TRANSPORT AND ENERGY

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Contents

Summary

The transport energy problem is oil. Transport systems, and the cities and regions they serve, are vulnerable as the world goes through the peak in oil production and enters an era of permanent decline in availability. In this article an overview of the most vulnerable parts of the transport system is provided, before the problem of transport energy in cities is examined in detail. The variations in transport are assessed in the light of vehicle efficiency, price and income, infrastructure, and land use. Physical planning is found to be a powerful determinant in how transport energy is used, and provides hope that the world's cities and regions can adapt to the challenge of a post petroleum world.

1. The Problem

Oil is the fundamental resource of modern cities and civilizations. It is the most concentrated of our energy forms (apart from nuclear power), it has been the most easily extracted, processed, and transported of all our fossil fuels, and we have become highly dependent on it for the majority of our transport needs. In addition, we have built our cities as though cheap, easily available oil would last through the next 50 years in the same way it has in the past 50 years. Most evidence is now suggesting that it will not.

The global oil situation was first questioned by M. King Hubbert in the 1950s and 1960s but it was only when his predictions about US oil production peaking in 1970 came true that his views were taken seriously. His scenarios for the world (Figure 1) suggested that global oil production will peak around the year 2000 or shortly thereafter.

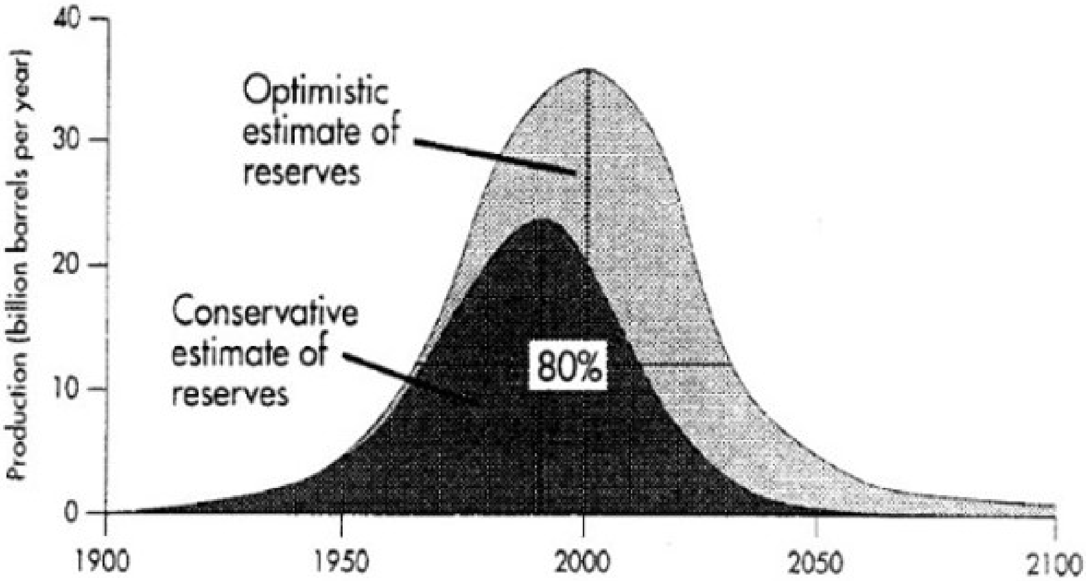

Figure 1. The cycle of world oil production as first set out by M. King Hubbert

The Hubbert projections have been questioned by many over the years, and were given prominence whenever the global oil price rose, but then in the periods after these peaks his analysis was shelved. As the oil crises continued to cause concern about underlying geophysical realities, a number of studies began to appear that have confirmed Hubbert's broad perspective. Campbell and Laherrere made a three-volume study of the world's oil assets, based on detailed geophysical data, and suggested that some countries had overestimated their reserves in the past in order to increase OPEC quotas. They suggest that between 1950 and 2050 we will have consumed 80% of the world's oil. This "golden age of oil" will begin to change quite dramatically as the world faces the reality of having to use less and less oil each year, rather than more and more as we have done for most of the twentieth century. Campbell (pp. 51–52) concludes his comments by suggesting that:

> The world is indeed approaching the midpoint in the depletion of its oil resources: the epoch of increasing production is almost over, and the epoch of declining production is about to begin… Future generations will likely look back and see this inflection point as one of the great turning points in history.

What this means is that world oil will become less and less available and comparatively more and more expensive over the next major planning horizon.

Obviously, the technological efficiency of motor vehicles will improve, though there are signs that thermodynamic limits mean that efficiency gains are becoming harder, and a further doubling in efficiency after the past one is much more difficult. New fuels will be developed, but these will be a good deal more expensive than oil has been, as their net energy efficiency is much less. No other fuel option has anything like oil’s energy profit ratio (EPR: the ratio of energy produced over energy used in its production). Early production oil had EPRs of over 100, offshore oil and late production oil wells are more like 5 to 10, whilst alternative fuels like oil shale and biomass are closer to 1.

Even with major breakthroughs in technology, which have not appeared in the decades since the first oil crisis, there are limits to how far technology can help if cities and regions continue to create the need for more and more transport energy use.

Global oil consumption has been relatively stable in the past two decades compared with the previous 50 years, as oil has been phased out of a lot of heating and power production (mostly replaced by natural gas) and efficiency has improved. However, some oil use continues to grow, especially in air travel, land freight, and in passenger transport in many cities (see below). Although some cities have shown how fuel use can be reduced, there are many wealthy cities that are continuing to expand rapidly in their car use and will be increasing their nation’s dependence on imported oil. At the same time there is a rapid increase (from what was a very low level) in the consumption of oil by newly industrializing countries and from Eastern Europe.

Meanwhile, in the rural villages of the developing countries there is a firewood crisis for cooking. Between 50% and 90% of energy use in Africa is fuel wood, and it is being stripped at unsustainable rates. In Sudan, between 1962 and 1980 wood fuel consumption contributed 92% of the deforestation of some 34 000 square kilometers. There are many aspects to the sustainability strategy on this issue, but a small amount of kerosene for cooking would be a short-term major step in preventing the further loss of trees in Africa.

The global sustainability agenda suggests that the moral case for a tiny increase in oil coming to rural Africa should have precedence over the continued growth in the rich world’s oil consumption.

Global oil reserves stand at around 45 years of current use, though the world is consuming four barrels of oil for every one barrel discovered. Most importantly all non-OPEC reserves (including Alaska and the North Sea) have now peaked, as have all of the world’s 37 biggest oil fields. We are approaching the point where world oil production is peaking. So the big problem defining this article is that the world’s oil is running down. It is not “running out” in the popular conception where we suddenly have no oil; indeed we are about halfway through the global oil well. But the global peak in oil production is beginning to reverberate through our cities and regions.

In most nations of the North transport accounts for around 30% of total energy consumption and most of their oil consumption; in the United States it is 37%. The average in the South is 22%, though it can reach as high as 35% in Mexico. Virtually all motorized transport uses oil even though there is a significant amount of electric public transport in some cities (as shown below).

The three global oil crises since 1973 were perhaps foretastes of how a disruption to oil flows can challenge the very core of city life and geopolitical stability. Stable oil prices in the 1990s led most commentators to cease worrying about the problem. In the early part of the new millennium, oil prices have again risen to record levels and once more, they raise the specter that transport is highly vulnerable to oil. This article tries to analyze how cities in particular may need to adapt to reduce their oil vulnerability.

2. Patterns of Transport Energy Use

2.1. Global Transport Trends

The trends in transport throughout the past 150 years have been depicted in Figure 2 for passenger use and freight.

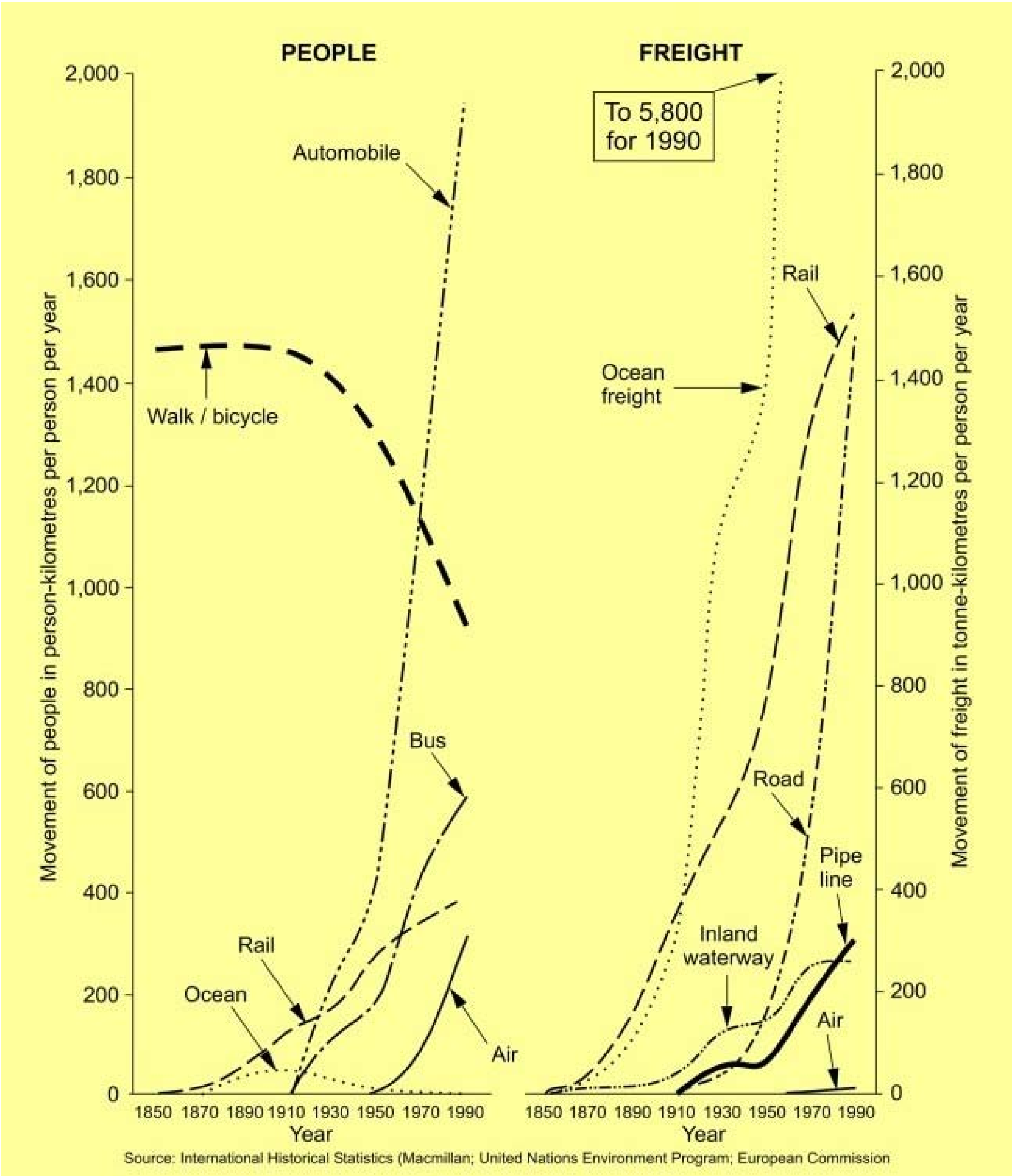

Figure 2. Worldwide trends in the movement of people and freight, 1850–1990

Although it is still comparatively small, the rapid growth in passenger air travel will need to confront the issue of declining global oil. Few alternatives exist at present, although some limited biomass fuels can be used, and in the long term the "hydrogen economy" can provide the necessary fuel for all forms of transport. It is hard to imagine however that such fuels will ever be as cheap as oil. Air travel may therefore face some real constraints in the future.

Freight is still much less than passenger transport in terms of total energy and in kilometers of travel, but the growth in road and ocean freight has been dramatic. Ocean freight is the most efficient and trucks the least efficient, and there is an option to transfer a considerable proportion of land freight to electric rail in order to bypass the oil situation. This will require more inter-modal transfer facilities to enable the small distance, flexible truck (possibly fueled by electricity via batteries or fuel cells) to be used in local areas, leaving trains and ships for long haul. The decline of oil may also mean that freight in general becomes rationalized, so that there is less need for so much movement: for instance, more local self-sufficiency in cities and regions, rather than every product being transported everywhere because of the availability of cheap transport.

The biggest issue for transport and energy is what to do in the world's cities. The growth of the automobile has been the major transport phenomenon of the twentieth century, and most of this has occurred in cities. Many cities of the North have adapted their form and structure to be automobile dependent, and as outlined below face a huge challenge in re-adapting to the new post petroleum order. But the same challenge confronts cities in the South, where car and truck traffic is now so dominant that other more sustainable modes are choked out. In Bangkok, the number of road vehicles grew sevenfold between 1970 and 1990. Other cities throughout the South have been growing in car ownership and traffic dramatically through the past few decades. I will now concentrate on a more detailed assessment of the key factors in the use of transport energy in cities.

2.2. Urban Transport Energy

The discussion commences with an overview of the patterns of urban transport energy use in a sample of 46 global cities. These cities are part of a Global Cities Study that is being conducted by the author's institute. Although the cities of the South examined in this study are restricted to Asia, there is an ongoing study to extend the data base to 100 cities, and first evidence suggests that the Asian cities are not atypical of the situation throughout the South.

City	Private transport			Public transport			Total trans. energy (MJ)	Total trans. energy/ $ of GRP
	Gasoline (MJ)	Diesel (MJ)	% priv of total	Diesel (MJ)	Elec. (MJ)	% pub. of total		(MJ/$)
Sacramento	65 351	10 998	100%	305	19	<1%	76 673	?
Houston	63 800	7 325	99%	499	0	1%	71 624	2.74
San Diego	61 004	5 689	99%	527	28	1%	67 248	?
Phoenix	59 832	4 507	100%	301	0	<1%	64 641	3.14
San Francisco	58 493	6 187	98%	935	275	2%	65 890	2.12
Portland	57 699	12 358	99%	614	27	1%	70 698	?
Denver	56 132	11 560	99%	594	0	1%	68 286	2.78

Los Angeles	55 246	6 279	99%	643	0	1%	62 167	2.50
Detroit	54 817	7 522	99%	405	0	1%	62 744	2.78
Boston	50 617	6 676	98%	845	252	2%	58 391	2.10
Washington	49 593	9 732	98%	753	376	2%	60 454	1.68
Chicago	46 498	8 355	98%	1 060	208	2%	56 121	2.16
New York	46 409	3 747	97%	975	494	3%	51 626	1.80
US average	55 807	7 764	99%	650	129	1%	64 351	2.38
Canberra	40 699	3 333	98%	962	0	2%	44 995	?
Perth	34 579	5 965	98%	851	0	2%	41 395	2.34
Brisbane	31 290	7 071	98%	632	284	2%	39 277	2.10
Melbourne	33 527	4 613	98%	411	338	2%	38 890	1.84
Adelaide	31 784	4 359	97%	953	6	3%	37 103	1.88
Sydney	29 491	4 481	97%	776	326	3%	35 074	1.63
Australian average	33 562	4 970	98%	764	159	2%	39 456	1.96
Calgary	35 684	10 535	98%	808	106	2%	47 133	?
Winnipeg	32 018	6 358	97%	989	0	3%	39 366	?
Edmonton	31 848	11 116	98%	1 027	69	2%	44 060	?
Vancouver	31 544	4 740	98%	743	184	2%	37 211	?
Toronto	30 746	1 058	95%	1 286	523	5%	33 613	1.49
Montreal	27 706	?	?	1 019	261	?	?	?
Ottawa	26 705	5 421	95%	1 526	0	5%	33 562	?
Canadian average	30 893	6538	97%	1 057	163	3%	39 173	?
Frankfurt	24 779	12 771	98%	243	499	2%	38 293	1.09
Brussels	21 080	6 297	95%	635	883	5%	28 895	0.96
Hamburg	20 344	15 463	98%	556	352	2%	36 716	1.21
Zurich	19 947	3 875	94%	609	813	6%	25 244	0.56
Stockholm	18 362	6 636	93%	1 068	751	7%	26 817	0.81
Vienna	14 990	4 387	94%	538	689	6%	20 603	0.74
Copenhagen	14 609	4 091	92%	1 313	372	8%	20 385	0.68
Paris	14 269	9 026	96%	323	946	4%	24 241	0.72
Munich	14 224	2 598	92%	210	1,166	8%	18 197	0.50
Amsterdam	13 915	5 096	96%	456	375	4%	19 843	0.79
London	12 884	9 140	94%	693	657	6%	23 374	1.05
European average	17 218	7 216	95%	604	653	5%	25 692	0.83

Kuala Lumpur	11 643	7 600	96%	774	0	4%	20 017	4.92
Singapore	11 383	4 957	90%	1 608	131	10%	18 079	1.40
Tokyo	8 015	9 305	95%	212	711	5%	18 243	0.49
Bangkok	7 742	7 409	83%	3 026	0	17%	18 176	4.75
Seoul	5 293	2 604	82%	1 551	168	18%	9 615	1.62
Jakarta	4 787	3 845	95%	440	0	5%	9 072	6.02
Manila	2 896	2 734	77%	1 698	8	23%	7 335	6.67
Surabaya	2 633	2 684	95%	294	0	5%	5 611	7.73
Hong Kong	2 406	5 679	84%	1 217	310	16%	9 612	0.68
Asian average	6 311	5 202	89%	1 202	148	11%	12 862	3.81

Note: The cities for which no energy per unit of GRP is available are those cities where we do not have the GRP data.

Table 1. Transport energy use per capita in global cities (1990)

As can be seen, there is an enormous range in per capita transport energy use across the global sample of cities (Table 1). The data show that US cities use on average 64.3 GJ of fuel per capita for urban transport compared with 39.5 GJ per capita in Australian cities, 39.1 GJ in Canadian cities, 25.7 GJ in European cities, and 12.9 GJ in Asian cities. These data include both gasoline and diesel fuel used in private urban passenger and non-passenger transport and public transport. The pattern of gasoline use per capita follows a similar pattern (55.8 GJ, 33.6 GJ, 30.9 GJ, 17.2 GJ, and 6.3 GJ per capita respectively for the regional groupings above).

These figures represent an enormous variation in the degree to which cities in different regions are dependent upon diminishing conventional liquid fossil fuel resources. US cities for example are some five times higher in their total per capita use of transport energy than the Asian cities. Even compared with cities of a similar nature in Australia and Canada, US cities are 1.6 times higher in their use of transport energy. Compared with even more wealthy European cities, US cities use 2.5 times more transport energy in keeping their urban passenger and goods movement systems operating**.**

The parameter of transport energy per unit of wealth (that is, MJ per dollar of GRP) also shown in Table 1 is an attempt to bring together both the environmental and the economic aspects of energy use. Gross regional product (GRP) is the measure of all goods and services produced in the regional urban area of the particular city noted. This parameter thus brings together the economic and environmental sides of the sustainability issue. Obviously on this very fundamental parameter there are some cities that are much more sustainable than others. For example, the US cities consume on average 2.4 MJ of transport energy for every dollar of wealth which they generate, ranging from a high of 3.1 MJ/$ in Phoenix to lows of 1.7 MJ/$ and 1.8 MJ/$ in Washington and New York respectively. Australian cities perform on average a little better than US cities, with 2.0 MJ/$ (though Perth is on the average) while Toronto, the only Canadian region for which these data are available, uses only 1.5 MJ/$ in keeping its transport system fuelled. The European cities are even more fuel-efficient in relation to their urban economies, with only 0.8 MJ of energy expended per dollar of wealth produced.

The Asian cities present a mixed picture on this factor due to the huge disparities in wealth involved. The wealthy Asian cities of Singapore, Tokyo, and Hong Kong expend a similar amount of energy per dollar as European cities (0.9 MJ/$), and are therefore low in an international context, whereas the developing Asian cities with much lower incomes spend on average 5.3 MJ/$, or more than twice the level of transport energy consumption relative to wealth as in US cities. The demand for energy to run the transport systems in these poorer cities appears to have a bigger impact on the local economy than in any of the other cities in the study.

The next section of this article attempts to analyze the many factors that can explain the variations in transport energy use. First, however, the differences in fuel types will be analyzed, as this begins to show how some of the variation is related to the type of city involved.

2.3. Fuel Types in Urban Transport

The breakdown by fuel shows that gasoline is by far the biggest contributor to transport energy use in the world's cities. This is most marked in US and Australian cities, where the automobile is more dominant, and gasoline use constitutes some 86% of total transport energy use and electricity constitutes only around 0.3%. In contrast, in cities that become more public transport-oriented, diesel and electricity become much more significant. For example, in European cities gasoline use reduces to 67% of energy used in transport, while in Asian cities it is 49%. Tokyo has 44% gasoline, 52% diesel, and 4% electricity, whereas Phoenix has 93% gasoline, 7% diesel, and no electricity.

The breakdown between private and public transport shows an overwhelming proportion of transport energy is consumed by private transport in every city. Public transport uses on average only 1% of transport energy in US cities, 2% in Australian cities, 3% in Canadian cities, 5% in European cities, and 11% in Asian cities.

Average diesel consumption has a remarkably uniform pattern across the cities, though there is some variation within the sample for each regional grouping of cities (US cities consume 8 GJ per capita, Australian cities 5 GJ, Canadian cities 6 GJ, European cities 7 GJ, and Asian cities 5 GJ). In other words, unlike gasoline use and indeed overall transport energy use, there is no systematic pattern of variation in this factor. This would appear to highlight the similar dependence that most cities now have on the light van and truck for urban freight movement. This suggestion is somewhat confounded in the developing Asian cities, where there is a higher proportion of diesel fuel for passenger transport.

The major difference between the cities is in the comparative use of gasoline and electricity. Gasoline-oriented cities are heavy energy users, while cities with any significant level of electricity use in their transport system are low energy users overall.

Of course, developing Asian cities again need to be qualified. Even though they have not yet developed electric rapid transit systems, and hence consume no electricity in transport, they are also low energy users overall because their motorization and gasoline use are still very low in international terms.

These fuel use patterns are important for discussions about greenhouse gases: transport-based CO_2 is an important issue in the post-Kyoto world. One of the immediate responses for cities is to try to reduce their use of coal. Although this is a generally positive policy to pursue, there is a twist to the greenhouse issue when cities are under the focus, rather than just nations, as shown in the data here. Despite coal-based electricity being less fuel-efficient than gasoline (and being four times worse than gasoline in terms of CO_2 produced per MJ of transport energy), it does not mean that cities with electric transport are worse in energy use or greenhouse gases; in fact the reverse is the case. This is primarily because of the nature of the technology and the effect of either the car or the train/tram on the city. This difference is fundamental to the concepts being presented**.**

The fact that cities that use a lot of electricity (even from coal) have lower energy and CO_2 production is an important factor in the energy and greenhouse debate, where coal is considered to be so much more damaging. If coal is used to provide electricity for an electric train or tram system, then the city will use less fuel overall and will produce lower greenhouse gases from the transport sector. The mechanism for this appears to be land use changes, greater walking and cycling in transit-oriented environments, and the linking together of a number of trip purposes when using transit—this phenomenon is called “transit leverage.”

In addition, the advantages of electric-based public transport become far greater in terms of greenhouse and other factors like smog and acid rain, when the source of power is renewable fuel. For example, Zurich, using mostly Swiss hydropower, produces only 6 grams of CO_2 per MJ of electricity whereas Melbourne, which uses very poor quality coal, produces 414 grams of CO_2 per MJ. This will become a more significant factor in the decades ahead as Climate Change Convention agreements have to be implemented. The renewable energy future will be one based on electricity, linking together the many dispersed ways of producing power from wind, sun, plantations, garbage, and waves. A future based upon electricity will favor electric transit, perhaps supplemented by electric automobiles. A renewable electricity-based system implies that energy conservation will be taken seriously, and so this will necessarily mean a substantial move towards electric transit-based cities.

3. Explaining Transport Energy Use Variations

The following sections will examine the potential factors that can be used to explain variations in fuel use discussed above. As suggested by Figure 3 there are four major groups of factors: technology, economics, infrastructure, and urban form.

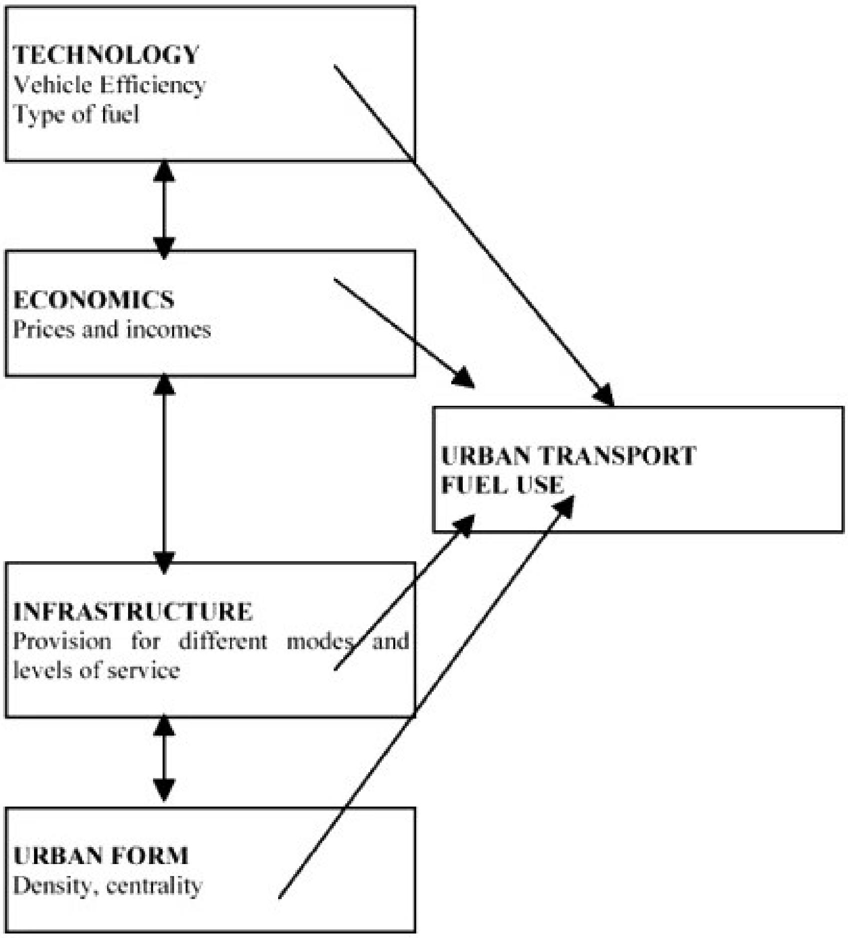

Figure 3. Interacting factors that explain differing levels of transport fuel use in cities.

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Biographical Sketch

Professor Peter Newman is on secondment to the Western Australian government where he is the Director of the Sustainability Policy Unit in the Department of Premier and Cabinet, co-coordinating the development of a Sustainability Strategy for the state. He is also the Professor of City Policy at Murdoch University in Perth where he has been since the university began in 1974. He has been an elected councilor with the City of Freemantle and had secondments to work with the WA Premier and the Minister for Transport in the 1980s. He is best known in Perth for his work in rebuilding the city's rail system.
Professor Newman's research is on global cities, seeking the links between transport, land use and energy. He first defined the concept of automobile dependence in a co-authored book with Jeff Kenworthy, *Cities and Automobile Dependence: An International Sourcebook.* He has over 100 refereed articles and book chapters. His book with Jeff Kenworthy, *Sustainability and Cities: Overcoming Automobile Dependence* was launched in the White House in 1999, and his 2001 co-authored book is called *Back on Track: Rethinking Australian and New Zealand Transport.*
Professor Newman teaches a course on Global Environmental Issues and assists in one on Cities and Sustainability. He is a Visiting Professor with the University of Pennsylvania where he teaches a Master's course on Sustainable Cities.