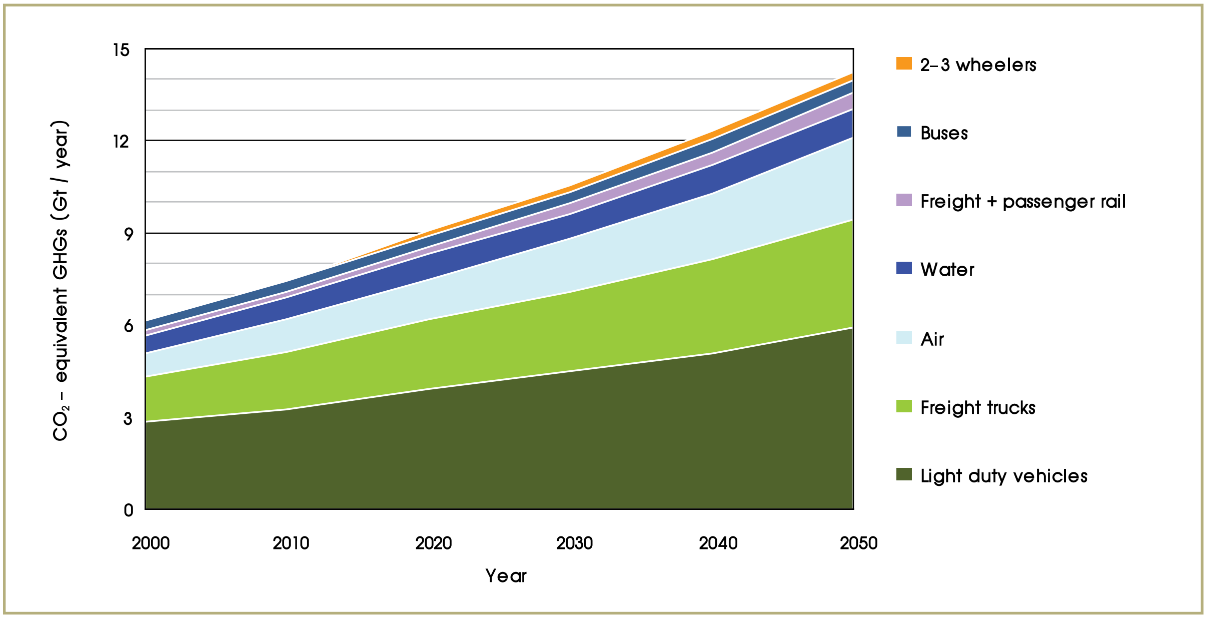
Despite significant advances in energy productivity, current rates of energy reduction for various transport modes, such as cars and aeroplanes,[8] are not keeping pace with the rapid growth of these modes. As can be seen in Figure 2.1, in 2001 cars (light duty vehicles) and freight trucks accounted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

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



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

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

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

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

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

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

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

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

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

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

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

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

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

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

How do cities vary in their transport greenhouse emissions?

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

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

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

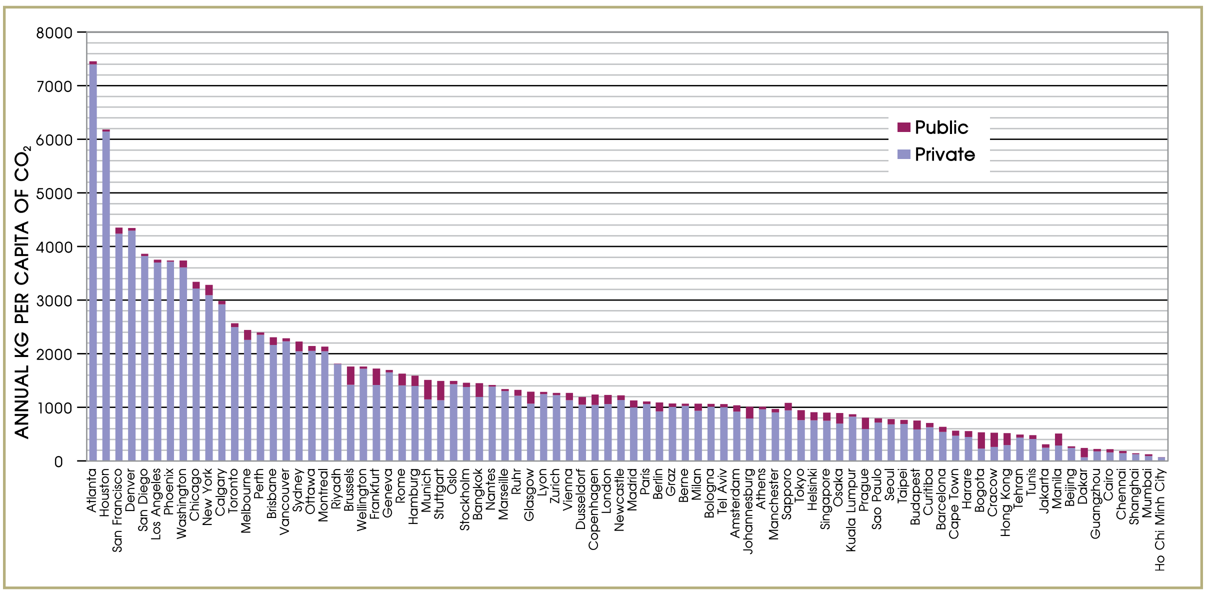


Table 2.4: Greenhouse gas emissions from transport per capita in low income cities

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

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

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

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

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

How does transport greenhouse vary by mode?

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The key insights from the above data are:

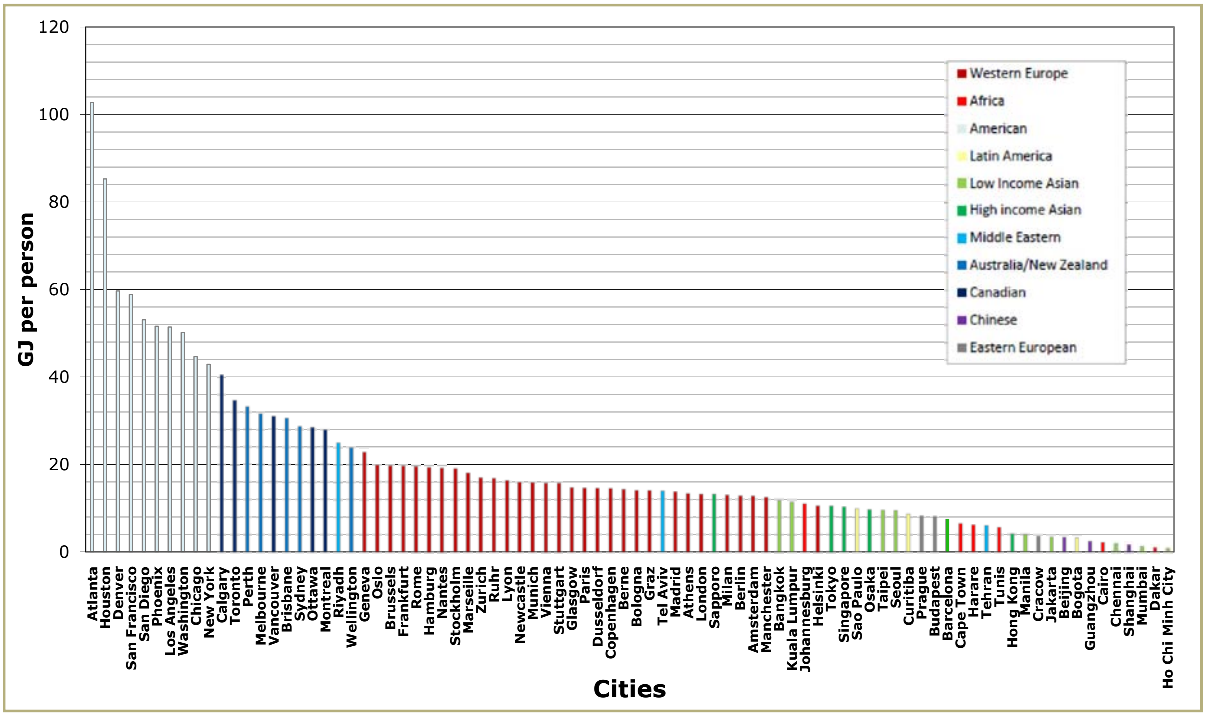
- Except for trams and light rail in Eastern European cities, rail modes use less energy than buses per passenger km in each region.
- There is, on average, not a huge difference in energy consumption between the different rail modes, and on average, rail systems in cities use about half the energy of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

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

Patterns of transport energy use

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

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



These data show:

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

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

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

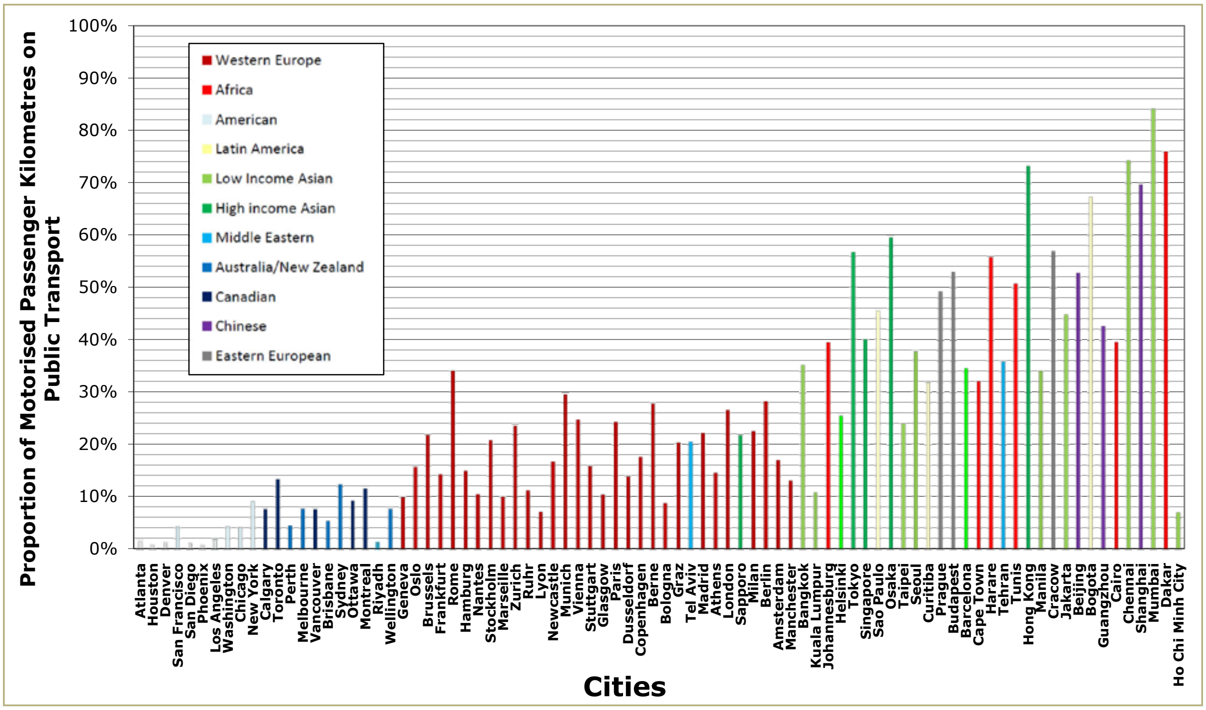


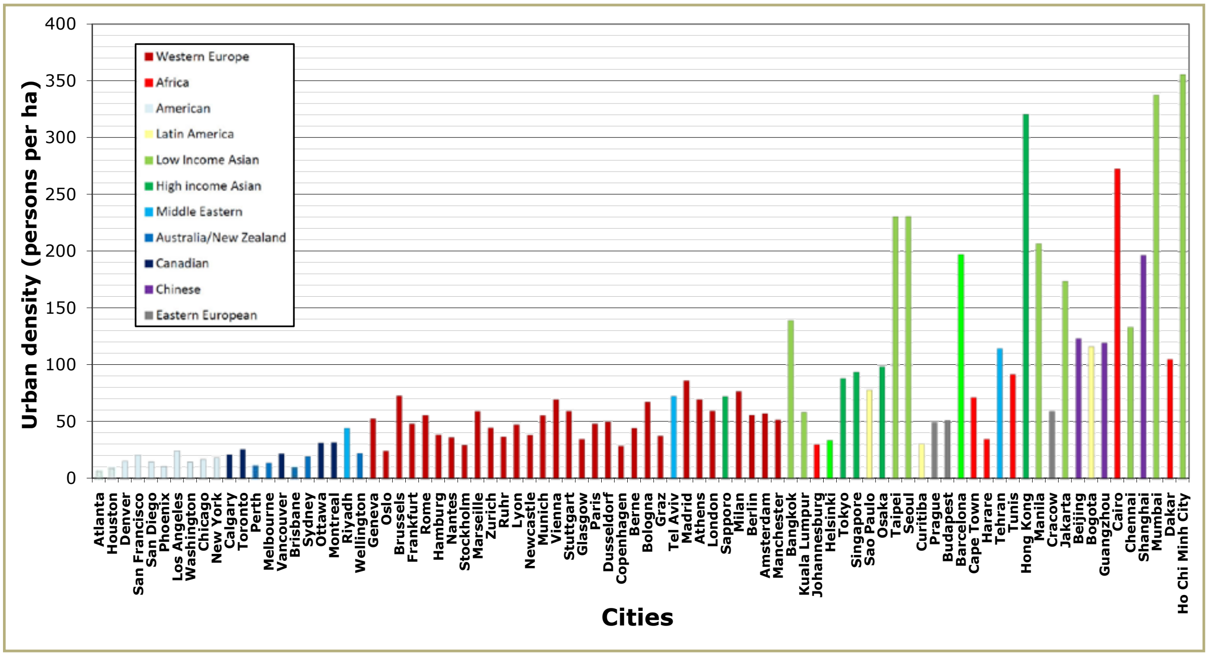
Figure 2.4 sets out the variations in the use of public transport as a proportion of all motorised transport used in the 84 cities, It shows a very large spread across these cities:

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

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

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

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



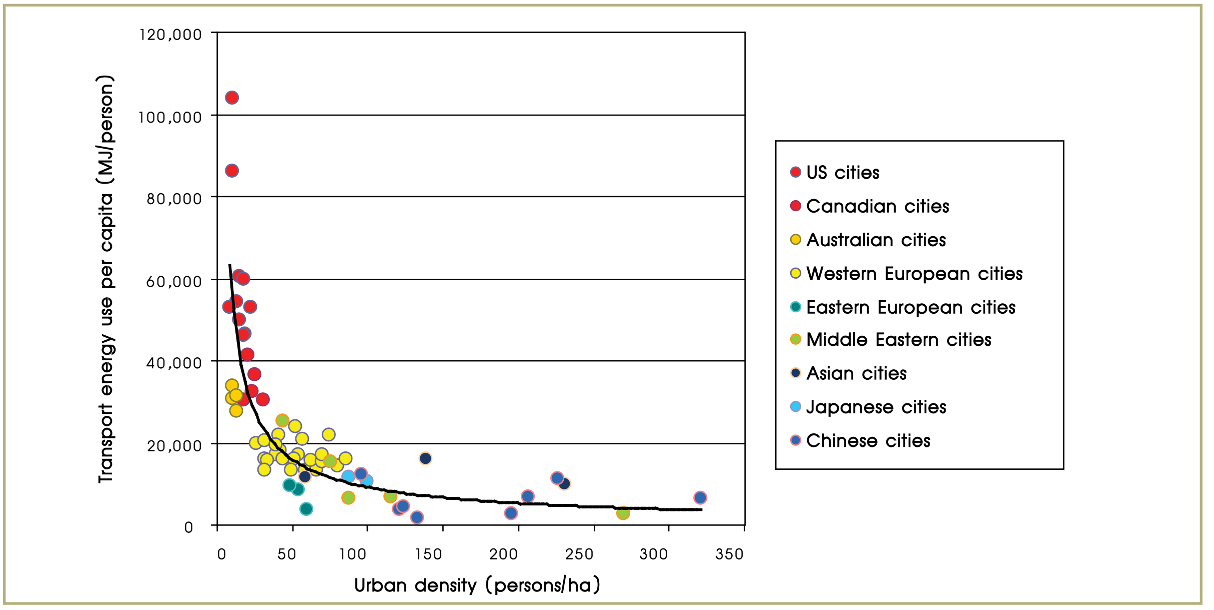
In Table 2.9 below the patterns of density are summarised in the regional groups of cities and are also related to the amount of walking and biking (called Non-Motorised Transportation or NMT).

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

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

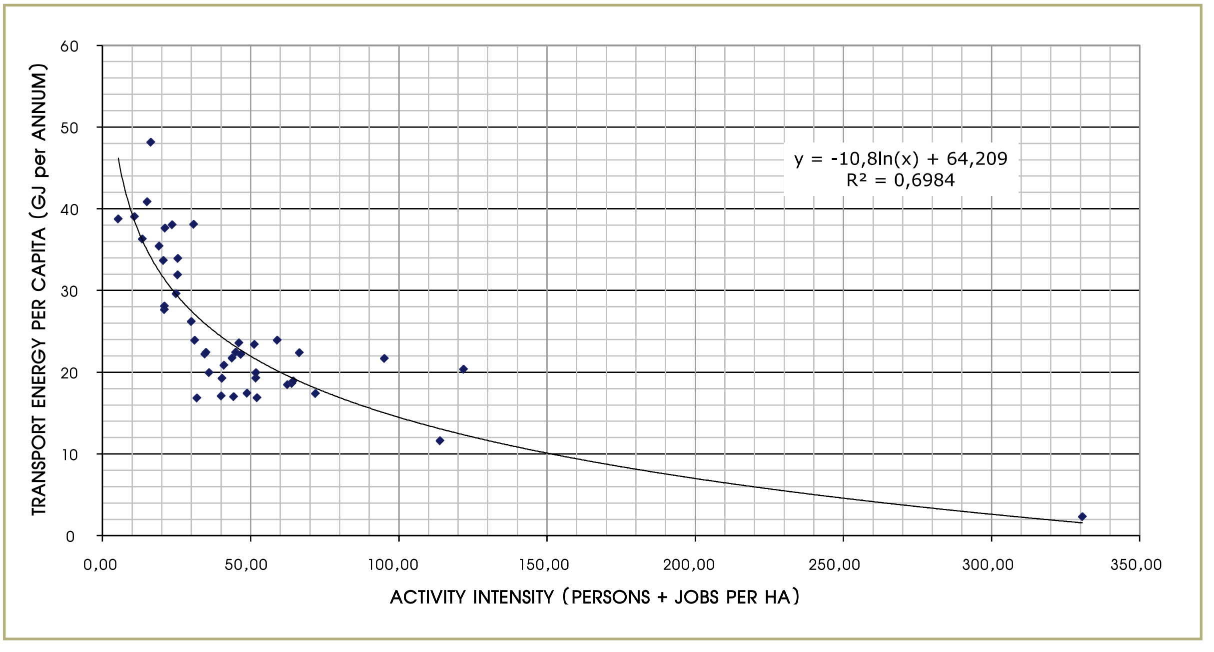
This relationship between transport energy use and density is also apparent within cities. Figure 2.7 shows the same pattern in relation to transport energy and density (of population and jobs) across Sydney's suburbs. The density of activity is very high in the centre and there the fuel use is similar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

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



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

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



Calculating greenhouse gas savings from sustainable low carbon policies

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

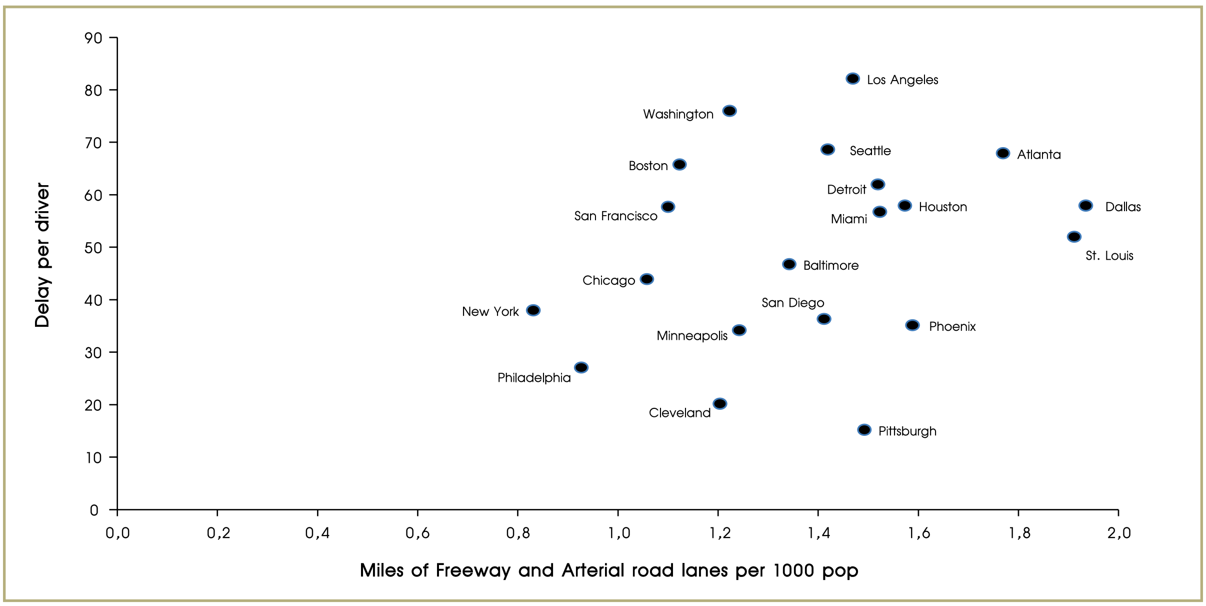
Drivers may use the savings from driving fuel efficient vehicles to simply drive more. This is called the Jevons Effect after the nineteenth century economist who predicted that more efficient coal-fired electricity would mean more coal was needed, not less.

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

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

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

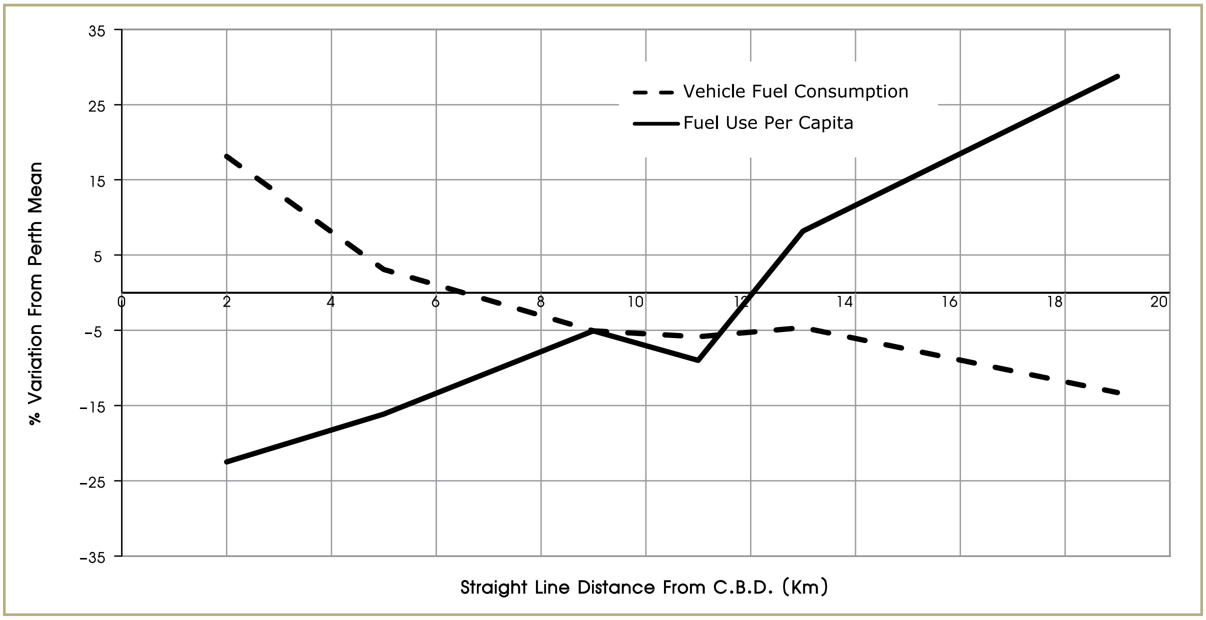
Figure 2.8: Miles of freeway and delay are not correlated in US cities



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

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

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



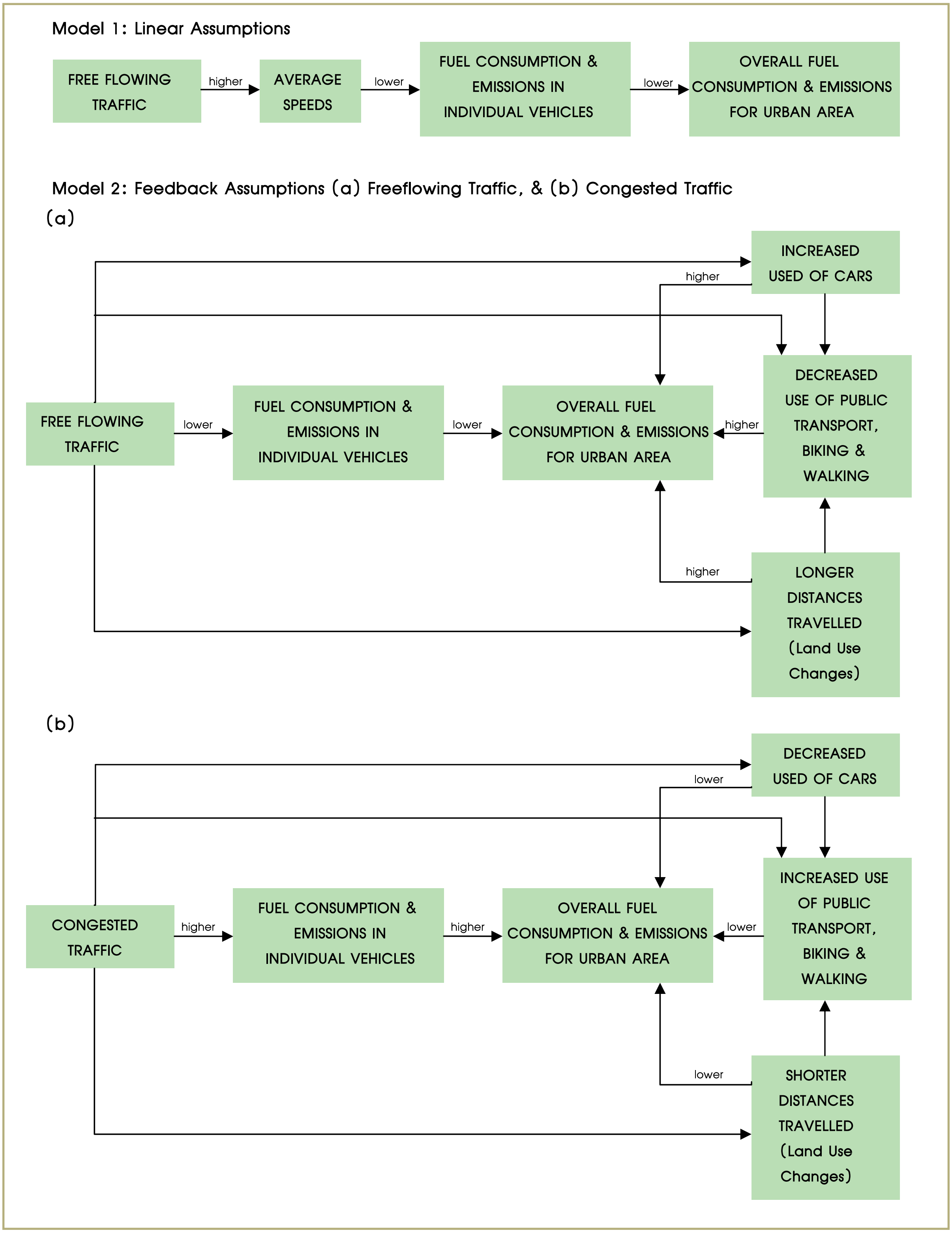
Data Source: P Newman & J Kenworthy, Cities and Automobile Dependence: An International Sourcebook, Gower, Aldershot, 1989.

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

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

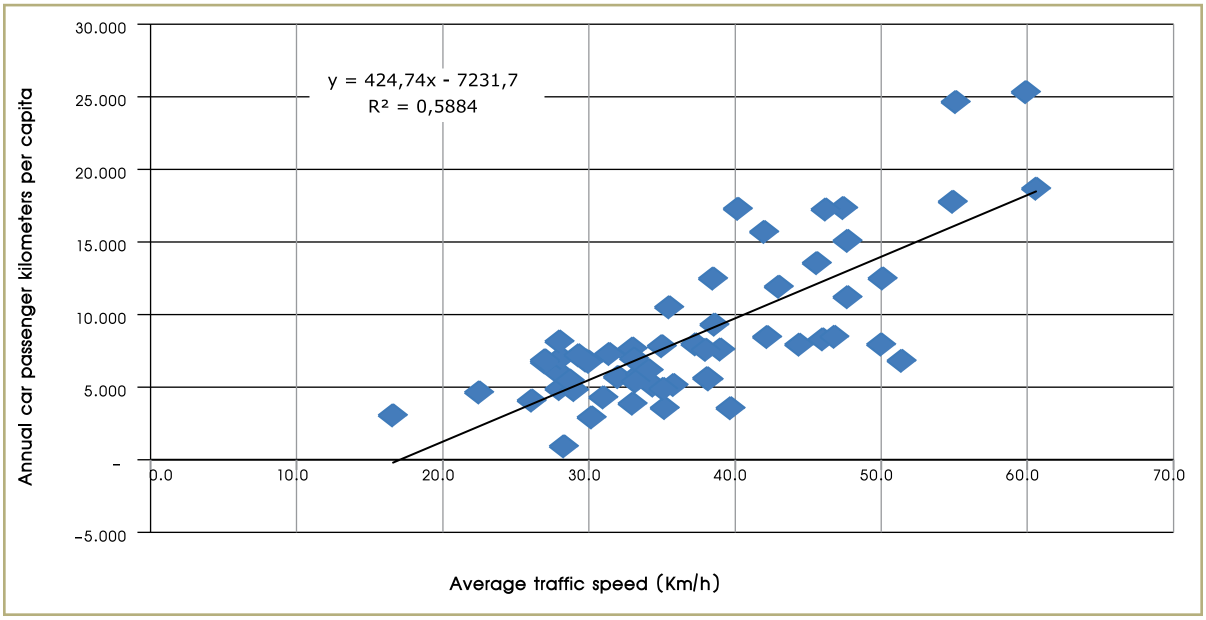
In contrast to the three reasons why there is a tendency to greatly overestimate the greenhouse gas reductions from the availability of more fuel efficient vehicles and more smooth flowing traffic (in fact there will often be increases rather than reductions), there is also a tendency to underestimate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

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



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

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



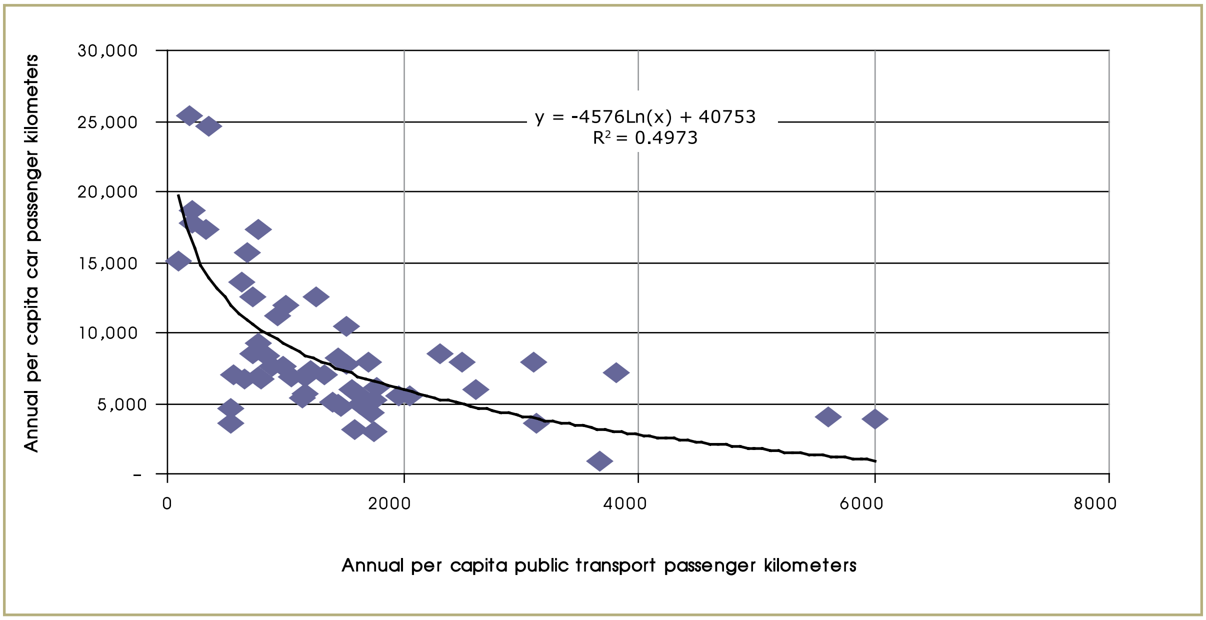
Box 2.2. A more sustainable way to reduce congestion

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

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

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

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



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

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

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

Endnotes

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6. P Newman & J Kenworthy, 'Greening Urban Transportation', in State of the World 2007: Our Common Future, The Worldwatch Institute, 2007.
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8. S Davidson, 'Air transport impacts take off', ECOS: Towards a Sustainable Future, Issue 123, CSIRO, 2005.

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10. Michael Renner, 'Global Auto Industry in Turmoil, but Chinese Production Surges', , Vital Signs, World Watch Institute, Washington DC, 11 Feb 2010.
11. Summarised in P Newman & J Scheurer, The Knowledge Arc Light Rail, CUSP, Curtin University, Perth, 2010, (http://sustainability.curtin.edu.au/research_publications/publications.cfm, viewed 23 Feb 2011.) and for eight nations in A Millard-Ball & L Schipper, 'Are we reaching peak travel? Trends in passenger transport in eight industrialised countries', Transport Reviews (in press).
12. Although the data in Table 2.3 are from 1990, some partial updated data currently being processed show that the relativities between modes in terms of energy efficiency have not changed significantly. The car is generally speaking, and most commonly, the most polluting mode from a carbon dioxide perspective. The possibility of elevated rates of CO2 per passenger km from rail occurs in the comparatively rare instances where particularly 'dirty' coal is used to produce the electricity (e.g. Melbourne's use of low quality brown coal). But even in these cases, it is impossible to conclude that those passenger kilometres would be better off driven in cars. The transit leverage effect, a demonstrated phenomenon in urban transit systems described by Neff, shows that one passenger kilometre on transit replaces between 5 and 7 passenger kilometres of car driving, and there are even reports of it replacing 8.6 to 12.0 km of car travel in the US (See J W Neff, 'Substitution rates between transit and automobile travel'. Paper presented at the Association of American Geographers' Annual Meeting, Charlotte, NC, April 1996. See also Peter Newman & Jeffrey Kenworthy, Sustainability and Cities: Overcoming automobile dependence, Island Press, Washington DC, 1999). Thus rail systems, even when they are using particularly poor fuels, have a net savings effect when it comes to CO2 reductions.
13. The 84 cities in the Millennium Cities Database for Sustainable Transport by Region, with populations in million as follows: USA: Atlanta (2.90), Chicago (7.52), Denver (1.98), Houston (3.92), Los Angeles (9.08), New York (19.23), Phoenix (2.53), San Diego (2.63), San Francisco (3.84), Washington (3.74) (Av. 5.74); CANADA: Calgary (0.77), Montreal (3.22), Ottawa (0.97), Toronto (4.63), Vancouver (1.90) (Av. 2.30); AUST/NZ: Brisbane (1.49), Melbourne (3.14), Perth (1.24), Sydney (3.74), Wellington (0.37) (Av. 2.00); WESTERN EUROPE: Graz (0.24), Vienna (1.59), Brussels (0.95), Copenhagen (1.74), Helsinki (0.89), Lyon (1.15), Nantes (0.53), Paris (11.00), Marseilles (0.80), Berlin (3.47), Frankfurt (0.65), Hamburg (1.70), Dusseldorf (0.57), Munich (1.32), Ruhr (7.36), Stuttgart (0.59), Athens (3.46), Milan (2.46), Bologna (0.45), Rome (2.65), Amsterdam (0.83), Oslo (0.92), Barcelona (2.78), Madrid (5.18), Stockholm (1.73), Bern (0.30), Geneva (0.40), Zurich (0.79), London (7.01), Manchester (2.58), Newcastle (1.13), Glasgow (2.18) (Av. 2.17); HIGH INCOME ASIA: Osaka (16.83), Sapporo (1.76), Tokyo (32.34), Hong Kong (6.31), Singapore (2.99), Taipei (2.96) (Av. 11.03); EASTERN EUROPE: Prague (1.21), Budapest (1.91), Krakow (0.74) (Av. 1.29); MIDDLE EAST: Tel Aviv (2.46), Teheran (6.80), Riyadh (3.12), Cairo (13.14), Tunis 1.87) (Av. 5.48); AFRICA: Dakar (1.94), Cape Town (2.90), Jo'burg (2.25), Harare (1.43) (Av.2.13); LATIN AMERICA: Curitiba (2.43), Sao Paulo (15.56), Bogota (5.53) (Av. 7.85); LOW INCOME ASIA: Manila (9.45), Bangkok (6.68), Mumbai (17.07), Chennai (6.08), Kuala Lumpur (3.77), Jakarta (9.16), Seoul (20.58), Ho Chi Minh City (4.81) (Av. 9.70); CHINA: Beijing (8.16), Shanghai (9.57), Guangzhou (3.85) (Av. 7.19).
14. An exception to this has been ferries which are sometimes more greenhouse gas emitting.
15. The primary energy use for electric rail modes in each city will vary according to the overall efficiency of electrical generation in each country, including power station efficiencies and transmission losses. The use of primary energy in modal energy consumption for electrical modes would have necessitated a fuller accounting of the energy used in producing and delivering petrol, diesel and gaseous fuels, if a genuine comparison were to be made.
16. Data are from J Kenworthy & F Laube, The Millennium Cities Database for Sustainable Transport. UITP, Brussels, 2001, which was a study of 100 cities (16 were incomplete) and 27 parameters using highly controlled processes to ensure comparability of data. See also J Kenworthy, F Laube, P Newman, P Barter, T Raad, C Poboon & B Guia, An International Sourcebook of Automobile Dependence in Cities, 1960-1990. University Press of Colorado, Boulder, 1999.
17. The lack of strong correlation between city wealth and car use is shown in Kenworthy & Laube.
18. P Newman & J Kenworthy, Cities and Automobile Dependence, An international sourcebook, Gower, Aldershot, 1989; Newman & Kenworthy, Sustainability and Cities; see also reference 19 below.
19. See Tod Litman, 'Generated Traffic or Induced Traffic' ITE Journal 71(4), 2010, pp 38-47, and Victoria Transport Policy Institute website, (www.vtpi.org, viewed 14 Dec 2010); also see special edition of Transportation on 'Induced Traffic', 1996, vol 23, no 1, 1996.
20. P Newman & J Kenworthy J, 'The Transport Energy Trade-off: Fuel Efficient Traffic vs Fuel Efficient Cities', Transportation Research, 22A(3), 1988, pp 163-174.
21. J W Neff, 'Substitution rates between transit and automobile travel'. Paper presented at the Association of American Geographers' Annual Meeting, Charlotte NC, April 1996.
22. P Newman, J Kenworthy & G Glazebrook, G (2008) How to Create Exponential Decline in Car Use in Australian Cities, Australian Planner, 2008; also published on AdaptNet Policy Forum 08-06-E-Ad, 8 July 2008.
23. Newman & Kenworthy, Sustainability and Cities.