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World Transport Policy & Practice is a quarterly journal which provides a high quality medium for original and creative work in world transport.

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WTPP has a commitment to sustainable transport which embraces the urgent need to cut global emissions of carbon dioxide, to reduce the amount of new infrastructure of all kinds and to highlight the importance of future generations, the poor, those who live in degraded environments and those deprived of human rights by planning systems that put a higher importance on economic objectives than on the environment and social justice.

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Urban transport patterns in a global sample of cities & their linkages to transport infrastructure, land use, economics & environment*Jeff Kenworthy & Felix Laube*

Urban transport and the issue of motorisation or 'automobile dependence' have become critical shaping factors in the future sustainability and livability of all cities. This paper provides an overview of a selected group of factors that help define some of the main features of urban transport in metropolitan regions around the world. The aim is to provide decision-makers and policy analysts some basic perspective on where cities in their region sit in a global context. The paper also points to some key policy issues that emerge from the data and which have considerable bearing on issues such as priorities in urban infrastructure development. The data are drawn from the *Millennium Cities Database for Sustainable Transport* compiled over 3 years by the authors for the International Association of Public Transport (UITP) in Brussels. The database provides data on 100 cities on all continents. Data summarised here represent regional averages from 84 of these fully completed cities in the U.S.A., Australia and New Zealand, Canada, Western Europe, Asia (high and low income areas), Eastern Europe, the Middle East, Latin America, Africa and China.

Keywords

Cars, cities, international comparison, livability, Millennium Cities Database, public transport, sustainability, urban transport

Travel Demand Management: The potential for enhancing urban rail opportunities & reducing automobile dependence in cities*Jeff Kenworthy & Felix Laube*

Using data from a large international comparison of cities in North America, Australia, Europe and Asia, a review is made of the role of transport infrastructure provision in shaping transport patterns and travel speeds in cities. A case is made for moving away from supply-side, road-oriented approaches to transport which induce more traffic, and towards demand management, that emphasises public transport, walking and cycling and de-emphasises investment in roads. Urban rail is shown to play a critical role in shaping urban transport patterns and in helping cities to manage travel demand and reduce their level of automobile dependence.

Keywords

Automobile dependence, cities, cycling, demand management, international comparison, investment strategies, public transport, railways, trams, walking

This is a special issue focussing on some of the work of the Institute for Sustainability & Technology Policy at Murdoch University in Western Australia. The ISTP has a very strong research focus and this is exemplified by the two articles in this issue. These highlight the results of the *Millennium Cities Database for Sustainable Transport* and the *International Sourcebook of Automobile Dependence in Cities*. These publications have added substantially to our understanding of complex subjects and contributed greatly to the transport debate. It is especially relevant that they highlight our energy use...

... As Britain and the USA once again prepare to bomb another small country in pursuit of the war against terrorism we should question the underlying causes of this disastrous lurch into war. In particular, we should question the role of oil in transportation in fuelling yet another international crisis. In the U.K. a prominent ex-member of the Cabinet (Mo Mowlam) has said that the war is a war to gain control of oil supplies. A current government minister (Peter Hain) has said that the costs of protecting oil supplies and dealing with international crises linked to oil are now greater than the value of the oil itself. Transport specialists and policy makers will no doubt feel a little uncomfortable in shifting the debate for a moment from bus services, bicycles, airport expansion and the rural poor but the geopolitical realities also require our attention.

The world is running out of oil (www.hubbertpeak.com) and peak production will be reached around 2010 or 2015. Some transport specialists fervently believe and hope that a hydrogen society and economy can step in to replace the missing oil but even if this is technologically and financially viable there will still be a lot of people looking for a large slice of the remaining oil for many years to come. India and China are not likely to be calm and reasonable about the USA swallowing up 25% of the world's oil as their combined 2 billion people climb up the car ownership ladder and seek their own modest share of

what is left. This gives us all a problem. US politics underpinned by US land use, urban sprawl, cheap oil and a deep belief in the American way of life cannot (it would seem) contemplate a shift away from car use or a reduction in oil use. There can be no doubt that the US determination to wage war against Iraq is fuelled by a desire to dominate an oil producing region and to secure oil supplies for the USA into the future. This really is part of the war against terrorism. If the USA is vulnerable to oil supply interruption then the 'homeland' is under threat.

The whole world is put at risk by any foreign policy aimed at dominating resources. Britain and Germany locked themselves into a fatal downward spiral in the early part of the last century through their competitive struggle to dominate colonial regions (resources) in Africa and elsewhere. The result was several million dead young men in an appalling war.

Transport specialists are under pressure. We have a lot to think about and even more to do. The rising demand for transport, the aviation growth curve going off the top right of the graph in spite of 9/11 and global highway construction still going strong in spite of Kyoto and the oil depletion curve. This is enough to trigger requests for early retirement. But it is not enough. We have an ethical and a social responsibility and we need to discuss and investigate the direct chain of causation between Californian sprawl, car use, cheap oil, Iraq and hundreds of thousands of dead civilians in Iraq to pay for the freedom associated with a car trip to WalMart to buy a 6 pack. We have very little time left to sort out this mess and we need a US commitment to scale down oil use, scale down greenhouse gases and scale down international military adventures. Is this too much to ask for and too much to hope for?

John Whitelegg
Editor
World Transport Policy & Practice

Urban transport patterns in a global sample of cities & their linkages to transport infrastructure, land use, economics & environment

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Abstract

Urban transport and the issue of motorisation or 'automobile dependence' have become critical shaping factors in the future sustainability and livability of all cities. This paper provides an overview of a selected group of factors that help define some of the main features of urban transport in metropolitan regions around the world. The aim is to provide decision-makers and policy analysts some basic perspective on where cities in their region sit in a global context. The paper also points to some key policy issues that emerge from the data and which have considerable bearing on issues such as priorities in urban infrastructure development. The data are drawn from the *Millennium Cities Database for Sustainable Transport* compiled over 3 years by the authors for the International Association of Public Transport (UITP) in Brussels. The database provides data on 100 cities on all continents. Data summarised here represent regional averages from 84 of these fully completed cities in the U.S.A., Australia and New Zealand, Canada, Western Europe, Asia (high and low income areas), Eastern Europe, the Middle East, Latin America, Africa and China.

Keywords

Cars, cities, international comparison, livability, Millennium Cities Database, public transport, sustainability, urban transport

Introduction

Urban transport and the issue of motorisation or 'automobile dependence' have become critical shaping factors in the future sustainability and livability of all cities. North American and Australian cities bear the strong imprint of the car in every aspect of their form and function. In rapidly developing cities, such as those in China, mass car ownership has only just begun and policy makers struggle with the rapidly escalating impacts of private transport and how best to provide for people's transport needs. This endeavour is set within the bigger quest for more sustainable and livable cities across a very broad range of factors, most

of which are impacted upon, or even shaped by, the nature of the evolving transport system. For example, land use patterns can be sprawling or more compact depending upon whether large freeways or public transport systems lead urban development and whether the planning system encourages consolidation of development around transit. This in turn has impacts for water management, land available for food production close to cities and access to quality open space. The impacts are not limited to the physical environment, but extend to social factors such as equitable access to affordable transport, severance of neighbourhoods and social isolation in remote, low density environments. Economic impacts include land lost to non-productive urban sprawl and bitumen, congestion costs, transport deaths and so forth (Newman & Kenworthy, 1999a).

At the very least, analysts in all cities need quality urban data with which to help assess these important issues in cities. In particular, they need to be able to judge their present transport and urban development position, to understand the key factors that lie behind this situation and the main areas that need concerted policy attention.

This paper provides an overview of a selected group of factors that help define some of the main features of urban transport in metropolitan regions around the world. The aim is to provide decision-makers and policy analysts some basic perspective on where cities in their region sit in a global context. The paper also points to some key policy issues that emerge from the data and which have considerable bearing on issues such as priorities in urban infrastructure development. The data are drawn from the *Millennium Cities Database for Sustainable Transport* compiled over 3 years by the authors for the International Association of Public Transport (UITP) in Brussels. The database provides data on 100 cities on all continents. Data summarised here represent regional averages from 84 of these fully completed cities in the U.S.A., Australia and New Zealand, Canada, Western Europe, Asia (high and low income areas), Eastern Europe, the

Table 1. Cities represented in the Millennium Cities Database for Sustainable Transport by region

Canada	CAN
Calgary *, Montreal *, Ottawa *, Toronto *, Vancouver *	
U.S.A.	USA
Atlanta *, Chicago *, Denver *, Houston *, Los Angeles *, New York *, Phoenix *, San Diego *, San Francisco *, Washington *	
Western Europe	WEU
Graz *, Vienna *, Brussels *, Copenhagen *, Helsinki *, Lille, Lyon *, Marseilles *, Nantes *, Paris *, Berlin *, Dusseldorf *, Frankfurt *, Hamburg *, Munich *, Ruhr *, Stuttgart *, Athens *, Bologna *, Milan *, Rome *, Turin, Amsterdam *, Oslo *, Lisbon, Barcelona *, Madrid *, Stockholm *, Bern *, Geneva *, Zurich *, Glasgow *, London *, Manchester *, Newcastle *	
High Income Asia	HIA
Osaka *, Sapporo *, Tokyo *, Hong Kong *, Singapore *, Taipei *	
Australia/New Zealand	ANZ
Brisbane *, Melbourne *, Perth *, Sydney *, Wellington *	
Latin America	LAM
Buenos Aires, Brasilia, Curitiba *, Rio de Janeiro, São Paulo *, Salvador, Santiago, Bogota *, Mexico City, Caracas	
Eastern Europe	EEU
Prague *, Budapest *, Krakow *, Warsaw, Moscow, Istanbul	
Middle East	MEA
Cairo *, Teheran *, Tel Aviv *, Riyadh *, Tunis *	
Africa	AFR
Abidjan, Casablanca, Dakar *, Cape Town *, Johannesburg *, Harare *	
Low Income Asia	LIA
Mumbai *, Chennai *, New Delhi, Jakarta *, Seoul *, Kuala Lumpur *, Manila *, Bangkok *, Ho Chi Minh City *	
China	CHN
Beijing *, Guangzhou *, Shanghai *	

Middle East, Latin America, Africa and China. Table 1 contains a list of the cities in the database (the cities with an asterisk are included in this regional overview).

The database contains data on 69 primary variables, which depending on the city and the administrative complexity and multi-modality of its public transport system, can mean up to 175 primary data entries. The methodology of data collection for all the factors was strictly controlled by agreed upon definitions contained in a 100 page booklet and data were carefully checked and verified before being accepted into the database. A detailed discussion of methodology is not possible in this short summary paper.

From this complex range of primary factors, some 230 standardised variables have been calculated. Cities can thus be compared across the areas of land use, private, public and collective transport performance, overall mobility and modal split, private and public transport infrastructure, the economics of urban transport (operating and investment costs, revenues), energy and environmental factors. For this overview only a selection of salient features are chosen for comment. Tables 2 and 3 provide these data summarised according to the 11 regions shown in Table 1, divided into higher and lower income parts of the

world. The data are for the year 1995. Data collection on these cities commenced in 1998 and was only completed at the end of 2000. At this point, data for 1995 provides the latest perspective one can reasonably expect for a study of this magnitude.¹

Findings

Income

The relative income or wealth of metro regions in this study is measured by the Gross Domestic (or Regional) Product (GDP) per capita in U.S. dollars of the actual functional urban region, not the state, province or country in which the city resides. This

¹ The key to regional abbreviations used in the Database and in the Tables is as follows:

Higher income

USA	USA cities
ANZ	Australia/New Zealand cities
CAN	Canadian cities
WEU	Western European cities
HIA	High income Asian

Lower income

EEU	Eastern European cities
MEA	Middle Eastern cities
LAM	Latin American cities
AFR	African cities
LIA	Low income Asian cities
CHN	Chinese cities

Table 2. Land use & transport system characteristics in higher income regions, 1995

		USA	ANZ	CAN	WEU	HIA
<i>Land Use & Wealth</i>						
Urban density	persons/ha	14.9	15.0	26.2	54.9	150.3
Proportion of jobs in CBD	%	9.2%	15.1%	15.7%	18.7%	19.1%
Metropolitan gross domestic product per capita	USD	\$31,386	\$19,775	\$20,825	\$32,077	\$31,579
<i>Private Transport Infrastructure Indicators</i>						
Length of freeway per person	m/ person	0.156	0.129	0.122	0.082	0.020
Parking spaces per 1000 CBD jobs		555	505	390	261	105
<i>Public Transport Infrastructure Indicators</i>						
Total length of reserved public transport routes per 1000 persons	m/1000 persons	48.6	215.5	55.4	192.0	53.3
Total length of reserved public transport routes per urban hectare	m/ha	0.81	3.41	1.44	9.46	5.87
Number of Park & Ride spaces per km of reserved public transport route	spaces/km	320	44	132	25	19
Ratio of segregated transit infrastructure versus expressways		0.41	2.00	0.55	3.12	3.34
<i>Private transport supply (cars & motorcycles)</i>						
Passenger cars per 1000 persons		587.1	575.4	529.6	413.7	210.3
Motor cycles per 1000 persons		13.1	13.4	9.5	32.0	87.7
<i>Traffic Intensity Indicators</i>						
Total private passenger vehicles per km of road	units/km	98.7	73.1	105.8	181.9	144.4
Total single & collective private passenger vehicles per km of road	units/km	98.9	73.3	106.1	183.1	149.6
Average road network speed	km/h	49.3	44.2	44.5	32.9	28.9
<i>Public Transport Supply & Service</i>						
Total public transport seat kilometres of service per capita	seat km/person	1556.8	3627.9	2289.7	4212.7	4994.8
Rail seat kilometres per capita (Tram, LRT, Metro, Suburban rail)	seat km/person	747.5	2470.4	676.4	2608.6	2282.3
% of public transport seat km on rail	%	48.0	68.1	29.5	61.9	45.7
Overall average speed of public transport	km/h	27.4	32.7	25.1	25.7	29.9
* Average speed of buses	km/h	21.7	23.3	22.0	20.2	16.2
* Average speed of metro	km/h	37.0		34.4	30.6	36.6
* Average speed of suburban rail	km/h	54.9	45.4	49.5	49.5	47.1
Ratio of public versus private transport speeds		0.58	0.75	0.57	0.79	1.04

factor is the basis for the split in the sample of cities between higher and lower income regions. The higher income cities have average GDP between \$ 20,000 and \$ 32,000, while the lower income metro regions range from \$ 2,400 to \$ 6,000. As will be seen later from the patterns of private and public transport, wealth alone does not provide a consistent or satisfactory explanation of the transport patterns in cities. This is despite claims by a number of commentators that increasing wealth automatically tends towards higher auto dependence (Gomez-Ibañez, 1991; Kirwan, 1992;

Lave, 1992). Rather, the data point towards deeper underlying policy and physical differences between cities in the different regions.

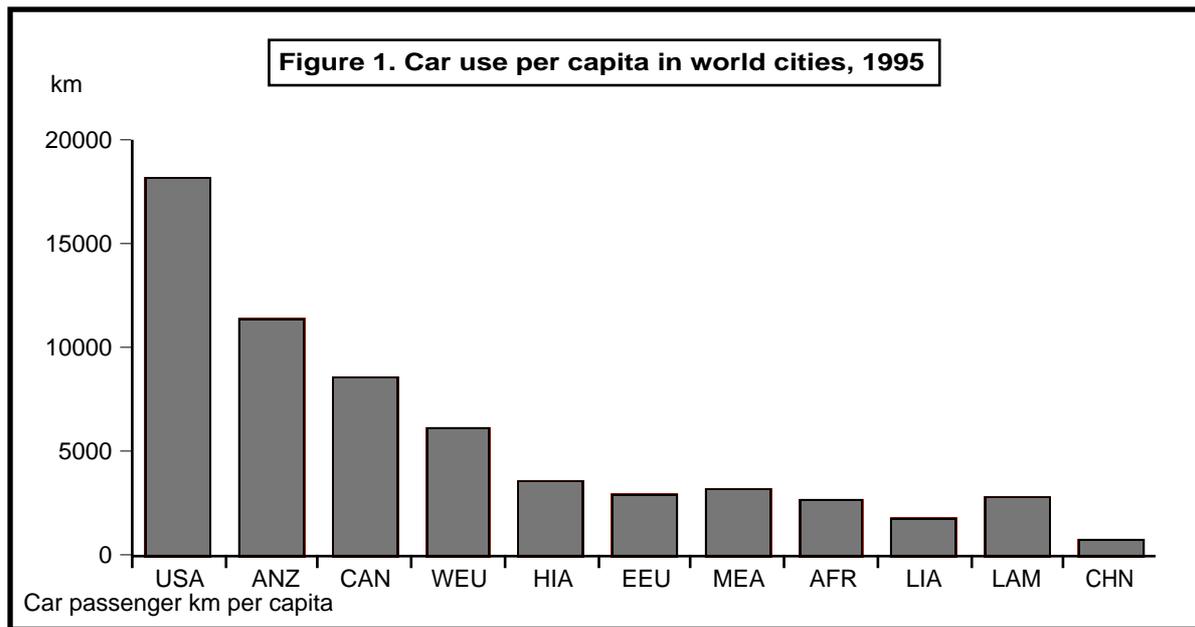
Private Transport: Related Outcomes & Impacts

Vehicle ownership

Globally there is an enormous variation in the magnitude of urban vehicle ownership and use. Clearly, North American and Australian/New Zealand cities lead the world in car ownership with over 500 cars per 1000 people (USA cities nearly 600).

Table 2 continued

		USA	ANZ	CAN	WEU	HIA
<i>Mode split of all trips</i>						
* non motorised modes	%	8.1%	15.8%	10.4%	31.3%	28.5%
* motorised public modes	%	3.4%	5.1%	9.1%	19.0%	29.9%
* motorised private modes	%	88.5%	79.1%	80.5%	49.7%	41.6%
<i>Private Mobility Indicators</i>						
Passenger car passenger kilometres per capita	passenger km/person	18155	11387	8645	6202	3614
Motor cycle passenger kilometres per capita	passenger km/person	45	81	21	119	357
<i>Public Transport Mobility Indicators</i>						
Total public transport boardings per capita	boardings/person	59.2	83.8	140.2	297.1	430.5
Rail boardings per capita (Tram, LRT, Metro, Suburban rail)	boardings/person	21.7	42.5	44.5	162.2	238.3
Proportion of public transport boardings on rail	%	36.7%	50.7%	31.7%	54.6%	55.4%
Proportion of total motorised passenger km on public transport	%	2.9%	7.5%	9.8%	19.0%	45.9%
<i>Public Transport Productivity</i>						
Public transport operating cost recovery	%	35.5%	52.7%	54.4%	59.2%	137.9%
<i>Transport Investment Cost</i>						
Percentage of metropolitan GDP spent on public transport investment	%	0.18%	0.30%	0.18%	0.41%	0.61%
Percentage of metropolitan GDP spent on road investment	%	0.86%	0.72%	0.87%	0.70%	0.84%
<i>Overall Transport Cost</i>						
Total passenger transport cost as % of metropolitan GDP	%	11.79%	13.47%	13.72%	8.30%	7.08%
Total private passenger transport cost as % of metropolitan GDP	%	11.24%	12.39%	12.87%	6.75%	5.45%
Total public passenger transport cost as % of metropolitan GDP	%	0.55%	1.08%	0.85%	1.55%	1.62%
<i>Transport Energy Indicators</i>						
Private passenger transport energy use per capita	MJ/person	60034	29610	32519	15675	9556
Public transport energy use per capita	MJ/person	809	795	1044	1118	1423
Energy use per private passenger kilometre	MJ/passenger km	3.25	2.56	3.79	2.49	2.33
Energy use per public transport passenger km	MJ/passenger km	2.13	0.92	1.14	0.83	0.48
<i>Air Pollution Indicators</i>						
Total emissions per capita (CO, SO ₂ , VHC, NO _x)	kg/person	264.6	188.9	178.9	98.3	36.9
Total emissions per urban hectare	kg/ha	3563	2749	4588	5304	5722
Ratio of emissions per capita to private, collective & transit travel		0.020	0.024	0.027	0.020	0.012
<i>Transport Fatalities Indicators</i>						
Total transport deaths per 100,000 people		12.7	8.6	6.5	7.1	8.0
Total transport deaths per billion passenger km		7.0	6.8	7.1	9.6	10.8



Western European cities are, however, closing on new world cities with 414 cars per 1000, while Eastern European car ownership is more moderate at 332, though it is rising rapidly. All other groups of cities average between only 100 and 200 cars per 1000 people, except for the Chinese cities which in 1995 had a mere 26 cars per 1000 people. Motor cycle ownership is relatively insignificant in all regions (between 5 and 30 motor cycles per 1000 people) except in the Asian cities. In the high and low income Asian cities, including China, motor cycles average between 55 and 127 per 1000 people and they form a significant part of the transport system. They are the most manoeuvrable motorised mode for avoiding traffic queues and the most affordable form of motorised private transport for moderate income people. As well, they are a major cause of air pollution, noise, traffic danger and transport deaths in these cities.

Car & motor cycle usage

Car usage follows a more extreme pattern than mere ownership, indicating that whilst cars may be owned to a similar degree in different regions, the need to use them varies dramatically. This in turn relates to land use factors and the viability of other modes for various trip purposes. USA cities require over 18,000 passenger km per capita in cars to meet their residents' access needs. By contrast, their high income counterparts require only between 20% and 63% of that level of use. In the lower income regions, car passenger km per capita range from a mere 814 (4% of the USA figure) in Chinese cities, up to 3,300 in Middle Eastern cities (18% of the USA figure).

Usage of motor cycles relative to cars is comparatively small in high income cities (motor cycle use as a percentage of total private passenger km

ranges from 0.25% in the USA cities up to 9% in the high income Asian cities). By contrast, in low income Asian cities and Chinese cities, motor cycle mobility represents 26%, while in the other lower income regions it again is small, at between 0.7% and 3.8%. Why motor cycles have burgeoned in such a dramatic way in most Asian cities and in no other parts of the world (nor in Manila where motor cycle ownership is actually about half the USA level), is an interesting policy question. The low penetration of motor cycles in Manila, totally out of character with its neighbours, is possibly a result of the extensive and effective jeepney system (Barter, 1998). The role of motor cycles in urban transport, their potential to facilitate urban sprawl by providing low cost private transport to large numbers of people, and their environmental and human impacts, are important issues to understand. This is especially so in cities like Taipei where ownership is some 200 per 1000 people and usage represents 35% of private mobility.

The final variable that provides insight into private transport patterns is the percentage of all daily trips (all purposes) that are catered for by private transport. Not surprisingly, USA (89%), ANZ (79%) and Canadian cities (81%) head the list. By contrast, their wealthier counterparts in Europe and Asia have only 50% and 42% respectively of all trips by private transport. This picture strengthens in the lower income cities where private transport caters for only between 16% (Chinese cities) and 36% (Asian cities) of all trips. The exception is the Middle Eastern cities where the proportion rises to 56%. This perspective is important. Despite the overwhelming impact that private transport has on the environment, the visual and sensory impacts of traffic and its capacity to rapidly saturate the public space of a city,

Table 3. Land use & transport system characteristics in lower income regions, 1995

		EEU	MEA	LAM	AFR	LIA	CHN
<i>Land Use & Wealth</i>							
Urban density	persons/ha	52.9	118.8	74.7	59.9	204.1	146.2
Proportion of jobs in CBD	%	20.3%	13.5%	29.4%	15.4%	17.4%	50.8%
Metropolitan gross domestic product per capita	US\$	\$5,951	\$5,479	\$4,931	\$2,820	\$3,753	\$2,366
<i>Private Transport Infrastructure Indicators</i>							
Length of freeway per person	m/ person	0.031	0.053	0.003	0.018	0.015	0.003
Parking spaces per 1000 CBD jobs		75	532	90	252	127	17
<i>Public Transport Infrastructure Indicators</i>							
Total length of reserved public transport routes per 1000 persons	m/1000 persons	200.8	16.1	19.3	40.2	16.1	2.3
Total length of reserved public transport routes per urban hectare	m/ha	10.67	2.18	1.15	2.39	2.50	0.32
Number of Park & Ride spaces per km of reserved public transport route	spaces/km	5	50	4	10	9	0
Ratio of segregated transit infrastructure versus expressways		9.11	3.54	3.36	3.16	1.33	0.77
<i>Private transport supply (cars & motorcycles)</i>							
Passenger cars per 1000 persons		331.9	134.2	202.3	135.1	105.4	26.1
Motor cycles per 1000 persons		20.8	19.1	14.3	5.5	127.3	55.1
<i>Traffic Intensity Indicators</i>							
Total private passenger vehicles per km of road	units/km	168.8	180.7	144.1	58.4	236.1	117.2
Total single & collective private passenger vehicles per km of road	units/km	170.9	197.1	146.2	60.0	249.1	131.8
Average road network speed	km/h	30.8	32.1	31.5	39.3	21.9	18.7
<i>Public Transport Supply & Service</i>							
Total public transport seat kilometres of service per capita	seat km/person	4170.3	1244.6	4481.2	5450.3	2698.8	1171.3
Rail seat kilometres per capita (Tram, LRT, Metro, Suburban rail)	seat km/person	2478.8	125.7	316.1	1715.5	402.4	44.6
% of public transport seat km on rail	%	59.4%	10.1%	7.1%	31.5%	14.9%	3.8%
Overall average speed of public transport	km/h	21.4	20.9	18.4	31.4	18.0	13.6
* Average speed of buses	km/h	19.3	18.5	17.8	25.8	16.2	12.5
* Average speed of metro	km/h	29.5		32.4		33.9	35.4
* Average speed of suburban rail	km/h	37.6	36.6	41.0	34.4	33.0	
Ratio of public versus private transport speeds		0.71	0.68	0.60	0.80	0.81	0.73

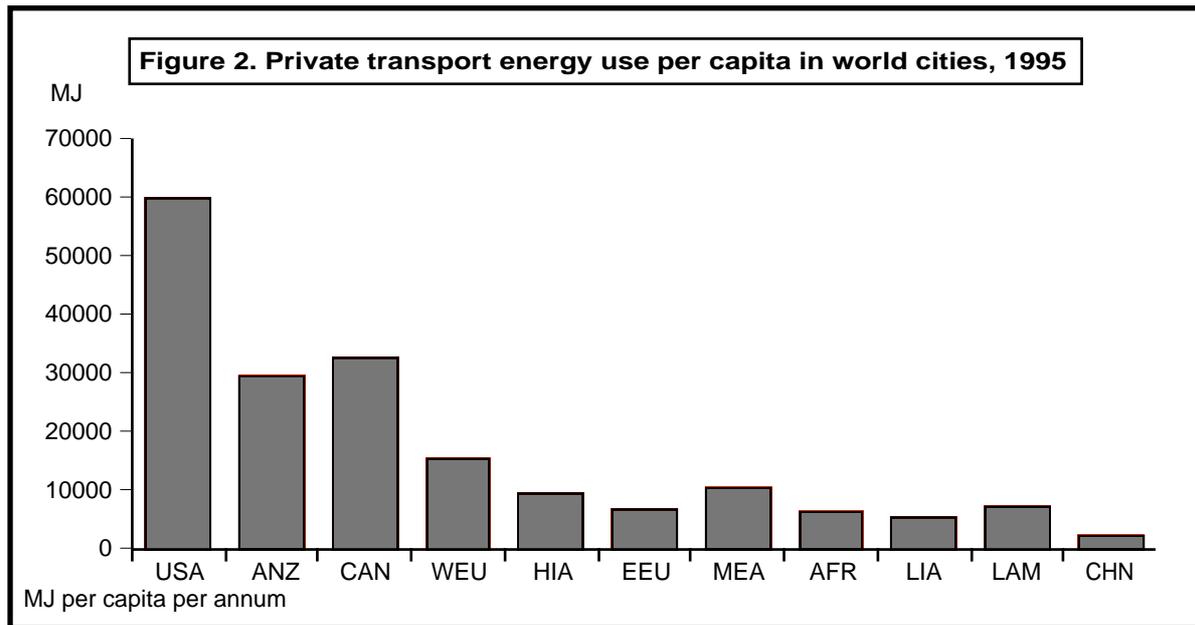
private transport is a minority player, relative to public transport and non-motorised modes, in 7 out of the 11 regions in this study. This of course has enormous social justice and equity implications if urban transport priorities are primarily directed towards facilitating car travel for the wealthier minority, especially in developing cities.

Non-motorised mode use

The most democratic and sustainable modes of urban transport, and the oldest, are foot and bicycle. There is an extraordinary range in the extent to which these

non-polluting and egalitarian modes are still used in cities today. In USA cities where obesity is a major problem and billions of dollars are spent annually on weight loss programs, only 8% of all urban trips are made by foot and bicycle. Other auto cities do a little better (respectively, 10% and 16% in Canadian and ANZ cities). Eastern and Western European, high and low income Asian, Middle Eastern and Latin American cities, all have very similar levels of non-motorised mode use ranging from 26% to 32% of all trips. The African cities with their large, poor minority populations have 41% walking and cycling, while the

		EEU	MEA	LAM	AFR	LIA	CHN
Table 3 continued							
<i>Mode split of all trips</i>							
* non motorised modes	%	26.2%	26.6%	30.7%	41.4%	32.4%	65.0%
* motorised public modes	%	47.0%	17.6%	33.9%	26.3%	31.8%	19.0%
* motorised private modes	%	26.8%	55.9%	35.4%	32.3%	35.9%	15.9%
<i>Private Mobility Indicators</i>							
Passenger car passenger kilometres per capita	passenger km/ person	2907	3262	2862	2652	1855	814
Motor cycle passenger kilometres per capita	passenger km/ person	19	129	104	57	684	289
<i>Public Transport Mobility Indicators</i>							
Total public transport boardings per capita	boardings/ person	711.5	151.8	265.1	195.4	231.0	374.9
Rail boardings per capita (Tram, LRT, Metro, Suburban rail)	boardings/ person	409.0	18.3	19.2	37.2	40.2	22.8
Proportion of public transport boardings on rail	%	57.5%	12.0%	7.2%	19.0%	17.4%	6.1%
Proportion of total motorised passenger km on public transport	%	53.0%	29.5%	48.2%	50.8%	41.0%	55.0%
<i>Public Transport Productivity</i>							
Public transport operating cost recovery	%	58.1%	88.0%	133.0%	95.2%	155.8%	40.7%
<i>Transport Investment Cost</i>							
Percentage of metropolitan GDP spent on public transport investment	%	0.50%	0.61%	0.42%	0.35%	0.65%	0.86%
Percentage of metropolitan GDP spent on road investment	%	1.02%	1.05%	0.11%	0.54%	1.28%	3.17%
<i>Overall Transport Cost</i>							
Total passenger transport cost as % of metropolitan GDP	%	14.76%	14.01%	14.27%	21.96%	14.50%	10.67%
Total private passenger transport cost as % of metropolitan GDP	%	12.39%	11.38%	11.69%	17.47%	12.19%	8.13%
Total public passenger transport cost as % of metropolitan GDP	%	2.38%	2.63%	2.58%	4.48%	2.31%	2.54%
<i>Transport Energy Indicators</i>							
Private passenger transport energy use per capita	MJ/person	6661	10573	7283	6184	5523	2498
Public transport energy use per capita	MJ/person	1242	599	2158	1522	1112	419
Energy use per private passenger kilometre	MJ/ pass. km	2.35	2.56	2.27	1.86	1.78	1.69
Energy use per public transport passenger kilometre	MJ/ pass. km	0.40	0.67	0.76	0.51	0.64	0.28
<i>Air Pollution Indicators</i>							
Total emissions per capita (CO, SO ₂ , VHC, NO _x)	kg/person	88.4	147.4	119.1	137.3	77.3	86.3
Total emissions per urban hectare	kg/ha	4543	12671	7362	5330	13506	11920
Ratio of emissions per capita to private, collective & transit travel		0.037	0.060	0.056	0.076	0.037	0.083
<i>Transport Fatalities Indicators</i>							
Total transport deaths per 100,000 people		10.8	11.3	27.6	18.0	15.2	8.6
Total transport deaths per billion passenger km		19.6	29.1	47.3	30.4	37.3	30.0



world leader is still the Chinese city with 65%, though this is under increasing threat from official policies against bicycles and the sheer scale of motorisation (Kenworthy & Hu, 2000). It would appear very sensible from a social, environmental and economic perspective, to prioritise the protection of non-motorised modes by ensuring that facilities for pedestrians and bicycles are actively promoted and not eroded by motorisation. This is especially urgent in lower income cities.

Energy

The level of automobile dependence in a city has large implications for resource consumption and transport externalities. In this new century, as the world is rocked by rapidly escalating oil prices and the fallout is felt everywhere from trucking industry blockades and protests, to the traumatic effect on household budgets of rising fuel prices, energy is back on the agenda. World oil production is predicted to peak by 2010 and then to enter a phase of irreversible decline, leading to shortage, rapidly rising prices and a concentration of oil power in the Middle East. This will have massive implications for those sectors, such as transport, that are utterly dependent upon conventional oil and cannot restructure overnight (Campbell, 1991; Campbell & Laherrere, 1995; Fleay, 1995).

The data show an extraordinary imbalance in energy consumption, with USA cities leading the world at over 60,000 MJ per person of energy used for cars and motor cycles. This is twice as high as their nearest rivals, the Canadian and Australian cities, and 4 to 6 times more than their biggest competitors in the global economy, the western European cities and wealthy Asian cities, such as in Japan. Even cities in the Middle East, where most oil is produced, only use

10,600 MJ per person, despite some fairly profligate and conspicuous consumption in cities such as Riyadh (25,082 MJ per person). The rapidly industrialising Chinese cities consume a mere 2,500 MJ per person, or 24 times less than American cities. As different countries stake out their claims on ever diminishing and more costly conventional oil, especially those who so far have not yet shared the benefits that flow from this valuable non-renewable resource, oil is likely to become a major destabilising geopolitical and economic issue early in this century.

It is also clear from the data how relatively energy-inefficient private transport is compared to public transport. 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 U.S.A. where large buses dominate public transport and attempt to pick up passengers in suburbs overwhelmingly designed around the car. Here public transport energy use per passenger kilometre stands at 65% that of cars. Energy used in public transport (a lot of which is electric energy and not dependent on oil) is also a minor player in overall passenger transport energy use. In higher income cities it ranges from only 1.3% of the total in USA cities to 13% in the heavy public transport environments in Asia. In the lower income cities where cars are used much less, public transport accounts mostly for around 15% to 20% of energy use (Middle Eastern cities are less at 5%).

Emissions

Local transport emissions of carbon monoxide, volatile hydrocarbons, nitrogen oxides and sulphur dioxide are important determinants of urban air quality. The per capita emissions rates from transport for these pollutants vary widely, according to both the level of auto dependence and the standard and

enforcement of emissions controls on vehicles. USA, Canadian and ANZ cities clearly lead the world in transport emissions per capita with between 180 kg and 265 kg per capita per year. By contrast, western European and wealthy Asian cities, where car use is low and emissions controls very strict, generate only 40 kg to 100 kg per capita of these emissions.

The problem in low income cities is that whilst they generally have much lower vehicle use than higher income cities, they have comparatively high transport emissions due to inferior emissions controls over all types of vehicles. This is seen in Tables 2 and 3 in the ratio of transport emissions to total vehicle km by private, collective and public transport modes. In high income cities this ratio sits consistently at around 0.02. In lower income cities it ranges from 0.04 to 0.08. This means the transport systems of these cities are emitting pollutants at between twice and four times the rate per kilometre of more developed cities.

The final issue that the data reveal about transport emissions in the global sample is that whilst per capita emissions may be higher in the low density auto-dependent regions, the rate of emissions per urbanised hectare are clearly lower. We thus have the situation in the high density cities, especially in the Middle East and low income part of Asia, including China, where emissions output is highly concentrated. This leads to more concentrated impacts and higher exposure (e.g. USA cities average 3,600 kg per urban ha, whereas low income Asian cities average 13,500 kg per urban ha per annum). This does not mean that high density cities should disperse and sprawl out, but it does mean that they must pay particular attention to emissions controls and enforcement and to maximising the amount of travel done on the least-polluting modes.

Transport deaths

Another important impact of urban transport is fatalities. The data reveal that to a considerable extent this is a direct function of automobile dependence with USA cities at 12.7 deaths per 100,000 people clearly leading the other high income regions, which range from 6.5 in Canada to 8.6 in ANZ. In other words, transport deaths in developed cities tend to be a function of exposure to car travel, though the trend seems to be downward in response to superior vehicle technology (Kenworthy & Laube, *et al.*, 1999). However, the pattern is confounded in the lower income cities where, despite much lower car use, deaths in transport range from 8.6 per 100,000 in Chinese cities up to 27.6 in Latin American cities. Some important factors in this disproportionately high death rate appear to be the clash between the onset of motorisation and the traditional non-motorised modes,

poor driver behaviour, education and traffic law enforcement and less developed, lower standard road systems.

Another way of looking at transport deaths is per billion passenger km of travel (motorised only). These figures cast the more auto-dependent regions in a better light and further emphasise the problems in developing cities. However, the higher death rate per passenger km in the less auto-orientated regions is partly due to the fact that passenger km by non-motorised transport, which are much higher in these regions (see modal split evidence), are not included in the denominator.

Obviously, reducing transport deaths must be tackled from multiple angles, including reducing private transport use *per se*, as well as safe vehicle technology and sound traffic management.

Public Transport Patterns

Public transport service levels

After examining the broad patterns of private transport and some of their implications, it is important to understand the patterns of public transport supply and use. Public transport supply in annual seat km per capita has an interesting pattern. It is by far weakest in Chinese cities, Middle Eastern cities and USA cities. Chinese cities still rely very heavily on non-motorised modes, though this is falling rapidly, and their public transport systems have consequently never been well developed (only 4% of service is by rail). Public transport in Middle Eastern cities relies quite heavily on minibus systems that restrict transit supply (only 10% of transit service is rail-based). USA cities, although having had some extensive transit systems earlier in the 20th century (e.g. Los Angeles' huge rail system), have had a long history of decline in public transport. This has only begun to change a little in the last 5 years and 48% of service is now rail-based in the cities in this study. The western and eastern European cities, high income Asian cities, Latin American and African cities provide the highest levels of public transport service. There are qualitative differences, however, with the European and Asian cities being more rail-oriented and offering services that compete with cars in quality, reliability and speed (46% to 62% is rail-based service). By contrast, African cities have 31% of service on rail, while Latin American cities have only 7%, notwithstanding Curitiba's fine bus system.

Public transport usage levels

There are two clear extremes in public transport use. The USA cities stand out globally with the lowest rate of trips per capita on public transport (59 per annum), while the eastern European cities are clearly the world leaders with 712 trips per person per annum (12

times more). This is also reflected in the overall modal split for all trips, where U.S. urban residents use transit for only 3% of daily trips and Eastern European city residents use transit for 47% of all trips. The other high users of public transport, either in terms of trips per capita or modal share of trips (but not always both) are high and low income Asian cities, western European cities, Latin American, African and Chinese cities. For example, Chinese cities, despite poor transit service, have high per capita usage due to captive riders (375 trips per capita), but the overall share of total trips is low (19%). This is due to very high walking and cycling (65% of total trips). African cities have only mediocre trips per capita on public transport (195 trips per capita) but the share of trips is quite high at 26% (due to the lowest overall daily trip rate of all cities).

ANZ cities, Canadian cities and Middle Eastern cities are comparatively low users of public transport in a global sense, regardless of the measure used. However, Canadian cities distinguish themselves within the most auto-orientated cities with transit use levels that are broadly speaking double those of the U.S. and ANZ cities. This relative success of Canadian cities in public transport is discussed elsewhere (Raad & Kenworthy, 1998).

Importance of rail & comparative modal speeds

The data in this paper highlight the importance of urban rail systems in developing competitive public transport systems. In the high income cities, only the European and Asian cities have public transport systems that capture a healthy share of the overall transport market and these are the cities where urban rail systems are most developed, especially in relation to their private transport equivalent, the urban freeway. The ratio of fully segregated transit infrastructure to urban freeways in these cities is over 3 compared to 0.4 and 0.5 in U.S. and Canadian cities and 2 in ANZ cities. In the lower income sample, by far the healthiest performing transit systems, by whatever measured used, are in the Eastern European cities where segregated transit infrastructure is some 9 times higher than urban freeways (see further discussion in next section).

It can be said that whilst there clearly are cities in the world (e.g. in Latin America, Africa and China), that achieve healthy public transport use with little or no rail, they rely mostly on poor captive riders, not choice riders, as in wealthier cities with high transit use. As incomes rise and car ownership levels grow, the public transport systems of these low-income, bus-based cities tend to get hit hardest for market share, because they cannot compete in speed or comfort with private transport. Motor cycles in particular tend to

compete heavily with bus systems that are engulfed in traffic (Barter, 1998).

This is seen in the comparative operating speeds between modes. There are no regions where the average speed of bus systems exceeds 26 km/h and the overall average across the 11 regions is only 19 km/h. In Chinese cities buses operate at an average 12.5 km/h, or about the same speed as cycling. On the other hand, metro systems operate between 30 and 37 km/h (average 34 km/h), while suburban rail systems across the regions average 42.9 km/h. When these speeds are compared to general road traffic speed, which averages 34 km/h across all regions, it can be seen that only rail systems can compete.

Any city wishing to rebuild its public transport base or prevent a dramatic collapse of ridership as incomes rise and competition from motor cycles and automobiles sets in, needs to seriously consider some form of segregated rail system. This strategy appears to be the only way to guarantee a future for urban public transport in any city.

Public & private transport infrastructure provision & investment

Underlying the patterns of urban transport are significant differences in the extent and type of infrastructure for private and public transport.

Public transport infrastructure

In accord with the data in the previous section, it is seen that Western European, high income Asian and Eastern European cities, and to a lesser extent the ANZ cities, are the only regions that have significant reserved alignments for public transport. This consists mainly of railways, but also a few totally physically segregated busways. All of the lower income city regions, apart from Eastern Europe, have comparatively scarce reserved public transport facilities that provide unimpeded paths for transit vehicles. Chinese cities stand out as being particularly low in this factor and in the auto regions, USA cities are clearly the lowest in segregated facilities for transit, though Canadian cities are not far behind.

It is often thought that park and ride (P & R) is an appropriate way of ensuring that a fixed route public transport system is properly fed with passengers, especially in low density areas, but also in environments where motorisation is proceeding rapidly. These data reveal that P & R as a transport planning approach to fixed route transit, is overwhelmingly an American phenomenon. USA cities have almost 3 times more P & R spaces per km of reserved public transport route (320) than their nearest rivals, the Canadian cities (132). This would appear to be more than just a response to low density, since ANZ cities are also low density but have 7 times less

P & R than USA cities. Outside of North America, the figures range from no P & R in Chinese cities, up to 50 P & R spaces per km of reserved public transport route in the Middle Eastern cities. All non-North American cities together have an average of only 18 P & R spaces per km of reserved transit route.

It is widely recognised today that the most effective way of building a 'transit metropolis' is to tightly integrate dense, mixed-use development around stops on a fixed-route transit network, thus maximising walk-up patronage and multiple trip making. This is the approach from Curitiba and Ottawa with their busways, through the urban rail systems in European cities, and in the modern Asian cities such as in Japan, Hong Kong and Singapore (Cervero, 1998). Bus or light rail feeders to the main rail system are also widely exploited.

Private transport infrastructure

The private transport corollary of fixed route transit is the urban freeway. USA cities, without any surprise, have the highest availability of freeway per person in the world, followed by ANZ and Canadian cities with 83% and 78% as much respectively. Outside of these three regions freeway provision falls away rapidly, especially in Latin American and Chinese cities (only 2% of the U.S. level). The other 8 regions altogether average only 0.028 metres of freeway per capita compared to 0.156 in USA cities (i.e. 18% of the USA level). It is not surprising that cities with the highest freeway provision also have the highest average speed of general traffic (44 – 49 km/h in U.S., ANZ and Canadian cities). The other cities with considerably lower freeway provision achieve only 29 km/h average road system speed. It has been understood in a systematic way since as early as 1974, how urban freeway provision is directly associated with higher car and energy use in cities (Watt & Ayres, 1974). The mechanism for this, in terms of longer travel distances rather than savings in time, has been explained elsewhere (e.g. Newman & Kenworthy, 1984, 1988, 1999b).

Parking in the central business districts (CBD) of cities is another indicator of private transport infrastructure, which varies dramatically across regions. Parking supply in central areas is an important factor in modal split to public transport for trips to this most critically space-constrained section of any city. The availability of parking, much more than price, tends to determine the attractiveness of car commuting to the central city. The highest parking suppliers are the USA, ANZ and, perhaps surprisingly, the Middle Eastern cities, all having more than 1 parking space for every 2 jobs. It must be said, however, that the

Middle Eastern cities are greatly affected by Riyadh which is a world extreme, having some 1,883 spaces for every 1000 jobs, due to its huge on-street parking supply. Teheran has only 22 spaces per 1000 jobs and Tel Aviv, the next highest after Riyadh has 467. By and large, other cities do not come close to these regions in CBD parking supply, ranging from averages of 17, 75 and 90 spaces in Chinese, Eastern European and Latin American cities respectively, up to 390 in Canadian cities.

Public & private transport investment

A potentially important indicator of how much priority is being given to public transport in a city is how much investment it is receiving. The data in Tables 2 and 3 show the percentage of a city's wealth (GDP per capita) being spent on new and refurbished public transport facilities and road investment (construction and maintenance by all parties) averaged over 5 years. The values for public transport investment range from a low of 0.18% in USA and Canadian cities up to 0.86% in Chinese cities. What is clear is that in no region except Latin America does the amount spent on transit infrastructure exceed that of road expenditure.² In fact, road spending exceeds transit spending by factors ranging from 1.4 times higher to 4.8 times higher. The high income Asian cities spend 0.61% of GDP on transit investment and 0.84% on roads and have the most equitable balance. This is reflected in healthy segregated transit infrastructure levels, as well as in high correlative transit service and usage levels. The Chinese cities, which although have the highest transit investment *per se*, actually spend 3.7 times more of their GDP on roads. As might be expected, the USA and Canadian cities, have the greatest imbalance towards roads with 4.8 times more investment expenditure. These patterns are partly reflected in the level of segregated transit infrastructure and freeways that exist in each region, as discussed above.

What appears to be clear is that for cities to move towards more sustainable transportation, a better balance between transit and road investment, or a more level playing field, as the economists like to say, is required.

² In Latin American cities the percentage of GDP spent on roads is only 0.11%. This figure is 5 times lower than its nearest rival for bottom place, the African cities (0.54%). The problem seems to stem from apparently very low road spending in Brazilian cities, where despite repeated attempts at clarifications, authorities insist that the figures are correct. The magnitude of the numbers received compared to the road lengths involved, seem to suggest that some major category of spending is missing but the data supplied have been reported as no further information was forthcoming.

Land Use Patterns

It has been widely demonstrated how important land use patterns are in helping to explain the macro patterns of urban transportation, especially the level of auto dependence (Cervero, 1998; Newman & Kenworthy, 1989, 1999a; Kenworthy & Laube *et al.*, 1999). Provided here are two key descriptors of land use, urban density and the degree of centralisation of work (proportion of jobs in the CBD). The data show how the higher car use cities are low in population density and more decentralised in the location of jobs, while the higher density and more centralised cities have reduced car use per person. Average densities range from lows of 15 per ha in the USA and ANZ cities up to 150 to 200 per ha in the Asian cities, including Chinese cities. In the high-income cities, 82% of the variance in car passenger km per capita is explained by density. In the low-income cities, where other factors such as extreme variations in income affect the outcome, still 47% of their variation in per capita car use is explained by density.

Job decentralisation primarily affects the capacity of public transport to service the journey-to-work, a major market segment for public transport, and in both income groups of cities this is reflected in statistically significant higher car use in more decentralised cities. The extent to which metropolitan jobs remain in city centres varies from only 9% in USA cities (vs. 15 to 16% in other auto cities), up to figures as high as 29% in Latin America. In China, 51% of jobs remain in the core area of the urban regions, though Chinese cities have difficulty conforming to strict western definitions of a CBD (Kenworthy & Hu, 2000).

Any city wishing to attend to issues of managing the automobile and minimising car use, must address urban land use patterns and their effects on urban transportation. The best policy response seems to be one of selective densification and mixing of compatible land uses, especially around areas of high public transport accessibility. As well, centralisation of jobs in the CBD, but also in satellite sub-centres built at transit nodes, appears to be an effective strategy.

The economics of urban transportation

The final section discusses some salient economic indicators of the performance of urban transportation systems.

Public transport operating cost recovery

Despite difficulties in reliably specifying this mercurial indicator, due to differences in accounting systems between transit operators, this study has determined the best available measures of the extent to which public transport covers its day-to-day operational costs from the farebox (including finance and depreciation charges).

Perhaps not surprisingly, the worst performing cities are found in the USA (36% cost recovery), which has gone farthest in marginalising public transport from mainstream use. For entirely different reasons, the Chinese cities only recover 41% of their costs due to strictly controlled fares and inefficient staffing levels on transit. ANZ, Canadian, and Western and Eastern European cities all recover 50-60% of costs, this recovery range being often considered 'fair' for this indicator. On the other hand Middle Eastern and African cities come quite close to cost recovery (88% and 95% respectively). Interestingly, high and low income Asian cities make healthy operating profits (138% and 156%), while Latin American cities also recover more than their operating costs (133%).

When the other data on transit service and use are weighed up, the key lesson here for cities appears to be not to try to improve cost recovery by cutting back services. Rather, cities should be creating a 'virtuous circle' of improved transit service and ridership, making transit central to the lives of a majority of the population and expanding market share (Kaufmann, 2000).

The cost-effectiveness of private & public transport

This study collected all the private and public transport investment and operating costs in all cities. The database therefore has a full picture of how much it costs to operate the passenger transport system in each city. One way of expressing this information is the percentage of a city's GDP that is spent on passenger transport (both investment and operating costs). Tables 2 and 3 show three such items – the total passenger transport cost and the private and public transport components of it. The significance of the data is that it allows an assessment to be made of the economic cost-effectiveness of passenger transport in different regions. It makes sense from an economic perspective to be spending as little as possible on this factor, since more of a city's wealth is then theoretically available for productive investment and other uses.

The data show that within the *higher income regions*, where GDP per capita is broadly comparable (\$ 20,000 to \$ 32,000), the more auto-oriented cities in North America and ANZ clearly plough back a lot more of their GDP into the means of moving people around (12% to 14%). This is in contrast to high income Asian cities and Western European cities which average 7% to 8%. And of interest from a cost-effectiveness point of view, public transport is responsible for a mere 0.6% to 1.6% of the above figures. The high income Asian cities have the biggest relative cost to public transport (1.6% out of 7.1% of GDP), but they also have by far the largest use of

public transport (46% of total motorised passenger km compared to 19% in western Europe, their nearest wealthy rival). Thus, to move 54% of the motorised transport task in high income Asian cities consumes 5.5% of GDP, and to move 46% accounts for only 1.6% of GDP (see further below).

In the *lower income regions* the picture is quite different, where due significantly to lower wealth (GDP per capita of \$ 2,366 to \$ 5,951), the percentage of GDP consumed on passenger transport is generally higher, ranging from 11% in Chinese cities up to 22% in African cities. The average for all lower income regions is 15% compared to 11% in higher income regions. Chinese cities perform better on this factor due to their still heavy reliance on non-motorised transport. Again, public transport cost is by far the minor player in these regions too, accounting for between 2.3% and 4.5% of GDP (average 2.8%).

It is interesting to compare the relative cost-effectiveness of private and public transport in each region. If we take the ratio of the percentage of GDP expenditure required to move a given percentage of the total motorised passenger transport task for the two sectors, the results shown in Table 4 are obtained.

It is clear that public transport is either equal to or greatly more cost-effective than cars in all regions except the USA where the car cost relative to the task performed is 60% that of transit. In light of the very low cost of car purchase and use (especially fuel) in the USA and the way in which the cities are optimised for car travel with extensive freeway systems and other factors, this is not a surprising result. Furthermore, USA transit systems for the most part operate in environments where it is difficult to service passenger needs (low density, dispersed land uses with road hierarchies difficult for transit to penetrate). If public transport is to play a greater role in USA cities and there is really no other direction for it according to the comparative data in this study, then a more competitive pricing structure between cars and transit would appear to be needed.

The opposite circumstance to this is in the wealthy Asian cities, where cars are almost 3 times more costly than transit in terms of achieved market share. This is a function of conscious policies, like those in Singapore and Hong Kong, to charge high prices for car ownership and use (Kenworthy *et al.*, 1995). But it is also an economy of scale factor where the cities are more optimised around transit and have more extensive, convenient transit systems.

Public transport is, however, clearly more competitive in cost terms in low income cities than in

Table 4. Relative cost-effectiveness of private versus public transport in high & low income cities

Region	Ratio of car cost to transit cost
<i>High Income</i>	
USA	0.6
ANZ	0.9
CAN	1.7
WEU	1.0
HIA	2.9
<i>Low Income</i>	
EEU	5.9
MEA	1.9
LAM	4.2
AFR	4.1
LIA	3.7
CHN	3.9

Note: Data are derived by dividing the respective total private & public transport passenger costs as a % of GDP, by the respective % of total motorised passenger km moved by private & public transport in each region, & then taking the ratio between cars & public transport.

higher income cities, which is hardly surprising. Eastern European cities with their extensive bus and rail systems developed under socialist policies, still carry formidable numbers of passengers at a relative cost that is 6 times lower than cars. It is important during this period of economic liberalisation for these cities to realise the economic advantage that these mostly old (and somewhat neglected) transit systems are providing as they attempt to compete in free market economies.

Conclusions

Patterns of urban transportation vary enormously around the world. These patterns in turn are associated with other critical issues such as land use, transport infrastructure priorities and transportation spending, as well as impacts from transport such as emissions and transport fatalities. The data point to a number of important findings, some key ones of which can be summarised as follows:

- There are strong local and global reasons for higher income cities in the USA, Canada and Australia/New Zealand to reduce their levels of private transport, transport energy demand and emissions. The level of automobile dependence in these cities exceeds all other parts of the world by considerable margins.
- The greater the reliance on private transport, the higher the proportion of wealth that a city has to spend on its passenger transport system. This is

money that is not available for productive investment and is a drain on economic competitiveness, considering passenger transport is a cost that is best minimised.

- Public transport systems are critical in both environmental and economic terms. They have large energy conserving potential and can carry a much larger share of the transportation task with little extra per capita energy use. Public transport is the most cost-effective motorised mode for moving people in an urban system, outperforming private transport by considerable margins in all cities, except in the USA where urban and economic policy is most highly favourable to cars.
- Cost recovery in public transport appears to be mostly a function of the centrality or marginalisation of public transport in society. Cities where public transport plays a critical role for all people, not just the poor, have transit systems that recover higher amounts from the farebox and can even make operating profits.
- In all cities it is critically important to develop public transport systems that are competitive with the car (and motor cycle). In all regions this points to a greater role for segregated transit infrastructure, especially urban rail. In cities that are rapidly increasing in income and vehicle ownership, bus riders can be all too easily poached from inferior bus systems, especially by motor cycles.
- Motor cycle levels and usage are very low in higher income cities but very high in some lower income cities, especially in Asia, but not consistently so. A better understanding is needed of the motor cycle 'phenomenon' in urban transport and the best way to manage it.
- Segregated transit infrastructure offering reliable and speedy transit services is transit's best antidote to the urban freeway. The more auto-oriented cities in the west are noticeably austere in their levels of such infrastructure. In particular, lower income cities also lack the levels of segregated transit infrastructure that would allow their public transport systems to compete with cars and motor cycles.
- Park-and-ride as a way of delivering people to fixed route transit is a peculiarly American phenomenon and is not favoured as a way of helping transit to improve its performance. Densification and mixing of land use around transit nodes and effective, space-conserving feeder bus services are more effective means to feed fixed transit and are more widely practised on a global scale.
- Extensive private transport infrastructure, including urban freeways and high levels of parking in the CBD, are clearly associated with the encouragement of greater private transport and are detrimental to public transport and hostile to non-motorised modes.
- In all regions, investment in road infrastructure considerably exceeds that of public transport investment, even where transport infrastructure funds *per se* are ostensibly scarce. The pattern seems to reflect a clear bias towards road funding. There is a clear need for a more level playing field in the access of all modes to transport funding, if sustainable transport is to be realised.
- There exists an urgent requirement to protect and encourage non-motorised modes, especially in lower income cities where they are under extreme threat from motorisation and where the cities cannot cope with the space requirements and other pressures of individual motorised transport. Non-motorised modes are the most democratic and cost-effective transport in all cities.
- Transport emissions need to be tackled from both a vehicle use perspective and the level of emissions per vehicle. The former is particularly critical in the higher income cities in order to reduce per capita emissions. The latter is badly needed in lower income cities, while at the same time controlling future growth in private transport use.
- Transport fatalities in cities are a clear function of the sheer level of use of private transport (automobile dependence), vehicle technology factors, and the quality of transport management reflected in the operating environments that people confront. Higher income cities need to tackle auto-dependence most strongly, while lower income cities must address the other factors, at the same time restraining motorisation.
- All cities need to move towards selectively denser, more mixed use and centralised land use patterns in order to minimise private transport use. Auto cities need to build these denser patterns of land use, especially around transit nodes, while already dense cities in Europe, Asia and other lower income regions need to guard against sprawl and monocultural land use patterns, which feed the need for more vehicle ownership and use. All cities need to avoid the 'salt and pepper' scattering of work and other destinations in favour of centralisation in city centres and sub-centres that prioritise walking, cycling and public transport access.

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Travel Demand Management: The potential for enhancing urban rail opportunities & reducing automobile dependence in cities

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Abstract

Using data from a large international comparison of cities in North America, Australia, Europe and Asia, a review is made of the role of transport infrastructure provision in shaping transport patterns and travel speeds in cities. A case is made for moving away from supply-side, road-oriented approaches to transport which induce more traffic, and towards demand management, that emphasises public transport, walking and cycling and de-emphasises investment in roads. Urban rail is shown to play a critical role in shaping urban transport patterns and in helping cities to manage travel demand and reduce their level of automobile dependence.

Keywords

Automobile dependence, cities, cycling, demand management, international comparison, investment strategies, public transport, railways, trams, walking

Introduction

In recent decades most cities have been rapidly increasing their dependence on the automobile with a corresponding decrease in the significance of public transport. This has led many cities in both developed and developing countries into difficult environmental, social and even economic problems. All the while cities have been expanding their road infrastructure in an effort to keep a step ahead of traffic growth and congestion or to relieve existing congestion, but with little success. This process has been driven by the increasingly discredited international urban transport planning process based on traditional 4 step land use – transport computer models. These models tend to extrapolate traffic projections indefinitely into the future. They usually end up recommending large increases in road transport infrastructure to keep pace with their traffic projections, thus turning into self-fulfilling prophecies (see Kenworthy, 1990). They generally ignore non-motorised modes as legitimate modes of transport and do not deal very well with public transport either. Their principal aim has been to project road needs for private transport.

Increasingly throughout the 1980s and 1990s the idea has been gaining rapid credence that traffic simply expands to fill the road space provided and that supply-side approaches to managing transport are doomed to failure (Goodwin, 1991, 1994, 1997; Royal Commission on Environmental Pollution, 1994; SACTRA, 1994). Traffic projections simply become self-fulfilling prophecies where road infrastructure is expanded to meet the expectation of those projections. The idea of 'induced traffic' has thus become the subject of quite a concerted research effort as well as a hotly contested policy issue which frequently arises when plans are put forward for significant additions to road capacity (Hansen & Huang, 1997). Will the new road or road widening simply add more traffic and exacerbate environmental pressures, rather than bringing claimed benefits of time and other savings? Mogridge (1997) suggests that policies for increasing urban road capacity are self-defeating and concludes that '...a necessary condition for increasing journey speeds in towns (for both car and collective transport users) is to improve the quality of collective transport.' (p.5).

As a consequence of such assessments, attempting to match or manage travel demand within the capacities of existing infrastructure has been gaining a far greater degree of acceptance both academically and as a fundamental pillar of transport policy in many cities (Goodwin, 1991). Nevertheless, in many cities freeways and highways are still being built on the basis that they will help solve traffic problems and contribute to time, fuel, emissions and other operational cost savings. This is chiefly because the aforementioned transport planning methodologies used to formulate the road proposals and to create the favourable benefit-cost ratios fail to take into account urban system feedback effects and the reality of induced traffic. This is also largely the basis of Mogridge's conclusions that '...increasing road capacity in congested conditions can make congestion worse.' (p.5) He says the failure lies in neglect of the '...interaction between private and public transport, or

rather between individual and collective transport.' (p.5).

In order to examine the interrelationships between transport infrastructure and transport patterns and the effects of road and rail systems on urban travel demand, this paper uses extensive urban transport, economic and environmental data collected on 46 international cities. It provides an overview of existing patterns of transport and transport infrastructure provision in cities and some key correlations between these factors that point to influences on urban travel demand. Using the international data, it then examines the urban travel demand benefits and broader positive spinoffs of limiting road capacity in cities and developing better urban rail systems. This includes economic, environmental and time savings implications. A few positive case studies are also outlined of road reduction and urban rail development in cities and a number of broad overall conclusions are drawn from the results.

Method

This paper draws upon a very large international urban database developed over a period of almost 20 years (Kenworthy & Laube *et al.*, 1999; Newman & Kenworthy, 1989, 1999a). Descriptions of the database, detailed definitions of all indicators and the methodologies behind the research can be found in Kenworthy & Laube (1999), Kenworthy & Laube *et al.*, (1999) and Newman & Kenworthy (1999a). Further details are also available in Kenworthy *et al.*, (1997) in a report prepared for the World Bank which partly funded the research.

Existing patterns of transport & transport infrastructure in cities

In order to examine the interrelationships between transport patterns and transport infrastructure, this section presents a set of relevant data on a sample of 46 international cities. It then examines some of the key relationships between these data which demonstrate the important influence of transport infrastructure on travel demand.

Table 1 provides some key data on patterns of private and public transport usage in the 46 cities. Table 2 provides important indicators of transport infrastructure and service provision and the resulting performance of that infrastructure in terms of the speed of travel achieved in both private and public transport.

Examination of the data reveals some fundamental patterns:

- The level of automobile dependence as measured by car use per person and how people get to work is clearly highest in US cities. It then systematically

diminishes in Australian cities, Canadian cities and European cities reaching a low in wealthy Asian cities and then rising slightly again in developing Asian cities.

- The level of public transport use mirrors these patterns, being lowest in US cities, reaching a peak in wealthy Asian cities and then declining to a degree in developing Asian cities. Cities with high public transport use tend also to have a higher percentage of their total public transport use being accomplished by rail.
- Private and public transport infrastructure also follow some clear patterns. Road provision as well as central city parking per 1000 jobs is much higher in the automobile dependent cities. Conversely, public transport service supply is comparatively low in the auto-dependent cities and rises in a systematic way as the cities become less auto-orientated.
- In particular, rail infrastructure and service provision is weak in the auto-orientated North American cities and also the developing Asian cities, but strong in Europe and wealthy Asian cities.
- The performance of transport infrastructure also has some clear patterns:
 - (1) Road traffic speeds are highest in the auto-orientated regions and decline systematically as the cities become more public transport-orientated.
 - (2) Public transport speeds do not follow such systematic patterns, but rather tend to be highest where rail is more significant within the public transport system.
 - (3) Bus speeds are generally quite low and remarkably consistent within the range of 20 km/h to 25 km/h, most often around the 20 km/h mark. Nowhere do they compete effectively with cars. On the contrary, there are numerous cities where the average rail speed exceeds road traffic speed.
 - (4) Where rail speed is high, the overall public transport system speed in many cases is in excess of road traffic speed. This ratio of public transport speed to average road traffic speed or *relative transit speed* is an important factor in securing the competitiveness of public transport in any city and can only be achieved with a high quality rail system (see Newman & Kenworthy, 1999b).

Table 1. Transport patterns in 46 international cities, 1990

<i>City</i>	<i>Private passenger vehicle km per capita</i>	<i>Private passenger vehicle km per capita</i>	<i>% of workers using transit</i>	<i>% of workers using private transport</i>	<i>% of workers using foot or bicycle</i>	<i>Transit passenger km per capita</i>	<i>% of total passenger km on transit</i>	<i>% of transit passenger km on rail</i>
US Cities								
Boston	10280	17373	14.7	77.8	7.4	627	3.5	75.7
Chicago	9525	14097	14.9	80.6	4.5	805	5.4	67.1
Denver	10011	13515	4.4	91.3	4.3	199	1.5	0
Detroit	11239	15846	2.6	95.4	2.0	171	1.1	0
Houston	13016	19004	4.1	93.3	2.6	215	1.1	0
Los Angeles	11587	16686	6.7	89.3	4.0	352	2.1	0
New York	8317	11062	26.6	66.7	6.7	1334	10.8	76.0
Phoenix	11608	15903	2.1	93.7	4.2	124	0.8	0
Portland	10114	14665	5.8	90.3	3.9	286	1.9	18.4
Sacramento	13178	19239	2.5	92.7	4.7	117	0.8	31.3
San Diego	13026	18757	3.4	90.8	5.8	259	1.7	27.0
San Francisco	11933	16229	14.5	80.0	5.5	899	5.2	56.6
Washington	11182	16214	15.1	80.6	4.5	774	4.6	64.1
Average	11155	16045	9.0	86.3	4.6	474	3.1	32.0
Australian Cities								
Adelaide	6690	11173	11.5	83.1	5.4	572	4.9	21.1
Brisbane	6467	11188	14.5	80.4	5.1	900	7.4	65.7
Canberra	6744	11194	10.0	84.0	6.0	660	5.6	0
Melbourne	6436	9782	15.9	79.4	4.7	844	7.9	79.7
Perth	7203	12029	9.7	86.2	4.1	544	4.3	17.9
Sydney	5885	9417	25.2	69.3	5.5	1769	15.8	62.6
Average	6571	10797	14.5	80.4	5.1	882	7.7	41.2
Canadian Cities								
Calgary	7913	11078	16.5	78.2	5.3	775	6.5	42.0
Edmonton	7062	10028	11.0	83.0	6.0	728	6.8	9.9
Montreal	4746	6502	21.3	72.6	6.1	952	12.8	50.3
Ottawa	5883	8236	27.0	66.0	7.0	850	9.4	0
Toronto	5019	7027	30.1	64.6	5.3	2173	23.6	55.1
Vancouver	8361	12541	12.4	81.9	5.7	871	6.5	24.2
Winnipeg	6871	9620	19.9	72.1	8.0	635	6.2	0
Average	6551	9290	19.7	74.1	6.2	998	10.2	25.9

Travel Demand – Relationships between key factors

The above broad patterns imply some strong relationships between the various transport characteristics in cities and the different influences they have on travel demand. This section confirms some of these relationships through a series of correlations. Table 3 sets out the relevant correlations.

The results show clearly how higher length of road per person and higher average speed of traffic are

associated very strongly with higher car use and lower public transport use. In other words, where cities facilitate higher speed of travel in cars through more roads (generally high capacity roads such as freeways), the further people will travel. Naturally, there is a link to land use involved here, in that activities will tend to spread at lower densities where road travel speeds are higher. This is confirmed by the data on urban density collected for each of the cities. It

Table 1 continued

City	Private passenger vehicle km per capita	Private passenger vehicle km per capita	% of workers using transit	% of workers using private transport	% of workers using foot or bicycle	Transit passenger km per capita	% of total passenger km on transit	% of transit passenger km on rail
European Cities								
Amsterdam	3977	6522	25.0	40.0	35.0	1061	14.0	71.2
Brussels	4864	6809	35.3	45.5	19.1	1428	17.3	76.4
Copenhagen	4558	7749	25.0	43.0	32.0	1607	17.2	65.4
Frankfurt	5893	8309	42.1	49.4	8.5	1149	12.1	86.3
Hamburg	5061	7592	38.1	49.4	12.5	1375	15.3	73.5
London	3892	5644	40.0	46.0	14.0	2405	29.9	74.2
Munich	4202	5925	46.0	38.0	16.0	2463	29.4	87.7
Paris	3459	4842	36.2	48.9	14.9	2120	30.5	82.8
Stockholm	4638	6261	55.0	31.0	14.0	2351	27.3	66.0
Vienna	3964	5272	43.9	44.1	11.9	2430	31.6	81.8
Zürich	5197	7692	39.8	36.0	24.2	2459	24.2	84.7
Average	4519	6602	38.8	42.8	18.4	1895	22.6	77.3
Wealthy Asian Cities								
Hong Kong	493	813	74.0	9.1	16.9	3784	82.3	43.4
Singapore	1864	3169	56.0	21.8	22.2	2775	46.7	31.3
Tokyo	2103	3175	48.9	29.4	21.7	5501	63.4	96.0
Average	1487	2386	59.6	20.1	20.3	4020	64.1	56.9
Developing Asian Cities								
Bangkok	2664	4634	30.0	60.0	10.0	2313	33.3	0.4
Jakarta	1112	1546	36.3	41.4	22.3	1323	46.1	2.9
Kuala Lumpur	4032	6299	25.5	57.6	16.9	1577	20.0	0.3
Manila	732	1582	54.2	28.0	17.8	2568	61.9	6.2
Seoul	1483	2464	59.6	20.6	19.8	2890	54.0	35.7
Surabaya	1064	1568	21.0	55.7	23.5	555	26.1	0
Average	1848	3016	37.8	43.9	18.4	1871	40.2	7.6

shows that as average road traffic speed increases, the density of the cities reduces exponentially ($r = -0.836$, $s < 0.0005$).

Conversely, the data show that where public transport speed is more competitive with car speed, this is associated strongly with lower car use and higher public transport use. It is also significant that where rail plays a much higher role within the public transport system (i.e. where a higher percentage of total passenger kilometres by public transport are accounted for by rail), the higher is the relative speed of public transport to traffic. In other words, rail is the crucial element in giving cities the capacity to compete effectively with cars in speed terms. This competitive position, in something as basic as travel time, is

fundamental in people's modal choice behaviour (see also Table 9 for further discussion of the significance of rail systems in cities).

Finally, Table 3 also shows that, as with roads, higher parking supply in the CBD is associated with higher car use and in particular, much lower public transport use, especially for the journey-to-work. This is hardly surprising, given that higher parking in the CBD is also associated with higher road traffic speed, poorer relative speed of public transport and most importantly, lower use of rail within the public transport system.

Table 2. Transport infrastructure & travel speed in 46 international cities, 1990

City	Road supply (m/person)	Road density (m/ha)	Rail route supply (m/1000 people)	Rail route density (m/1000 ha)	Transit vehicle km of service per person	Rail service km per ha	Transit service km per km of road	Parking spaces per 1000 CBD jobs	Average traffic speed (km/h)	Average speed of transit (km/h)				
										Bus	Train	Tram	Ferry	Total
US Cities														
Boston	6.7	80	135.6	1521	36	230	5373	285	52.3	20.1	33.2	17.2	21.5	29.5
Chicago	5.2	86	135.1	2390	41	341	7885	128	45.0	17.9	46.1	-	-	36.8
Denver	7.6	97	0	0	21	0	2763	606	58.1	24.2	-	-	-	24.2
Detroit	6.0	77	0	0	14	0	2333	706	56.3	22.5	-	-	-	22.5
Houston	11.7	111	0	0	17	0	1453	612	61.2	23.6	-	-	-	23.6
Los Angeles	3.8	91	4.1	97	20	0	5263	520	45.0	19.9	-	-	-	19.9
New York	4.6	88	81.9	1573	63	760	13696	60	38.3	18.8	39.0	-	16.6	34.2
Phoenix	9.6	101	0	0	10	0	1042	906	51.5	24.5	-	-	-	24.5
Portland	9.1	106	20.4	239	27	21	2967	403	49.7	26.0	31.5	-	-	27.0
Sacramento	8.8	112	21.7	340	10	26	1136	777	63.9	22.7	30.7	-	-	25.2
San Diego	5.5	72	21.4	299	24	36	4364	688	55.7	26.7	35.0	-	-	28.9
San Francisco	4.6	74	64.4	1049	49	338	10652	137	44.3	20.1	46.6	14.5	20.0	33.2
Washington	5.2	75	104.7	1508	37	236	7115	253	42.4	19.3	39.4	-	-	32.2
Average	6.8	90	45.3	694	28	153	4174	468	51.1	22.0	37.7	15.9	19.4	27.8
Australian Cities														
Adelaide	8.0	94	136.2	1601	46	86	5750	580	46.4	22.1	27.0	19.9	-	23.0
Brisbane	8.2	80	147.0	1438	55	262	6707	322	50.1	28.7	44.0	-	-	38.8
Canberra	8.8	84	0	0	68	0	7727	842	49.5	34.5	-	-	-	34.5
Melbourne	7.7	115	224.3	3345	50	420	6494	337	45.1	21.0	33.0	18.0	-	27.1
Perth	10.7	113	55.1	586	47	51	4393	631	45.0	24.6	34.0	-	12.6	26.3
Sydney	6.2	104	241.2	4057	94	905	15161	222	37.0	19.0	42.0	-	23.0	33.5
Average	8.3	98	134	1838	60	287	7258	489	45.5	25.0	36.0	19.0	17.8	30.5
Canadian Cities														
Calgary	4.9	102	41.1	854	50	183	10204	522	47.1	24.6	32.0	-	-	27.7
Edmonton	4.8	144	18.1	539	51	97	10625	593	40.0	19.5	32.0	-	-	20.7
Montreal	4.5	152	50.0	1688	60	740	13333	347	43.3	20.5	29.7	-	-	25.1
Ottawa	7.1	225	0	0	56	0	7887	230	40.0	24.0	-	-	-	24.0
Toronto	2.6	108	132.4	3433	98	1469	37692	176	35.0	20.3	35.4	14.3	-	26.1
Vancouver	5.1	106	13.7	285	50	241	9804	443	38.0	20.1	41.7	-	13.5	25.3
Winnipeg	4.2	89	0	0	41	0	9762	546	35.0	19.0	-	-	-	19.0
Average	4.7	132	36.5	971	58	390	12229	408	39.8	21.1	34.2	14.3	13.5	24.0

Benefits of managing urban travel demand through less priority on road supply

Economic and environmental aspects of higher versus lower road capacity cities

The above analysis suggests that the greater the priority is to providing roads in cities, the more that this will simply encourage higher travel in private transport. This will also tend to systematically

damage public transport and its contribution to travel in cities. This link between higher versus lower road capacity in cities and other transport performance indicators in cities can be examined more systematically for its environmental and economic implications by breaking the cities in Table 2 into two groups according to road supply. The data show that it is the US and Australian cities that can be considered the higher road capacity cities, while the Canadian,

Table 2 continued

City	Road supply (m/person)	Road density (m/ha)	Rail route supply (m/1000 people)	Rail route density (m/1000 ha)	Transit vehicle km of service per person	Rail service km per ha	Transit service km per km of road	Parking spaces per 1000 CBD jobs	Average traffic speed (km/h)	Average speed of transit (km/h)					
										Bus	Train	Tram	Ferry	Total	
European Cities															
Amsterdam	2.6	127	234.7	11458	60	1877	23077	354	35.0	16.3	38.6	11.8	-	22.5	
Brussels	2.1	157	237.5	17791	63	2253	30000	314	37.9	19.1	36.0	17.6	-	28.8	
Copenhagen	4.6	132	166.0	4739	121	1948	26304	223	50.0	24.2	59.2	-	-	47.1	
Frankfurt	2.0	93	208.1	5117	48	1283	24000	246	30.0	19.6	52.2	17.6	-	45.8	
Hamburg	2.6	103	117.7	3742	71	1581	27308	177	30.0	22.0	37.3	-	12.2	33.2	
London	2.0	85	247.1	6221	138	3635	69000	?	30.2	19.0	48.3	30.0	18.0	43.4	
Munich	1.8	96	285.7	8571	91	3374	50556	266	35.0	23.2	47.8	17.5	-	42.6	
Paris	0.9	41	171.9	7933	71	2310	78889	199	25.7	19.3	41.8	-	-	38.0	
Stockholm	2.2	117	178.9	6536	133	2441	60455	193	30.0	27.2	43.9	24.4	-	38.2	
Vienna	1.8	123	332.0	22087	73	3594	40556	186	27.5	19.1	36.3	17.2	-	25.1	
Zürich	4.0	188	694.6	32706	148	15864	37000	137	36.0	21.1	54.7	15.5	21.9	44.7	
Average	2.4	115	261.3	11536	92	3651	38233	230	33.4	20.9	45.1	19.0	17.4	37.2	
Wealthy Asian Cities															
Hong Kong	0.3	84	21.2	6382	140	7863	500000	33	25.7	18.4	41.4	12.3	17.6	27.9	
Singapore	1.1	95	24.8	2150	114	1722	103636	164	32.5	19.2	40.0	-	-	25.7	
Tokyo	3.9	277	67.9	4820	89	5156	22821	43	24.4	12.0	39.6	13.0	-	38.5	
Average	1.8	152	38.0	4451	114	4914	64962	80	27.5	16.5	40.3	12.7	17.6	30.7	
Developing Asian Cities															
Bangkok	0.6	90	15.7	1238	110	21	183833	397	13.1	9.0	34.0	-	16.0	9.2	
Jakarta	0.5	85	5.9	1143	55	141	109000	?	23.6	14.6	35.6	-	-	15.2	
Kuala Lumpur	1.5	88	15.0	2662	50	16	33133	297	29.4	16.3	-	-	-	16.3	
Manila	0.6	119	9.7	1919	258	180	430000	27	25.5	15.4	37.5	-	-	17.1	
Seoul	0.8	193	16.2	3786	114	3479	144177	49	24.0	18.8	39.8	-	-	25.7	
Surabaya	0.3	53	0	0	62	0	207333	?	27.0	17.5	-	-	-	17.5	
Average	0.7	105	10.4	1791	108	639	151189	192	23.8	15.3	36.7	-	16.0	16.8	

European and wealthy Asian cities can be considered the lower road capacity cities. The former 19 cities have average per capita road supply of 7.3 metres per person, while the latter group of 21 cities has an average of 3.1 metres per person, or less than half the per capita road supply. It should also be noted that in terms of the infrastructure data in Table 2, the high road cities have 474 parking spaces per 1000 CBD jobs compared to 270 in low road cities, so are lower in this aspect of private transport infrastructure too. For the purposes of the analysis in Table 4, which involves economic indicators, the developing Asian cities have been excluded because of the confounding influence of their significantly lower wealth or gross regional product per capita (GRP).

Table 4 provides the data for a series of key economic and environmental indicators for the two groups of cities. The economic data show that the more road-oriented cities are less wealthy and spend much more on roads for construction and maintenance (both in per capita terms and as a proportion of city wealth). They have much poorer cost recovery on public transport, even though the level of public transport service has in many cases been cut back to a minimum in a vain attempt to improve cost-effectiveness (38 vehicle km per person per year in high road cities compared to 84 vkm in low road cities). Overall, they spend a lot more on running their private and public passenger transport systems, both in per capita terms and as a percentage of their wealth.

Table 3. Relationships between various urban transport characteristics relevant to travel demand.

	Length of road per person	Average speed of traffic	Relative speed of transit	Parking spaces per 1000 CBD jobs
Average speed of traffic	+ 0.817	Not Applicable	- 0.609	+ 0.644
	pow		exp	lin
	s<0.005		s<0.0005	s<0.0005
Relative speed of transit	- 0.556	- 0.609	Not Applicable	- 0.756
	exp	exp		exp
	s<0.0005	s<0.0005		s<0.0005
Car VKT per capita	+ 0.870	+ 0.837	- 0.599	+ 0.735
	pow	lin	exp	pow
	s<0.0005	s<0.0005	s<0.0005	s<0.0005
Car passenger km per capita	+ 0.888	+ 0.888	- 0.604	+ 0.746
	pow	pow	exp	pow
	s<0.0005	s<0.0005	s<0.0005	s<0.0005
% workers using transit	- 0.767	- 0.796	+ 0.782	- 0.852
	exp	exp	pow	exp
	s<0.0005	s<0.0005	s<0.0005	s<0.0005
Transit passenger km per capita	- 0.721	- 0.799	+ 0.831	- 0.837
	exp	exp	pow	exp
	s<0.0005	s<0.0005	s<0.0005	s<0.0005
% of total passenger km on transit	- 0.803	- 0.874	+ 0.751	- 0.807
	exp	exp	pow	log
	s<0.0005	s<0.0005	s<0.0005	s<0.0005
% of transit pass km on rail	- 0.247	- 0.146	+ 0.725	- 0.617
	lin	lin	log	lin
	s<0.05	s>0.05	s<0.0005	s<0.0005

Notes:

The first number in each cell is 'r', the correlation co-efficient of the relationship between the two variables.

The more the number approaches 1 the stronger the relationship. Positive numbers indicate that the two variables increase together, a negative number indicates an inverse relationship.

The abbreviations, lin, log, pow & exp indicate linear, logarithmic, power or exponential relationships between the two variables.

The 's' value is the level of statistical significance. The lower the number the more statistically significant is the result. A value for 's' of equal to or less than 0.05 means that there is only a 5% or less probability that the observed relationship is a chance one. Where 's' is greater than 0.05 the relationship is not considered statistically significant.

In terms of environmental aspects, the data reveal that high road capacity cities use more than twice as much energy per capita in transport, produce twice as much CO₂ per capita and generate well over twice the level of local smog emissions per person. Transport deaths are nearly 70% higher than in lower road capacity cities.

The economic and environmental data on cities, together with the data on the levels of car use and public transport use indicate that restraint on road supply (and parking) is an important element in attempting to manage urban travel demand and in developing more sustainable and livable cities.

Travel time implications of Higher versus Lower road capacity cities

Another aspect that needs to be considered here is the issue of time spent travelling. One of the most basic justifications for building new roads is to save time. The analysis so far has demonstrated that cities that prioritise roads and achieve higher road speed, experience greater travel distances. From this it might be surmised that any of the potential time savings from faster traffic may be eaten up by the longer distances travelled.

The data we have collected clearly support this proposition. First, we have gathered data on journey

Table 4. Economic & environmental implications of high road capacity in cities, 1990.

Indicator	US & Australian cities – 'higher road capacity cities'	Canadian, European, wealthy Asian cities – 'lower road capacity cities'	Compared to low road cities, high road cities are or have:
Infrastructure Indicators			
Length of road per person (metres)	7.3	3.1	136% higher road supply per person
Parking spaces per 1000 CBD jobs	474	270	77% higher central city parking
Public transport service supply (vehicle km per person per annum)	38	84	55% less public transport service
Economic Indicators			
GRP per capita	\$24,468	\$29,033	16% less wealthy
Road expenditure per capita	\$223	\$126	77% higher road expenditure
Road expenditure per \$1,000 of GRP	\$9.19	\$4.49	105% higher proportion of wealth spent on roads
Public transport operating cost recovery (%)	37%	68%	46% less cost-effective public transport
Total per capita operating costs of passenger transport (public & private per annum)	\$3,033	\$2,157	41% more total passenger transport costs
Percentage of city wealth spent on passenger transport (%)	12.7%	7.4%	72% higher financial drain on wealth by passenger transport
Environmental Indicators			
Energy use in passenger transport (MJ per capita per annum)	48,782 MJ	20,355 MJ	140% higher fuel use in passenger transport
Carbon dioxide emissions per capita from transport sector (kg per annum)	4,114 kg	2,075 kg	98% higher greenhouse contribution
Smog emissions per capita per annum (kg)	245 kg	101 kg	143% higher local air pollution load
Transport deaths per 100,000 people per annum (WHO ICD codes E810-E825)	13.7	8.2	67% higher transport deaths

Note: The currency used to express the Economic Indicators is US\$, taking 1990 as the base year

to-work trip times and distances (all modes). The cross-section of cities examined reveal that mean travel times for the journey-to-work are remarkably similar. These are summarised in Table 5. On average, individuals living in the cities examined are budgeting somewhere between 25 to 30 minutes for the journey-to-work. These results are supported by other research on travel times for the journey-to-work, including Szalai (1972), Manning (1978), Pederson (1980) and Hodges (1993). SACTRA (1994) has shown how journey-to-work times in the UK have held constant at around 30 minutes for some 600 years. A *constant travel time budget* appears to operate for the journey-to-work regardless of the type of city or transport infrastructure.

However, what the data in Table 5 show is, that despite the very similar trip times for the journey-to-work, there are quite large differences in trip length and in the speed of the journey-to work. The higher

road capacity cities in the US and Australia have longer trip lengths and higher speeds in traversing these distances. The lower road capacity cities have shorter trip lengths and slower speeds of travel.

It is possible to extend this analysis even further to include travel time for all trip purposes using the data we have assembled on private and public transport. Using detailed data for each city in the global survey it is possible to calculate the per capita hours of travel experienced in private transport, public transport and for total motorised travel (Kenworthy & Laube *et al.*, 1999). This is achieved by dividing per capita passenger kilometres in cars by the average road traffic speed and per capita public transport passenger kilometres by the weighted average speed of the public transport system (all kerb-to-kerb speeds). Table 6 contains the results for the regional groupings of cities, along with the respective average speeds of the road systems and public transport systems.

Table 5. Journey-to-work trip times, distances & average speeds in cities, 1990

<i>Cities</i>	Average journey-to-work trip time (minutes)	Average journey-to-work trip distance (km)	Average speed of journey-to-work (km/h)
American cities	26.1	15.0	34.5
Australian cities	26.4	12.6	28.6
Toronto	25.3	11.2	26.6
European cities	28.2	10.0	21.3
Asian cities (all)	34.0	7.9	13.9
Average all cities in study	28.9	11.3	25.0

Table 6. Annual per capita hours of travel in motorised modes & average speeds in cities, 1990

<i>Cities</i>	Per capita hours in cars	Per capita hours in public transport	Total per capita hours of travel in motorised modes	Average road traffic speed (km/h)	Average public transport system speed (km/h)
American	314	17	331	51.1	27.8
Australian	237	29	266	45.5	30.5
Canadian	234	42	275	39.8	24.0
European	198	51	249	33.4	37.2
Wealthy Asian	87	131	218	27.5	30.7
Developing Asian	127	111	238	23.8	16.8

The results show that despite having the fastest road traffic systems, residents of the high road capacity cities spend more hours in motorised travel than residents in low road capacity cities. US city residents spend 331 hours per capita per year travelling (all purposes) and this is 20% higher than their closest rivals, the Canadian cities, followed closely by Australian cities. The data also show that, generally speaking, as the cities become more transit-oriented, the per capita hours spent in cars declines. By contrast, although per capita hours spent in public transport rise as the cities become focussed around transit, these extra hours do not equate to the lower hours spent in cars in transit-oriented cities. In other words, as cities become less auto-dependent, the total time invested in travelling in motorised modes declines. The average wealthy Asian city's resident spends only 218 hours per year in motorised travel which is 52% below the US city resident.

Ideally the data in Table 6 should incorporate the time spent travelling on foot and by bicycle. In practice, these data are almost impossible to get with any degree of reliability across so many cities. This is mainly because of the problem outlined briefly in the introduction that the methods of transport planning focus almost entirely on motorised travel and in particular, the travel time 'savings' possible for cars by building faster road links within the urban system. Walking and cycling in these terms almost do not exist within the computer-based models used in

conventional transport planning.

Notwithstanding this problem, it can probably be argued that walking and cycling become more and more important for all trips as the cities become less orientated to cars. This is certainly shown in the modal split data for the journey-to-work for these cities which show the European and Asian cities average between 18% and 20% of workers using and foot and bike, compared to only 5% to 6% in US, Australian and Canadian cities (Newman & Kenworthy, 1999a). As such it can be expected that all cities would increase in the hours spent travelling each year, but that the European and Asian cities would increase much more.

One would thus expect a levelling out of per capita hours of travel for all modes at around the 350 hours per capita in all cities. This figure, averaged across all days of the year, equates to about 58 minutes per person per day.

Other studies on constant travel time budgets have suggested between 60 and 66 minutes, so these global city data would appear to be in the right range (Zahavi, 1976; Manning, 1978; Neff, 1996; Schafer & Victor, 1997). This regularity appears to occur irrespective of the vastly different transport technologies, levels of wealth, degree of industrialisation or cultural norms that prevail in the cities studied. Marchetti (1994) suggests that throughout history, cities have always been about '1 hour wide'.

Quite clearly, the reality of constant travel time budgets makes it impossible to actually save travel time in any city by building transport infrastructure that offers a higher travel speed *per se*. Rather, investment in travel time seems to be a physically determined

constant and that populations divide their travel budget between the modes that are best provided for in the city or modes that offer the best service for each trip type. Therefore, if the aim is to manage travel demand and to produce a more sustainable city that uses public transport, walking and cycling for more trips, then, as suggested earlier, the *relative speed between modes* rather than absolute speed of any mode is likely to be a key determining factor in mode choice. Nevertheless, building freeways and large highways that provide cities with higher absolute traffic speed, means that this relative speed term is pushed in favour of private transport and away from more sustainable modes (see correlations in Table 3).

The evidence from the journey-to-work and travel for all trip purposes is that higher speeds, derived principally from higher capacity road systems in cities, are not used to save time. Rather, higher speeds are used to travel further and are thus strongly counter-productive in travel demand management.

Effects on travel demand of reducing road supply

The above analysis has suggested that increasing road supply leads to increases in travel demand and increased automobile dependence. It is one issue to try to redress this by ceasing to add to road capacity in cities and better managing existing road supply. It is quite another issue to actually remove road capacity through mechanisms such as pedestrianisation schemes, traffic calming schemes and building of light rail lines on roads by reclaiming traffic lanes. Some evidence exists however that the effects of such schemes are not a dramatic increase in congestion and chaos on surrounding streets. Rather, the evidence suggests that traffic tends to disappear or contract in the same way that it appears or expands with increases in road capacity.

In this way it has been suggested that traffic behaves much more like a gas than a fluid. Gases expand and contract according to the size of the container they are placed in, while fluids retain their volume characteristics. Traffic engineers are trained to think of traffic as having the flow characteristics of a liquid, just like in water and wastewater engineering.

Table 7. Nuremberg's trip degeneration after traffic calming.

Streets closed	Year closed	Proportion of closed street's traffic found on surrounding streets
Museumbrücke & Fleischbrücke	1972-3	24%
Karolinenstrasse & Kaiserstrasse	1972-3	26%
Bankgasse & Alderstrasse	1982	20%
Rathausplatz	1988	29%

This leads them to believe that if a road is closed or restricted, traffic volumes will remain constant and simply seek another channel in which to flow, leading to unmitigated congestion and traffic chaos. This seems to be a reason why studies which show that a significant amount of traffic actually disappears with road closures or restrictions, cause considerable angst in some professional circles.

Most experience with the effect of traffic calming schemes on traffic has been in Europe and some key case studies are summarised here. Monheim (1990) has examined the direct effect of traffic calming in Nuremberg when he assessed the impact of 5 km of city street pedestrianisation. These were converted without the building of by-passes and indicate how traffic calming can lead to traffic 'dissolving' or trip 'degeneration' (Table 7).

The data show that only around one quarter of the former traffic appeared on the surrounding streets; as these streets had some spare capacity the diverted quantities were easily absorbed. The pedestrianised areas became economically much more vital despite the apparent loss of vehicle traffic. Obviously people movements have increased but car movements have decreased.

London's Oxford Street, which is now one of the most prosperous shopping streets in the world, was pedestrianised (with bus and taxi access) in 1972 by the Greater London Council and its impact evaluated (Abouseif & Townley, 1973). Traffic monitoring in surrounding streets showed: no increase (Brook Street), a 12% increase (Grosvenor Street) and a 25% increase (Wigmore Street). Such minimal changes do not indicate the need for by-passes as so often predicted (and built). The success of traffic calming schemes in reducing travel demand seriously questions such assumptions. Monheim (1990) shows how few of the traffic calming experiments in Europe involved building by-passes.

Further to this argument, a detailed evaluation of Cologne's traffic calming has revealed that traffic has disappeared as a result of reducing road capacity (Table 8). The data show considerable reductions in traffic at all the test points together with speed

Table 8. Some before & after effects of traffic calming in quarters of Cologne (1984-88)

Measuring point House number, Street	PCUs per hour		Car speed km/h*		Braking distance**	
	Before	After	Before	After	Before	After
KOLN-NIPPES						
19, Turmstr.	165	79	36	29	18	13
21, Mauenheimerstr.	209	65	40	31	22	15
30, Kuenstr.	206	128	44	34	25	17
27, Gocherstr.	432	309	41	30	23	14
KOLN-AGN-ESVIERTEL						
22, Neusser Wall	322	234	52	28	32	12
48, Schillingstr.	149	119	42	22	23	9
8, Lupusstr.	73	48	38	24	21	10
89, Balthasarstr.	51	19	32	30	16	14
3, Niehlerstr.	109	94	47	20	28	8
14, Niehlerstr.	424	462	46	45	27	26
KOLN-KALK						
135, Eythstr.	176	93	48	24	28	8
120, Buchforststr.	481	235	45	44	26	25
24, Remscheiderstr.	247	73	42	33	23	16
21, Wiersbergstr.	57	19	44	38	25	20
18, Manteuffelstr.	149	27	53	38	34	20
59, Steinmetzstr.	418	25	49	43	29	24

Source: Stadt Koln (1989).

Notes:

PCU is similar to the German PKW-E (Personen Kraftwagen Einheit), both meaning 'Passenger car unit'; a private car is 1 PCU while a double-deck bus is 3PCUs, for example.

* = Mean speed of 85% of the vehicles using the street.

** = Stopping distance in metres, measured from initial recognition by the driver of a problem to a complete stop

reductions of between 10 and 15 km/h. The result for the drivers on the traffic calmed streets was a considerable reduction in the distance needed for braking. This highlights the importance of physical layout and landscaping as the basic technique of traffic calming which changes the perception of road space and hence builds in reduced speeds.

A large before and after study of the effects of area wide traffic calming in six German urban areas (Berlin-Moabit, Mainz, Borgentreich, Buxtehude, Esslingen and Ingolstadt) suggests that there has been a reduction in longer trips as closer urban areas become more congenial environments for shopping and visiting. As well, the total number of walking trips within the traffic calmed areas rose by 28% (Brög & Winter, 1990; Lappe & Monheim, 1991; Baier *et al.*, 1992).

More recently Kruse (1998) has provided a brief review of extensive worldwide evidence that reducing road capacity does cause traffic to disappear to a very significant extent. Specific cases referred to include:

- Tower Bridge in London, closed in 1994 and three years later traffic had not returned to its original level;
- London's ring road, the 'ring of steel' was closed in 1993 and traffic dropped by 40%;
- London's Hammersmith Bridge, deemed incapable of carrying its 30,000 vehicles per day, was closed to all traffic except buses and cyclists in February, 1997. A survey of the same people before and after closure revealed 21% changed to public transport, walking or cycling and congestion in surrounding areas did not markedly increase;
- New York's West Side Highway, part of which collapsed in 1973, led to closure of most of the route. A study was completed in 1976 of the remaining section and it was found that 53% of trips that were there three years before closure had disappeared by 1975 and of those trips 93% had not reappeared anywhere else;

- In San Francisco after the 1989 earthquake the Embarcadero Freeway collapsed and was not rebuilt. The predicted traffic chaos did not eventuate. Similarly, in 1996 the upper deck of the unstable Central Freeway was torn down, and none of the dire predictions of traffic chaos materialised;
- Harbor Drive, a six lane freeway in Portland, Oregon was replaced with a 37 acre waterfront park with no major traffic problems.

It can be concluded that available evidence on road capacity reduction points to traffic acting more like a gas than a liquid and contracting in response to reductions in road space. Predictions of unmanageable congestion and diversion of traffic onto other streets are not supported by case studies.

Benefits of managing urban travel demand through the development of better urban rail systems

Urban systems evidence

The preceding sections have suggested that urban rail systems are associated with higher public transport speeds relative to private transport, higher public transport use and lower car use in cities. This section strengthens this perspective by dividing the international set of cities into two categories (Table 9): those that have what might be called strong rail systems and those with weak rail systems. Cities with more than 50% of their public transport passenger kilometres on rail are classified here as strong rail cities (SRCs from hereon) and those with less than 50% are called weak rail cities (WRCs from hereon).

Some of the latter cities are without any rail system. The SRCs incorporate cities from all regions, while the WRCs exclude Europe. Table 9 draws together the key transport, infrastructure, economic and environmental characteristics of the two groups of cities. The data in Table 9 confirm the earlier analysis in a dramatic way. The SRCs have significantly better public transport supply and use, public transport performs better in terms of speed compared to the car and they have much lower road and parking requirements.

The significance of this result is accentuated within the US sample by comparing the cities with *no rail systems* in 1990 and those with rail. Those with rail systems have some 117 annual public transport trips per capita, while those that have only buses have a mere 30 trips per capita. Likewise, the proportion of total passenger travel captured by public transport is 4.2% in rail cities and 1.3% in bus-only cities in the US. In Canada, the pattern is similar though public transport use is much better overall. The five cities with rail have 178 annual public transport trips per capita versus the two without rail (Ottawa and

Winnipeg) with 116 trips, and public transport accounts for 11.2% of total motorised passenger travel in the Canadian cities with rail, but 7.8% in those without rail. In terms of private transport, car ownership and use is much lower in SRCs and modal split for the journey-to-work is much more in favour of public transport and non-motorised modes.

The SRCs are also 45% wealthier than the WRCs. This result cuts against arguments used by some commentators that as cities become more wealthy they are on an inevitable trajectory towards greater auto dependence, with an inexorable process of declining public transport (e.g. Gomez-Ibañez, 1991; Lave, 1992). In fact the reverse seems to be true. The wealthier cities are more public transport-orientated and certainly have better rail systems. They also clearly have lower car use. Indeed, we have argued elsewhere that excessive automobile dependence drains the economy of cities and this is borne out to an extent by the lower wealth found in more auto-orientated urban areas (e.g. see Kenworthy *et al.*, 1997).

Continuing with the economic perspective, SRCs spend much less on roads but have only marginally better operating cost recovery in public transport overall. However, it should be pointed out that inclusion of Hong Kong and Singapore in the WRC category is almost solely responsible for the closeness between the two cost recovery results. This is because Hong Kong's and Singapore's entire public transport systems operate on very strict commercial principles and made operating profits of 36% and 15% respectively in 1990. The operating cost recovery for the rest of the WRCs is 30% compared to 53% in SRCs.

The environmental indicators show that SRCs significantly outperform the WRCs. The SRCs consume 35% less energy in their private transport systems and not surprisingly they have markedly lower per capita greenhouse gas emissions. Local smog producing emissions (nitrogen oxides, carbon monoxide, sulphur oxides, volatile hydrocarbons and volatile particulates) are also significantly lower in SRCs than WRCs (22% less). Finally, the costs incurred through transport-related accidents in cities are significant, especially the loss of life. The data in Table 9 reveal how the more public transport and rail-orientated cities, have some 30% lower mortality from transport accidents compared to the more auto-orientated cities.

Case study evidence

It is useful to build on the above evidence about the effectiveness of urban rail in increasing public transport use and reducing car use with a brief case study of the success of the rail system in Perth over recent years. In the last decade Perth has electrified its rail system and added a 30 km line to Currambine in

Table 9. Characteristics of strong rail cities versus weak rail cities

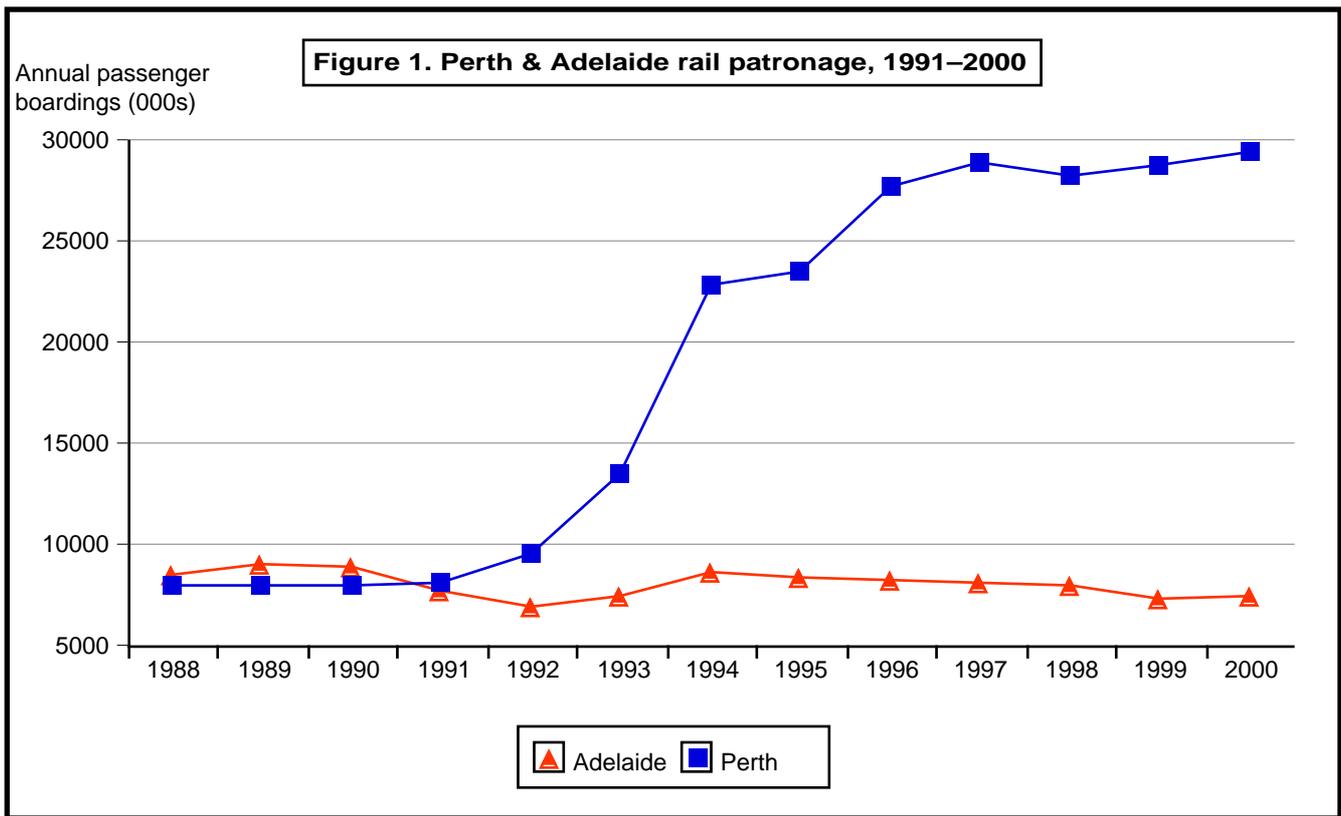
<i>Indicators</i>	Strong Rail Cities	Weak Rail Cities
Public transport operational performance indicators		
Percentage of public transport passenger km on rail	73%	15%
Annual public transport vehicle kilometres of service per person	77	45
Annual rail service provision per capita (wagon km)	47	5
Annual rail service provision per ha (wagon km)	2319	574
Annual public transport passenger trips per capita	248	113
Annual public transport passenger km per capita	1701	773
Percentage of total motorised passenger km on public transport	19%	11%
Annual public transport energy use per capita (megajoules: MJ)	1217	858
Transport infrastructure & performance indicators		
Rail route supply (metres per 1000 persons)	194	21
Rail route density (metres per 1000 urban hectares)	6987	743
Road supply (metres per 1000 persons)	3909	6504
Road supply (metres per 1000 urban hectares)	113783	105729
Parking spaces per 1000 CBD jobs	219	545
Annual car kilometres per kilometre of road	1801934	1464833
Overall public transport system speed (km/h)	34.7	25.0
Ratio of public transport system speed to road traffic speed	0.98	0.56
Private transport indicators		
Total vehicles (all types) per 1000 people	524	645
Passenger cars per 1000 people	444	521
Total private vehicle kilometres (VKT) per capita (all types of vehicle)	6977	9705
Private passenger vehicle kilometres (VKT) per capita	5982	8492
Private passenger vehicle passenger kilometres per capita	8849	12416
Percentage of workers using public transport	30.4%	15.5%
Percentage of workers using private transport	56.9%	77.9%
Percentage of workers using walking and cycling	12.7%	6.6%
Economic indicators		
Annual Gross Regional Product (GRP) per capita (US\$, 1990)	\$29,493	\$20,352
Percentage of GRP spent on operating passenger transport	8.9%	12.7%
Annual road expenditure per \$1000 of GRP (US\$, 1990)	\$5.96	\$9.07
Transit operating cost recovery	53%	51%
Environmental indicators		
Annual private passenger energy use per capita (MJ)	27354	41807
Annual carbon dioxide emissions per capita (kg)	2592	3596
Annual smog emissions per capita (NO _x , CO, SO _x , VHC, VP: kg)	175	224
Annual transport deaths per 100,000 people	9.7	13.9

the northern suburbs.

First, the use of rail has grown dramatically in the Perth region since the rail system was upgraded. Figure 1 shows the growth in rail use over the period 1991 to 2000 compared to Adelaide which has retained an old diesel rail service and has cutback rather than expand this service.

In terms of the new rail line, which operates in

what was previously a bus-only corridor using line haul buses on a freeway, the improvements have been marked. First, the new line increased public transport patronage in the corridor by 40% in the first year, rising to 56% a few years later. As well, it has been shown that 25% of the patrons of the new line gave up using their cars for the journey-to-work in the first year of operation (Alexander & Houghton, 1995).



Second, the new line has had a marked effect on overall rail system characteristics between 1991 and 1996. Table 10 summarises these results. The data show how rail service provision, rail use and rail speed have all achieved large increases. Based on this success, Perth is about to start constructing a new 74 km urban rail line to Mandurah in the south of the metropolitan region at a cost of A\$1.4 billion.

In summary, the above data all point to the idea that public transport systems based on buses alone cannot achieve the same positive urban system results across a wide range of factors as cities that develop more around rail systems. The mechanisms for this are complex. However, they appear to relate at least in part to the legibility and the greater permanence of rail services, the positive image of rail in the mind of the public and business community, people's willingness to use rail systems over buses and land use change facilitated by urban rail.

On the last point, rail has very important impacts on urban form in terms of its capacity to densify and consolidate both residential and mixed use development around centres or nodes. Urban land use change is in itself a critically important factor in managing travel demand by creating development that has less built-in demand for car travel. In other words, land use can be made much more amenable to public transport, walking and cycling through increases in density, better mixing of activities and better integration around public transport nodes.

The positive land use impacts of urban rail and their transport flow-ons are partly responsible for the urban system benefits outlined in Table 9 of this paper. Nodes of development are easier to service with public transport (including bus systems), walking and cycling is more viable for more trips, and a polycentric city based around rail stations can help to minimise urban sprawl. These aspects of urban rail and its city-shaping capacity are discussed in detail in other works (Vuchic, 1981; Bernick & Cervero, 1997; Cervero, 1998; Laube, Kenworthy & Zeibots, 1998; Newman & Kenworthy, 1999a).

None of the above discussion, however, diminishes the critical role that buses play in public transport systems. Buses are essential public transport providers to areas that simply cannot be served by rail, and they provide critical feeder systems into major sub-centres and into rail systems. Well-patronised urban rail systems are usually associated with healthy levels of bus use.

It can be concluded that any city wishing to develop a better public transport system, to better manage urban travel demand and to become more environmentally and economically sustainable, should not ignore the potential for building a strong rail backbone as part of the city's basic infrastructure.

Table 10. Impact of the introduction of the Currambine Line on rail performance indicators for Perth, 1991-1996.

<i>Indicator</i>	1991	1996	% change
Rail vehicle km per capita	4.8	10.0	108%
Average rail speed	34.0	50.0	47%
Rail passenger km per capita	97.3	275.4	183%
Rail boardings per capita	7.0	22.5	221%

Table 11. Transport trends in Freiburg, West Germany, 1976-1991

<i>Transport Factor</i>	1976	1991	% Increase
Total daily trips	385000	502000	+ 30.4%
Total daily auto trips	231000	234000	+ 1.3%
Auto's share of non-pedestrian trips	60.0%	47.0%	n.a.
Bicycle's share of non-pedestrian trips	18.0%	27.0%	n.a.

Conclusions

Travel demand management is a large subject area about which much has been written. The potential range of tools available to planners and decision-makers to reduce private transport use is enormous and an excellent review of TDM methods is provided by Ferguson (1999). The approaches include both physical and economic tools. This paper has not concerned itself with the minutiae of such methods and their potential benefits, but has rather taken a more strategic, urban systems approach that has highlighted the critical role that choices in transport infrastructure play in shaping travel demand. This has revealed the need for cities to minimise the extent to which traffic growth is catered for with new roads. Attempting to keep ahead of congestion by increasing road capacity has been shown to be self-defeating in terms of the extra travel generated, the economic and environmental costs involved and the mythology of travel time savings. No amount of extra road capacity or improved travel speeds is able to save time in an urban system sense because constant travel time budgets are a physically determined reality in cities.

On the reverse side of this argument it has been shown that removing road space through road closures, traffic calming schemes, pedestrianisation or other projects, can cause traffic to disappear. As a policy that can potentially reap major travel demand management benefits, as well as have significant environmental and livability gains for cities, strategic reclamation of road space for other purposes should be firmly on the agenda of all city authorities.

Urban rail systems have also been shown capable of yielding major benefits in urban travel demand management, as well as a host of economic and environmental gains for cities. The international

evidence suggests that investment in urban rail as a backbone for a city's public transport system is well-worth making. The experience in Perth has certainly shown this to be the case. The capacity of rail to reshape urban land use into denser, more sustainable patterns is a key factor in this success.

In summary, we conclude with one case study that draws these results together and demonstrates the benefits for travel demand management of a three-pronged approach to managing private transport. The three elements are: reducing or tightly managing road supply, prioritising investment in urban rail (as well as non-motorised modes) and compact urban development linked to rail. The city is Freiburg (im Breisgau) in Germany.

Pucher and Clorer (1992) provide data which show how Freiburg's car ownership has risen from 113 per 1000 people in 1960 to 422 per 1000 in 1990, only 12% less than the national average for West Germany (481 per 1000).

Table 11 shows how, despite this growth in availability of cars, car use has virtually remained constant since 1976. Public transport passengers have increased 53% and bicycle trips have risen 96% between 1976 and 1991.

Freiburg's growth in car trips in 15 years was only 1.3%, yet total trips increased 30%. Freiburg's growth in mobility was supplied principally by increased public transport and bicycling. In fact the share of trips by car reduced over the 15 years from 60% to 47%.

Pucher and Clorer attribute Freiburg's success at 'taming the automobile' to a combination of transportation and physical planning strategies:

'First, it has sharply restricted auto use in the city. Second it has provided affordable, convenient, and safe alternatives to auto use. Finally, it has strictly regulated development to ensure a compact land use pattern that is conducive to public transport, bicycling and walking' (p. 386).

Restricted auto use has been achieved through mechanisms such as pedestrianisation of the city centre, area-wide traffic calming schemes (citywide speed limit of 30 km/h in residential areas) and more difficult, expensive parking. Freiburg's improvements to transit have focussed on extending and upgrading its light rail system as opposed to buses. Buses are used as feeders to the light rail system. Land use regulations are similar to many other parts of Europe and have involved limiting the overall amount of land available to development and strictly zoning land for agriculture, forests, wildlife reserves or undeveloped open space.

The lesson is that if cities get serious about managing travel demand it can be achieved, but the successes will be far greater if the key policies are co-ordinated.

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An International Sourcebook of Automobile Dependence in Cities, 1960-1990

J.R. Kenworthy & F.B. Laube with P. Newman, P. Barter, T. Raad, C. Poboon & B. Guia (Jr)

University Press of Colorado, Boulder, CO
1999

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Price: \$ 125

Reviewed by John Whitelegg

Global interest in solving transport problems is running at an all time high. Most of us want to know how American cities compare with European cities or how Copenhagen has handled its transport problems by comparison to London, Paris or Hamburg. Most of us are impressed with levels of public transport use in German cities and cycling use in Denmark and the Netherlands and we worry a great deal about the links between land use, density, geography and the rise of motorised transport. All of these discussions have been very difficult to conduct in a situation where data is scarce, definitions are infinitely variable and interchangeable and even geographical boundaries are unclear. When we talk about London, Paris or New York what do we mean? Without very careful definitions and a rigorous attention to detail any comparison is likely to be worthless. Most if not all of these problems have been solved by the timely appearance of this huge statistical and analytical piece of work. In more than 700 pages the book romps through 46 cities and a vast array of land use, transport, energy, economic, road safety and environmental variables. Now, for the first time, it is possible to have an intelligent discussion about how the world's most important cities have organised their transport systems and how all this relates to geography and policy.

The book is most definitely not a dry statistical compendium. Information is presented for each city in tabulated form (plus maps) and this takes up about 500 pages of the book but then the authors turn to the really interesting task of discussing the relationships between vehicle ownership and use, modal split and geography, transport and energy use, public transport service and use, congestion and travel speeds, transit and car speeds, urban density and public transport use

and much more. When all of this is done with data on cities from Asia, Europe and North America we can begin to see the enormity of the task and the significance of the achievement. When one also factors in the time series information on trends over the 1980-90 period it is even more obviously a huge achievement and one of considerable value to transport researchers and policy makers.

Chapter 5 also carries out a 'clustering exercise' to identify which cities are in each of 5 categories ranging from 'extreme automobile dependence' at one end of the scale to 'very low automobile dependence' at the other end of the scale. The results will surprise some readers especially the finding that London is in the 'very low' category; this is not immediately apparent to the resident or visitor to London having to negotiate a route through dense traffic and traffic that severely impacts on pedestrians and cyclists. Researchers will also find the section on correlations with urban structure very relevant to many of the debates we are all having about how to make progress towards sustainable urban transport. Chapter 6 continues in the same detailed analytical vein with an emphasis on economic and environmental variables (including road safety).

This book deprives us all of the excuse that we didn't really know what was going on or we didn't really understand how to encourage transit (public transport) use. It provides as much information as any policy making process could wish for to get transport back on the right track. What is really interesting and worrying is the likelihood that the rich resources to be mined in this book will be ignored by policy makers in the usual rush towards low intelligence, mythology- and ideology-based transport planning. It is especially relevant that this review is appearing at exactly the same time as the U.K. government has returned to major road building in an attempt to ease traffic congestion (December, 2002). Evidence of any kind is frequently a nuisance in that it gets in the way of our prejudices and preferences. Kenworthy and Laube *et al.* have done a great service to the world of transport planning but not even their efforts can overcome the disadvantages and barriers of a political decision making system that is not interested in evidence.

Millennium Cities Database for Sustainable Transport

J. Kenworthy & F. Laube

International Association of Public Transport (UITP),
Brussels

2000

UITP code : 01/02-03MCDB

Price: € 800.00, Members price: € 400.00

Reviewed by Pascal Desmond

Not unlike the *International Sourcebook of Automobile Dependence in Cities*, the *Millennium Cities Database for Sustainable Transport* CD ROM is a massive undertaking. Over 200 indicators have been collected for each of the 100 cities for the year 1995.

There are two key questions to consider with any CD ROM. Is it usable, and is it useful?

Firstly, it won't work on Apple Macintosh computers but it could have done if a cross-platform Runtime Development Engine such as that bundled with *Macromedia Director* or *FileMaker Pro Developer* had been used by UITP to amalgamate the information. Be that as it may, the *PowerPoint* 'Help' file opened without bother on my Mac so I was able to get a flavour of its contents.

I tested the CD ROM on a Windows 98 PC. Some of the colours used in the tables of data are unhelpful. I very strongly dislike black text on an orange

background as this is a little too reminiscent of those eye-burning PC screens which were in vogue until the late-1980s. What is wrong with good old-fashioned black-on-white? Newspapers, journals and books have been using these colours for centuries. The designers at UITP have a lot to learn about presentation.

Extracting the data from the tables was not obvious although it was possible to copy figures and paste these into a document for printing or presentation. However, extracting the raw data to create tables is extremely limited. Similarly, it is not possible to print out many of the tables. With some exceptions, the only way to do this is by typing the required information into a separate document in your chosen word processor or spreadsheet program.

In answer to the second question, the collected data looks at population, the economy and urban structure, the number of road vehicles, taxis, the road network, parking, public transport networks, individual mobility and choice of transport mode, transport system efficiency and environmental impact. There is a phenomenal amount of extremely useful data and the researchers at ISTP are to be lauded for compiling it.

A *PowerPoint* presentation of the Database may be downloaded at www.uitp.com/publications/index4.cfm#statistics

Letter in response to the special issue on disability and the elderly, Volume 8, Number 2 (2002)**Karin Sandqvist**

On reading Kit Mitchell's very interesting article on older people and road safety, I first want to applaud the employment of accident rates per journey, rather than per km, which seems to be more common, but is very misleading.

Then I want to take issue with the conclusion that car driving is a safer mode than walking, for elderly people. It seems to me that the possibility of a selection effect is not taken into account. The drivers

might well be over-represented among the healthier of the elderly, compared to pedestrians, resulting in better survival rates after an accident, even apart from the fact that they are obviously more protected (by their car) than a pedestrian when an accident occurs.

Karin Sandqvist
Department of Child & Youth Studies
Stockholm Institute of Education

Contributions to *World Transport Policy & Practice* are welcome. Whether you are a novice author or an experienced one, the Editor would like to invite you to consider sharing your thoughts and experiences with others like yourself. We can promise a considered and constructive review of your article and, for contributions deemed suitable, publication in *World Transport Policy & Practice*.

Read through the following guidelines and feel free to contact John Whitelegg, the Editor, who will be pleased to offer comments on drafts, work in progress, or ideas which could be made into an article.

Editorial objectives

The journal aims to provide validated information about the latest developments in transport policy to enable local authorities, governments, consultancies, NGOs and supra-national organisations to speed up their policy development and implement new ideas from around the world. It will:

- cover all passenger and freight transport
- deal with global as well as local issues
- include the development of the ideas of sustainability, the design of cities and rural areas, transport corridors and international links to improve health, the economy and the environment.

Article composition

Articles should normally be between 2,000 and 4,000 words. Shorter articles can be published as 'Comment' pieces. Responses to papers which have appeared in the journal, either as letters to the Editor or as response articles, will be welcomed.

Submitting articles

1. By e-mail

Articles for publication may be submitted by e-mail attachment to Pascal Desmond. It is useful if authors indicate what software is required to read any attachments and if they include the letter combination 'zq' in the title. Please DO NOT name articles 'whitelegg', 'wtp' or variations of these. Authors are advised that they may need to provide a version on paper and/or on 3.5" disk prepared on an Apple Macintosh or PC system.

2. On paper

Three copies of articles, typescript and double spaced with wide margins are needed. Manuscripts will not normally be returned, so you should ensure you retain a copy. Provide the article on paper of no less than 80 gsm weight with high quality print. This will enable electronic scanning if needed. Please supply the same version of the article on a 3.5" disk prepared on a Macintosh or PC system in ASCII format. Mark the disk clearly with your name, the article title and the software you have used. Where there is ambiguity, the disk version will normally be considered definitive.

Presentation

Headings and subheadings should be used at approximately 500–750 word intervals. Ensure that headings and subheadings are clearly identified.

Charts, diagrams and figures

These should be called 'Figures' and numbered consecutively (e.g. Figure 1, Figure 2, etc.). Make sure they are clear and can be reproduced easily. In addition, provide the raw data so that we can redraw them, if necessary.

Indicate where in the text they should appear ('Figure 1 about here'). Each figure should have a brief title (e.g. 'Figure 1. Schematic of the Programme').

Tables

Tables should be numbered consecutively, independently of figures. Indicate in the text where they should appear. Give them a brief title. Ensure that they are clear and legible. Authors should not use many tabs or spaces between columns of data – normally, one tab is sufficient.

Maps

Maps are especially welcome as 'tiff', 'pict' or 'jpeg'. They should be numbered consecutively, independently of figures and tables and their location in the text should be indicated. Ensure that they are clear, uncluttered and legible. They should have a title.

Measurements

SI units should be used throughout.

Abstracts & Keywords

Write an abstract of 75 words or so which summarises the main points of the article. It should be sufficient for a reader to decide whether or not they want to read the whole article. Also note up to six keywords which describe the content of the article. These could include geographical area, if specific, industry, functions, managerial activity and process.

References

Authors should keep references to a minimum, ideally no more than ten to fifteen. References should be confined to essential items only and those that are necessary to establish key steps in an argument or key areas of support for a particular proposition.

Reference citations within the text should be by the author's last name, followed by a comma and year of publication enclosed in parentheses. A reference list should follow the article, with references listed in alphabetical order in the following form:

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Articles: Surname, Initials (Year of Publication) 'Title' *Journal* Volume, Number, Pages.

Originality

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