ENERGY USE AND SUSTAINABILITY OF TRANSPORT SYSTEMS

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Introduction

There is widespread concern about the long term sustainability of the present way of life in the developed world. It has been widely recognised that emissions of greenhouse gases as a result of human activity have the potential to alter the climate system. There are also ongoing concerns both about the excess usage of limited resources, and the creation of environmental pollutants which may have long term effects. Dealing with these issues is now an important part of engineering design. Transport policy in many major countries is now set by concerns about energy and emissions.

The most widely accepted definition of sustainable development is that given in the Brundtland Report from the World Commission on Environment and Development (1987). There it is suggested that sustainable development is “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”.

There are a wide variety of suggestions as to the most appropriate interpretation of this recommendation. There are two main elements to sustainability, the use of materials, especially those for which supply is limited or recycling is difficult, and the use of energy. The utilisation of material resources is an important issue, but will only be considered briefly in the present paper. From the energy point of view, one issue which is sometimes quoted is the remaining fossil fuel reserves. Although this matter remains controversial in some quarters, there appears to be good evidence that early limitation of energy availability simply due to fuel source depletion is unlikely. Further, according to the US geological survey, Dillon (2001), deposits of methane hydrates, a crystalline solid consisting of gas molecules, usually methane, each surrounded by water molecules, are estimated to contain twice the amount of carbon to be found in all known fossil fuels on earth. Thus even in the absence of a nuclear based energy supply structure it appears practicable to develop alternative energy sources.

However, at present a major part of the worlds energy demands are met by oil. Further world oil dependence is largely driven by demands from transport. In the US, transport use amounts to 68% of all oil use. Recent events have reinforced the sensitivity of the developed world to continuity of supply of hydrocarbon fuels. In these circumstances, it must be prudent wherever possible to seek to limit the energy and thus fuel use of transport.

A more fundamental issue is global warming. It is widely argued that current “greenhouse” gas emissions have already caused climate change, which will accelerate if steps are not taken to limit the their production.

The basic mechanism is that increases in the concentrations of greenhouse gases reduce the efficiency with which the Earth’s surface radiates to space. More of the outgoing terrestrial radiation from the surface is absorbed by the atmosphere and re-emitted at higher altitudes and lower temperatures. This results in a warming of the lower atmosphere and surface. Because less heat escapes to space, this is described as the greenhouse effect. Greenhouse gases which have this effect include: water vapour, carbon dioxide, ozone, methane and nitrous oxide. The two most important greenhouse gases emitted by transport are Carbon dioxide and Nitrogen oxides.

Extensive research has been performed to allow comparison of the ability of each greenhouse gas to trap heat in the atmosphere relative to CO2. It has been found that the effects of various gases on global warming are too complex to be precisely summarized by a single number. Further understanding of the subject also causes frequent changes to estimates. Despite that, the scientific community has developed approximations. In the UK it is assumed that Nitrogen oxides are 296 times more effective than CO2 while in the US the most usual figure taken, for a 100 year time horizon, is 310.

The output of greenhouse gas from transport is directly affected by the design of the engine, especially the fuel control system. It is also directly controlled by the addition of catalytic converters, mandatory on a wide range of vehicles in developed countries. New vehicles have significantly less emissions than older vehicles. Thus, determination of the precise level of greenhouse gas produced by transport requires extensive assumptions. However, it is indisputable that, regardless of the measure adopted, outputs of greenhouse gases are directly related to the energy used by the vehicle. Also, most energy comes directly from the combustion of carbon in fossil fuels, so that energy and CO2 emissions can be correlated directly. Thus, a comparative study of energy use provides an excellent starting point for evaluation of the greenhouse gas impact.

There has been wide discussion about the level of energy use which can be regarded as sustainable. This is a highly politicised area, with vocal pressure groups. However there does appear to be some measure of consensus.

The fundamental energy source for the earth, and the origin of energy now locked in fossil fuels, is the sun. It is therefore logical to relate energy use to the energy arriving from the sun. This can be established with some precision. The solar constant, which measures the mean amount of energy reaching the earth over all wavelengths is 1367 W/m^2 and the mean radius of the earth is 6371 km. Thus, the total solar energy reaching the earth is $174x10^{12}$ kW. This is the average over the whole globe for the whole day. The population of earth is estimated to be about $6x10^9$.[1] Thus, the average solar energy arriving per person is 29 MW. Total World energy use is approx 375 x 10^{18} joules per year (359 quads). This corresponds to an average use of about 12 Billion kW. Note that this is less than 0.01% of the total solar energy flux. Assuming a world population of around 6 Billion gives an average current power usage per person of 2kW.

Several authors have suggested approaches which quantify the use of energy which can be regarded as sustainable. Dürr (1994) suggested a limit of 1.5 kW per person, related to the solar energy radiation to the earth's surface. Mulder and Biesot (1998) made a slightly

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[1] Current world population in 2002 is estimated to be around 6,230,000,000. The world population grows by around 77 million each year. Since the energy data used in this paper is generally from 1999 figures it seems appropriate to use a 1999 estimate here, so that for comparative purposes a round figure of 6 billion is acceptable.

different calculation which gave a figure of 1.8kW. Imbomen (1999) reports the Swiss ETH value of 2.0 kW per person based on current world wide energy consumption, consistent with the figures calculated above. Thus there is a consensus eg Bouwman (2001) that 1.8 kW per person can be considered a sustainable energy use.

The Intergovernmental Panel on Climate Change (IPCC) was established by the World Meteorological Organisation (WMO) and the United Nations Environment Programme (UNEP) in 1988 to provide an assessment of all aspects of climate change, including how human activities can cause such changes and be impacted by them. The IPCC has recommended that CO2 emissions should be reduced by at least 60% by 2050. This figure has been generally accepted within Europe and provides a starting point for a consideration of sustainable transport and a clear target for energy reduction of Cybercar vehicles.

However in order to determine the target level for future vehicles it is necessary first to understand and calibrate the existing situation. This is the objective of the present report.

2 Impact of Transport

Transport is responsible for between one quarter and one third of energy use in most developed countries. This also implies that transport is responsible for about the same proportions of CO2 emissions, the major concern in Global Warming scenarios.

An analysis based on the most recent published figures for emissions in the EU (Eurostat 2001) is given in Table 1.

		Total	Transport	%
Greenhouse Gases M tonnes CO2 equiv	CO2	3037	804	26
	Methane	93.7	4.0	4
	N2O	52.7	15.5	29
Other Emissions M tonnes	NOx	11.9	6.3	52
	CO	41.0	25.5	62
	VOC	13.8	4.8	35
	SO2	9.4	5.6	6

Table 1 EU Emissions

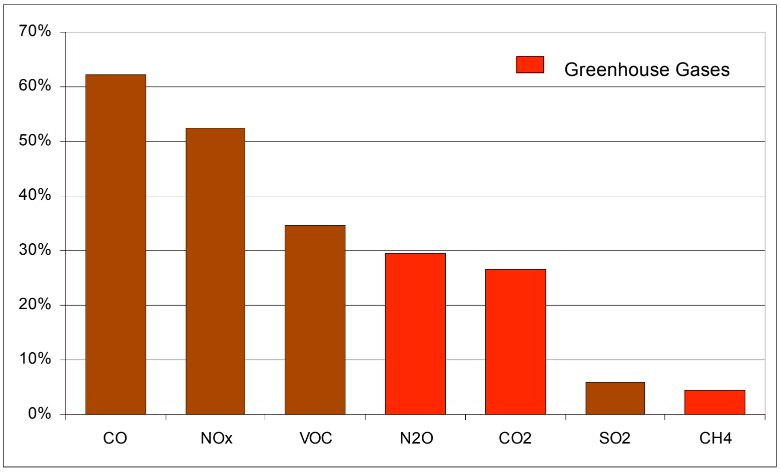

Figure 1 Percentage of EU Emissions produced by Transport

These figures show figures for million tonnes of emissions. For Greenhouse gases the figures have been given in million tonnes of CO2 equivalent. It can be seen that transport is responsible for over 50% of some other airborne emissions

However transport is also an inescapable component of modern life. Further, transport is dominated by the car. Public transport is only used for a minority of trips in all developed countries.

Mobility is widely agreed to be a key requirement of contemporary living. Cities and towns have been, and continue to be, restructured to aggregate the services required by present day consumers. This trend applies equally to shopping and to social services such as hospitals and schools. This aggregation process is driven by the needs for higher efficiency in supplying the service, but brings with it a need for greater mobility for those using the services. Fifty years ago the shop, the doctor and the school were likely to be within easy walking distance. Today it would be extraordinary to find these services in proximity. New demands for transport have been created.

Some figures taken from the UK National Travel Survey are given below. The limit of 6 mins corresponds to about 0.5 km walking, widely regarded as a limit of accessibility. The figures therefore show that very few people are within easy reach of everyday facilities. Equally importantly, in most cases bus services offer little benefit. This is despite the fact that 89% of people in the UK live within 6 minutes of a bus stop. The problem is that the buses do not go where people wish to make their trips. Only a minority of people in the UK have a bus route available to take them to the Doctor/Post office/Chemist or Food Store. In any case, the figures for buses take no account of walking time and likely waiting time, which is dependent on the service frequency. These add significantly to the bus trip times shown.

Percentage of Households	Doctor		Post Office		Chemist		Food Store		Shopping Centre		Hospital	
	Walk	Bus	Walk	Bus	Walk	Bus	Walk	Bus	Walk	Bus	Walk	Bus
6 mins or less	17	10	41	10	32	11	57	7	9	12	2	3
7-13 mins	20	13	32	6	28	10	25	4	15	23	3	10
14-26 mins	30	13	21	2	25	7	13	2	30	25	11	23
27-43 mins	15	4	4	1	7	2	3	1	18	8	13	23
44 mins or more	18	3	2		9	1	3		28	4	71	31
No bus/quicker to walk		57		80		69		86		28		10

Table 2 Percentage of trips with various travel times

Manufacturing and distribution processes are also being brought together into larger units to provide increased efficiency. Increasingly these rely on just in time transport. Jobs are generated at these centres, requiring additional mobility, and thus again an increasing demand for transport.

Meeting these new demands for transport is associated with significant external costs. As indicated by the table above, old forms of public transport are severely mismatched to serving the distributed demands generated by the present day usage patterns. In very many cases, the only satisfactory means of meeting these demands is the car.

Some data on this transport usage in the EU is shown in Table 3A. This is taken from Eurostat Data and generally refers to a 1999 base.

	B pax km	km/yr/head	% Total	% surface
Car	3784	10067	78.5%	83.5%
Bus/Coach	403	1072	8.4%	8.9%
Railway	292	777	6.1%	6.4%
Tram & Metro	51	136	1.1%	1.1%
Waterborne	31	82	0.6%	
Air	260	692	5.4%	
Total	4821	12825		
Total surface	4530	12051		
Fatalities	42100			
Population M	376			

Table 3A EU Key Data on Passenger Transport

	B pax km	km/yr/head	% Total	%surface
Car	6216	22769	85.5%	95.6%
Bus/Coach	239	875	3.3%	3.7%
Railway	23	84	0.3%	0.4%
Tram & Metro	22	81	0.3%	0.3%
Waterborne	1	4	0.0%	
Air	767	2810	10.6%	
Total	7268	26623		
Total surface	6500	23810		
Fatalities	41600			
Population M	273			

Table 3B US Key Data on Passenger Transport

Table 3B gives equivalent data for the US. Comparison shows up some interesting differences. In particular, it can be seen that the US has a far higher dependence on the car, and uses public services for little of its surface transport needs. It can also be seen that the actual level of transport per head is far higher than in the EU.

Figure 2 shows a comparison of the surface transport modal split in the two areas. In the EU the average level of public transport use is around 16%. In the US however, public transport amounts to only just over 4% of surface passenger transport. More detailed analysis (cf Section 4 of this report) shows that a significant part of this is long distance transit. Thus use of public transport for commuting is less than 3%.

Table 4 gives a more detailed breakdown of transport usage in the EU 15. There are inevitably variations from country to country is the relative use of motorcycles and buses. However perhaps the most striking aspect of the data is how little variation there is from the mean figure of 84% private 16% public transport in any country.

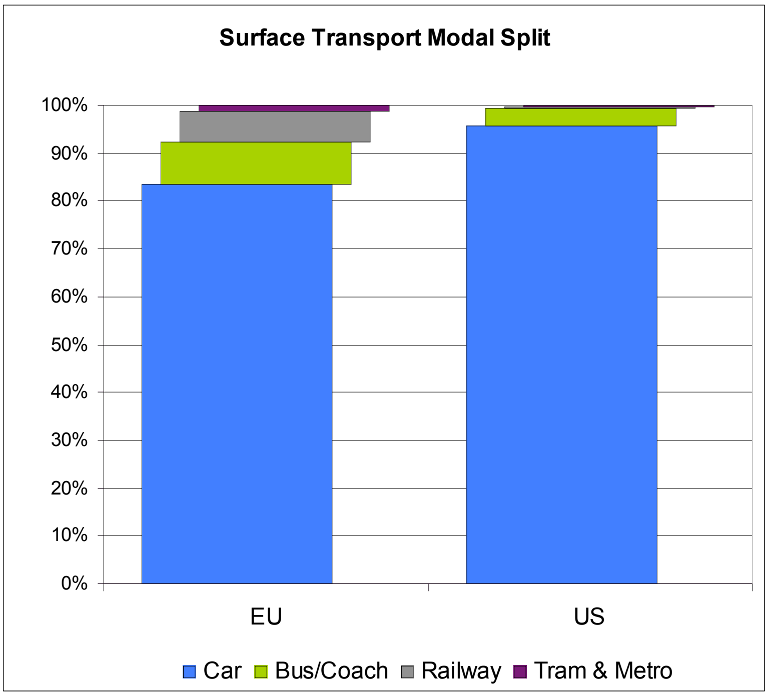

Figure 2 Modal Split of Passenger Surface Transport in the EU and US

	Cars	M/cycle	Bus/ Coach	Urban Rail	Heavy Rail	Total Personal	Total Public
B	81.8	1.2	10.2	0.7	6.2	83	17.1
DK	79.4	0.8	13.4	0	6.4	80.2	19.8
D	81.4	1.8	7.4	1.6	7.9	83.2	16.9
EI	66.7	11.4	19.7	0.7	1.5	78.1	21.9
E	78.6	3.4	12.1	1.2	4.6	82	17.9
F	84.3	1.5	4.9	1.3	8	85.8	14.2
IRL	80.3	0.8	15.3	0	3.6	81.1	18.9
I	76.6	7.5	10.5	0.6	4.8	84.1	15.9
L	79.9	1	14.4	0	4.8	80.9	19.2
NL	81.5	1.9	8.1	0.8	7.7	83.4	16.6
A	73.1	1.7	13.7	2.9	8.6	74.8	25.2
P	78.1	6.3	11	0.5	4.1	84.4	15.6
FIN	81.6	1.3	11.3	0.7	5	82.9	17
S	80.2	1.2	10.1	1.4	7.1	81.4	18.6
UK	86.8	0.7	6.2	1	5.3	87.5	12.5
Total	81	3	8.6	1.1	6.2	84	15.9

Table 4 Modal Split of Passenger Transport Across the EU

The key conclusion to be drawn from this analysis is that usage of private versus public transport is driven by fundamental features of European society, not something that is readily adjusted by policy initiatives. In turn, this means there is a conflict between the mobility demands of a developed society and the requirement for a sustainable future. In these circumstances, it is of obvious interest to establish the relative effectiveness of various modes of transport as in energy and emission terms.

This paper attempts to bring together data from several sources to provide a starting point for wider discussion. This paper is intended to provide a unified basis for making a comparison of the relative energy usage of various transport modes in transporting passengers. Other authors have attempted to make such estimates but there is still no consensus on the results.

3. Basic Comparisons

Transport uses energy from a variety of sources, most importantly from petroleum fuels and from electricity. These must be put on an equivalent basis before any comparisons can be made. Comparison of energy statistics requires establishment of agreed criteria against which different forms of energy use can be compared.

The most satisfactory basis for comparison is primary energy use. Even at this primary level, the heating value of fuel may be legitimately measured in two ways. Gross energy from combustion assumes that the water vapour by products is condensed. The net energy value assumes that the water produced by combustion remains as a vapour. These two values can vary by between 5 and 8%.

The primary energy measure provides a basis for comparison of transport using electrical and hydrocarbon based power. This is illustrated by the diagram below. At the lowest level, the vehicle requires an energy supply to overcome mechanical and aerodynamic drag and other losses. For internal combustion engines, the fuel is supplied directly at the vehicle, while for electrically powered vehicles the energy is converted at a power station. Comparing primary energy supply allows these two power sources to be compared, but does require secondary assumptions about the conversion efficiency of electrical power.

Internal Combustion Engine	*Electrical power*
Primary Energy supplied from fuel	Primary Energy supplied from fuel(s)
Fuel energy converted by engine to mechanical energy	Fuel energy converted to electrical energy at power station
Final energy used at vehicle	Electrical energy distributed to vehicle
	Electrical energy converted to mechanical energy at vehicle
	Final energy used at vehicle

There is further energy consumption which has not been included for both of these processes. The formation of hydrocarbon fuels at the refinery requires additional expenditure of energy. Similarly, the transport of the unrefined oil to the refinery, or of coal etc to the power station will involve energy consumption. More importantly, transport vehicles and their infrastructure have both to be manufactured and finally to be disposed of. A full accounting would require each of these additional sources also to be included. Studies normally show that the additional energy used in these other parts of the chain is typically 10% or less of the primary energy used. In general, it seems that the overhead from these other factors would be insufficiently different to justify a detailed analysis. Thus, the present analysis has been limited to primary energy only. Primary energy is most frequently measured in Mega Joules (MJ).

There is also some question about the parameter which should be used as a measure of transport. There are three potential measures

- Energy used per trip
- Energy used per hour
- Energy used per kilometre travelled

The energy used per trip will clearly vary with trip length and does not appear to be a rational measure. For sustainability arguments there is a case for considering energy used per hour. This matches the arguments presented in the last section, but is mismatched to the key reason for transport viz getting from A to B. It appears that Energy used per passenger kilometre provides the most useful measure of transportation delivery. Thus, the principal criterion adopted for comparison is primary energy use per passenger kilometre, MJ/pax km.

There is in essence no Europe wide source on energy use by transport. The starting point for the present work is analysis reported by Lowson (1999). This work used base data from a number of UK sources to provide a direct comparison of energy use. The results are given in Table 5.

MJ/passenger kilometre	ACEC (1976)	Leach et al. (1979)	Hillman and Walley (1983)	Hammar-strom (1988)	Martin and Shock (1989)	Wood (1995)	Coffey and Lowson (1996)
Train MU	1.35	1.7	1.9	1.3	1.2-1.4	1.4 (av)	1.0-1.4
Urban bus	0.8	-	0.75	0.9	0.3-0.9	1.4 (av)	1.2
Tram / Light Rail	-	-	-	-	-	0.7	2.4-2.5
Urban car	3.1	-	3.2	2.2	-	2.0	1.9-2.0
Electric car	-	-	-	-	-		1.7
Plane	-	-	-	-	-	3.6	3.3
Motorcycle	1.7	1.0	1.8	-	-	1.6	1.6

Table 5. Comparison of Various Studies of Energy Use by Transport.

Generally, there is reasonable agreement between the various figures. The major discrepancy is between the two figures for light rail. The Coffey and Lowson (1996) data was based on actual data obtained from the Manchester and Tyne and Wear metros.[2] An interesting trend is the improvement of car energy consumption with time, primarily reflecting improvements in engine technology. The second trend is the higher recent estimates of energy use by the bus. These reflect current statistics on the use of smaller buses which have been found to be more effective for transportation purposes, although less energy efficient. However, the essential conclusion from Table 5 is that there is surprisingly little difference in energy use between current public and private modes of transport once full account is taken of the actual levels of

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[2] A recent recalibration using up to date figures on light rail passenger loads and fuel use has given essentially equivalent results.

utilisation. However, several of the sources are now rather old and are not suited to be the basis of a policy for the future decades. It appears desirable to look for a recalibration of this data.

It is important that any statistics used should, as far as possible, be from a respectable source, and have been brought together on the same basis. Unfortunately, there appears to be no comparative data on transport energy use which has been brought together on a European basis. In the absence of any existing authoritative collection of European data, recourse has been had to US data. This allows useful comparative information to be obtained, and acts as a initial benchmark for European levels

The starting point for the further analysis was the excellent compendium of statistics produced by APTA (2001). This provides a wide variety of data, but for the present purposes, the key data of interest is that on total passenger miles travelled and total fuel used. The APTA data is provided on a uniform basis and provides data covering the whole of the US. It is therefore an unusually good source of base data permitting average figures for the whole of the US to be derived.

A further and even more complete source of US data was found part way through the present work. This is the compilation by the US Department of Energy, Davis (2001). The data in Davis 2001 was based on a variety of sources. However, the majority of the data on transit comes from data originally published by APTA (2001) . This original source has been used to provide additional breakdowns between modes where not given directly in Davis 2001.

4 Comparative Figures

The DOE Transportation Data Energy Book, Davis (2001) gives a direct comparison of primary energy by various modes of transport. As noted in that report

"Great care should be taken when comparing modal energy intensity data among modes. Because of the inherent differences between the transportation modes in the nature of services, routes available, and many additional factors, it is not possible to obtain truly comparable national energy intensities among modes. These figures are averages, and there is a great deal of variability even within a mode"

While this caution is justified, there remains a need to make comparisons between modes. It must be accepted that there will be error margins, but comparative analysis is an essential element of developing an effective policy.

Results taken directly from Davis (2001), but converted to ISO units[3], are shown in Table 6.

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[3] Conversion to ISO unit of MJ and km has been made by using 1 kJ = 0.9478BTU and 1 mile = 1.609 km. Where averages were not given in the report these have been calculated from the figures provided. The measure used, MJ/passenger km, does not include life cycle issues such as construction etc. This would require separate accounting, but generally would not have a major effect on relative assessments.

	MJ/paxkm	Passenger km	% passenger km
Personal			
Automobiles	2.38	4,039,929	68.8%
Personal Trucks	2.96	1,677,180	28.6%
Motor cycles	1.36	20,436	0.3%
Total Personal	2.55	5,737,544	97.7%
Bus			
Transit	3.15	34,119	0.6%
Intercity	0.74	55,832	1.0%
Total Bus	1.65	89,951	1.5%
Rail			
Intercity	2.01	8,510	0.1%
Transit	2.08	22,700	0.4%
Commuter	1.92	14,104	0.2%
Total Rail	2.02	45,314	0.8%
Total all public	1.77	135,265	2.3%
Public less intercity	2.56	70,923	1.2%
Total	2.53	5,872,810	100.0%

Table 6 Comparative Energy Use Figures for US Transport Modes

The most obvious point from Table 6 is the very low number of passenger miles provided by public transport in the US, as already indicated by Table 3B, prepared on a somewhat different statistical basis. In the present figures, usage of public transport is only 2.3% of the total. Further, much of this is intercity. Only 1.2% of non-intercity passenger km is provided via public transit. This figure increases to 1.4% if all personal transport trips over 75 miles (16% according to Davis (2001)) are also discounted. There has been a 4-5% per annum increase in the usage of public transport in the US in recent years. However, this increase is on too low a base level to have any significant effect on the overall balance of transport use.

A second key conclusion from Table 6 is that most forms of urban transport, whether public or private, have similar levels of energy use. This is a similar conclusion to that drawn from analysis of UK transport modes shown in Table 5. A direct comparison is shown in Table 7, which allows a useful calibration.

MJ/paxkm	Davis (2001)	Coffey & Lowson (1996)
Automobiles	2.38	1.95
Personal Trucks/SUV	2.96	
Motor cycles	1.36	1.60
Transit bus	3.15	1.20
Intercity bus	0.74	
Airliner	2.61	3.30
Intercity Rail	2.01	
Commuter Rail	1.92	1.20
Light Rail	2.14	2.45
Vanpool	0.81	

Table 7 Comparison of UK and US figures for transport energy efficiency

Table 7 includes data for Light Rail and Vanpool which are not given directly by Davis and have been calculated from the APTA data. It can be seen that results for most transport modes are essentially equivalent. The differences generally appear explainable. The higher figure for US cars is unsurprising given the larger size of typical US cars. SUV figures, described as "personal trucks" by Davis, are somewhat larger again. The low figure for UK commuter rail reflects calculations for modern Diesel Multiple Units, rarely seen in the US. It is however surprising to note that DOE figures show that the average US bus uses more energy to deliver their transportation capability than even Personal Trucks. The UK figures were based on the recent development of using small eg 20 passenger vehicles which offer a frequent service. Despite only achieving a 20% load factor the efficiency of this form of transport is high. Incidentally, the DOE figures also show that scheduled air carriers only use 2.61 MJ/passenger km, only just above auto levels, and lower than personal trucks or buses. It does appear that there is an opportunity for a significant improvement in the energy usage of US buses.

However, the essential conclusion from Table 1 is that there is surprisingly little difference in energy use between current public and private modes of transport once full account is taken of the actual levels of utilization. In particular the data does not support the widely canvassed view that public transport has significantly less energy use than conventional automobiles. Indeed further analysis of Davis' (2001) data shows that, excluding intercity bus and rail (and air), the average energy use per passenger km of all public transit in the US is higher than the average used by all personal transport ie automobiles, personal trucks and motorcycles.

5. Sustainability

The figures above can be presented directly as carbon savings. Savings in energy per passenger mile transfer directly to savings in CO2. Figure 3 shows a sustainability comparison from both UK and US statistics, which compares alternative forms of transport with the car.

	UK Data	US Data
Light Rail	-26%	-12%
Motor cycles	18%	29%
Bus	38%	-39%
Rail	38%	14%

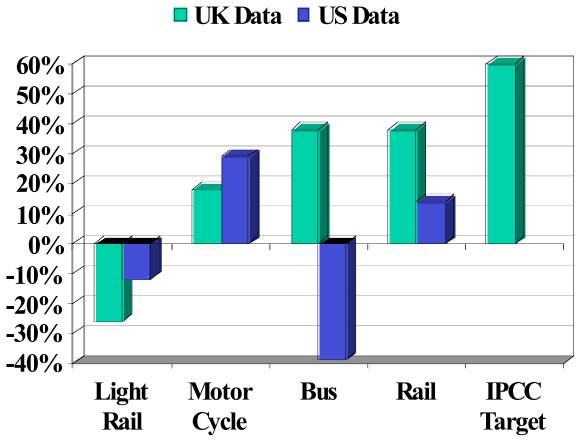

Figure 3 Carbon benefit compared to the car for various forms of transport

These figures show that although some forms of public transport can offer a benefit, no current form of public transport meets the IPCC recommendations for reduction of Carbon emissions.

A second aspect of sustainability is resource usage. There are many aspect to this, including the relative usage of scarcer materials and issues such as recyclability. However a key issue in resource usage is simply the amount of resources used. Figure 4 shows an evaluation of this, comparing the empty weight of vehicle required by various forms of transport divided by the number of seats provided. This is a simple measure, but one which does provide a measure of the effectives of the various types of transport in base resource use.

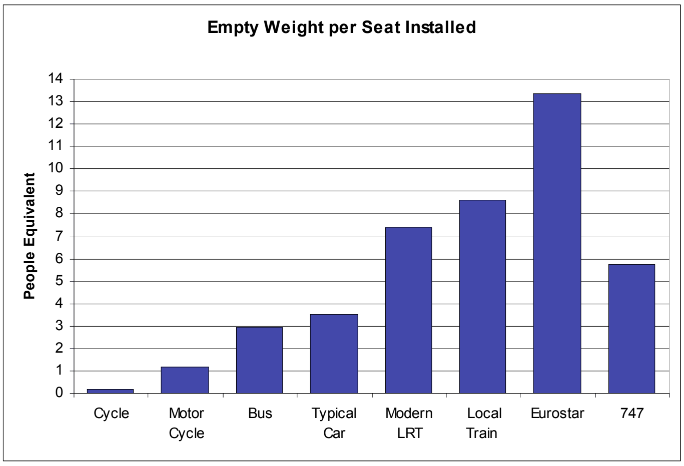

Figure 4 Empty Weight per Seat Installed : People Equivalent

The Eurostar train, in service in for the Channel Tunnel, typically weighs 300 tonnes and provides 300 seats, ie 1 tonne per seat installed. Taking an average person as weighing 75 kg shows that the Eurostar has provide base materials more than the weight of 13 people for every seat provided. This is a major commitment of resources. It can be seen that rail transport generally is relatively wasteful of resources and on this measure is significantly worse than the car. Bus transport provides somewhat better resource effectiveness, although few modes of transport can compete with the bicycle.

These figures suggest that major improvements in resource usage could be achieved in comparison to typical current public transport. This would provide a further useful gain in sustainability.

Conclusions

The key conclusion from the analysis presented is that transfer from car to conventional forms of public transport is unlikely to provide major benefits in sustainability. In any case, the analysis presented in Section 2 shows that current forms of public transport are mismatched to the needs of present day living, so that substantial change is not practicable.

The analysis suggests that major gains are only likely to arise from a new approach matched to personal travel requirements and explicitly designed for improved sustainability. This offers a significant opportunity for new designs of Cybercar.

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ENERGY USE AND SUSTAINABILITY OF TRANSPORT SYSTEMS

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Abstract

A comparison is made of energy use and sustainability of various forms of private and public transport systems. The key comparison is based on MJ per passenger kilometre. In the absence of available comparative data across the EU, the analysis is based on older UK data together with more recent data from US experience which enable direct comparisons to be made. US and UK figures for energy use by equivalent modes show broad agreement. The key conclusion is that most currently avaialbe forms of transport have essentially similar levels of energy and resource usage. The data also shows that several forms of current public transport system are less sustainable than the car in terms of the key parameters analysed.

It is suggested that there is an opportunity to provide a new form of public transport which would meet modern sustainability objectives.