Transport energy consumption

A discussion paper

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Increasingly ***sustainable*** and ***environmentally friendly*** are essential labels – no more so than when transport is involved. However it is far from clear what they mean and which modes of transport could validly claim them. For years the train has epitomised the green option, but, in 2004, is this still the case?

The Bruntland Commission defined *sustainability* as "the ability to meet the needs of the present without compromising the ability of future generations to meet their own needs." Even within that definition, the term is used differently by different people; some include economic, political or social sustainability in their definition, others have a more restrictive meaning. However, most people would expect sustainable transport to give the "right" answers to three questions:

1. Does our transport system rely on fuel or other natural resources that are likely to become exhausted in the foreseeable future?
2. Are levels of local pollution caused by transport likely to impose significant limits to its use?
3. Are transport policies compatible with national targets to reduce global pollution – in particular of "greenhouse gases"?

Resource depletion

The imminent exhaustion of natural resources – in particular hydrocarbons – has been predicted for more than half a century; with great effect in the reports of the Club of Rome in the mid-1970s. Notwithstanding these predictions, liquid fuel continues to be available at pump prices (excluding tax) similar to those 30 years ago. Optimists point out that the rate at which reserves are discovered continues to match the rate at which they are depleted, although the auditors of some international oil companies may beg to differ. However no-one seriously expects oil reserves to become exhausted in the next 50 years, although prices are likely to rise.

For transport, an increase in the price of crude oil is unlikely to change the economic viability of using liquid fuels – not least because such a large fraction of the pump price is represented by taxation that the "price" is effectively set politically.

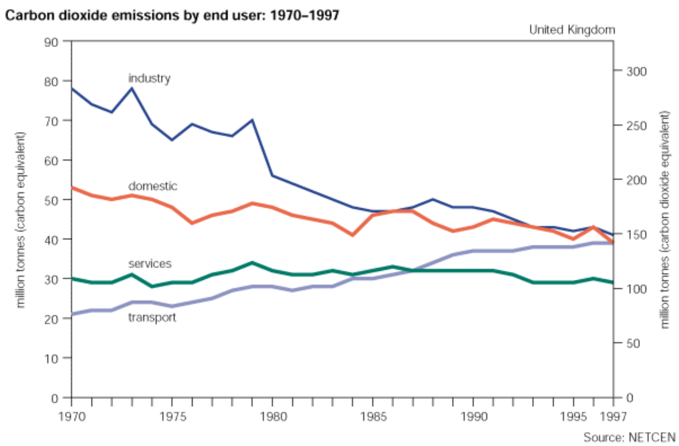
Local pollution

When the Royal Commission on Environmental Pollution reported in 1994,[1] much of their report concerned local pollution caused by transport – in particular oxides of nitrogen (NO_x), carbon monoxide, volatile organics compounds (VOCs), sulphur dioxide and particulates (from diesel engines). Over the last ten years NO_x emissions from transport have fallen by

34%, VOCs by 40%, CO and particulates by 42%, smoke by 50% and lead by over 90%[2], despite a 10% increase in personal travel and a 15% increase in goods movements[3]. Progressively more stringent European standards for new road vehicles will ensure that improvements continue, and it is anticipated that over the next 10 to 15 years emissions may fall below those in 1970 when road traffic was only 40% of today's volumes[4].

Global warming

At the end of the 1990s transport accounted for more than one third of Britain's energy consumption; most of this was liquid fuels used in road transport. Transport is one of the major sources of greenhouse gases (principally CO_2) in the UK and, unlike other users of energy, has continued to increase over the past decades.[5]



DfT data show that the greatest contribution is attributable to petrol-fuelled cars (55%) and the second greatest to HGVs (23%).

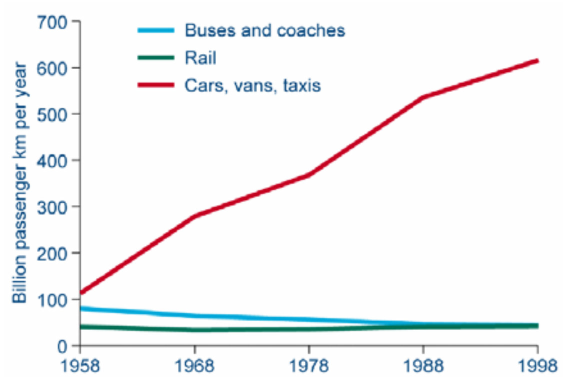
Current UK transport policy envisages a reduction of emissions of greenhouse gases from transport by 2010 that would leave emissions from the sector slightly above 2000 levels. This reduction is dependent on two key policies: the voluntary agreement between the European Commission and European car manufacturers to reduce average carbon dioxide emissions from new cars to 25% below 1995 levels by 2005 [6], and the Government's 10 Year Plan for transport [7]. In the longer run demand for transport is expected to increase and in the absence of further efficiency gains or developments in low carbon technologies for transport, emissions would then be expected to rise.

Targets for CO_2 concentration

There are different views about what represents a sustainable limit for CO_2. The European Commission[8] and the Royal Commission on Environmental Pollution[9] both suggest 550 ppm. The IPCC[10] have calculated that this would result in a temperature change greater than 2.0˚C which the Stockholm Environment Institute[11] describes as a high risk situation that would "elicit rapid, unpredictable, and non-linear responses that could lead to extensive ecosystem damage". The Global Commons Institute (GCI) [12] suggests a lower target of 450 ppm.

Implications for UK transport

The 10-year transport plan produced statistics showing the inexorable rise in private car usage over the previous 40 years, coupled with a slow decline in the use of buses and coaches and a very slow rise in the number of rail passengers:



The Plan was ambitious in that it set out to reverse these trends, stabilising the growth of road travel and transferring much future growth to rail. This was intended to stabilise land transport CO_2 emissions in 2010 at a level 6% below the 2000 figures. In retrospect, it is clear that the 2000 Transport Plan was too ambitious to be politically acceptable. The Sustainable Development Commission [13] estimate that the 20% reduction target for CO_2 will not be met and consider savings from the 10-year plan "insecure".

However others think that the 10-year plan was nowhere near ambitious enough to stabilise CO_2 concentrations at the levels now thought necessary. Work at Leeds Institute for Transport Studies[14] has investigated the reduction in transport fuel emissions necessary to stabilise CO_2 concentration at 450 or 550 ppm. This shows that a 450 ppm stabilisation target requires a 79% reduction in carbon dioxide emissions from 1997 levels by 2050. A 550 ppm stabilisation target requires a 58% reduction.

These figures are based on those for all UK emissions and make the assumption of "equal pain" for different sectors. There is a fundamental question as to whether this is the appropriate way of looking at the problem. Some in the road lobby argue that, as it is more difficult to transfer car energy consumption to renewable or other carbon-free sources, the electricity supply industry should reduce its carbon emissions by more than its "fair share" and transport should take an increasing proportion of the UK's carbon emissions. Taken to its extreme and assuming a 450 ppm target, such a scheme could see the transport sector producing almost all the UK's "quota" of greenhouse gases and placing unrealistic demands on other sectors.

However one divides the CO_2 quota, it would be unrealistic for transport to adopt a favoured approach allowing "business as usual". A substantial reduction in greenhouse gas emissions can be brought about by four possible routes:

- ◊ Increasing the efficiency of road and rail vehicles so they use less fuel per passenger-km or tonne-km;
- ◊ Reducing the overall amount of personal travel and movement of goods;
- ◊ Transferring passengers and freight from high-consumption modes to low-consumption modes;
- ◊ Obtaining energy from non-carbon sources.

Road vehicle efficiency

Average fuel efficiency of petrol-fuelled cars improved significantly in the decade from 1978 but has been largely static thereafter. Although the efficiency of petrol engines continues to improve, this has been partially offset by the higher proportion of larger luxury cars and SUVs being sold. In the US the trend has been negative and the average fuel efficiency fell to 20.4 MPG (US) in 2001, the lowest level since 1980 and a drop of nearly 2 miles per gallon from the 1987-88 peak of 22.1 MPG. The main reason cited for this drop is the growth in large SUVs.[15]

The European Community's wider strategy is to reduce average CO_2 emissions from new passenger cars to 120g/km by 2010, compared to the 1998 estimated average level of 186g/km. The strategy includes voluntary agreements with the European, Japanese and Korean automobile manufacturers to reduce average CO_2 emissions from new passenger cars to 140g/km by 2008 and fiscal measures.

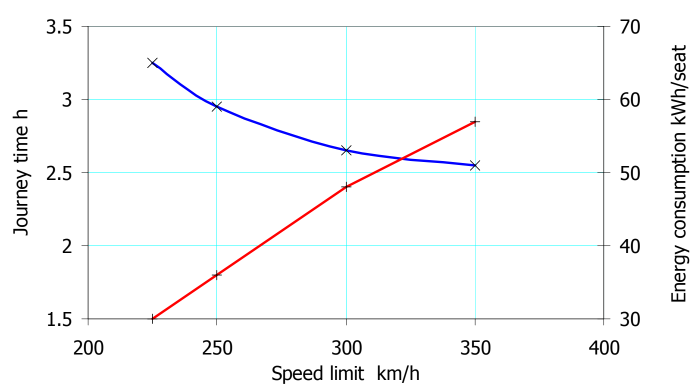
New hybrid technology offers the possibility of improving fuel economy during urban use but will have less effect on consumption on motorway journeys. As an example, the US Government official fuel consumption data for 2004 [16] shows an electric-petrol hybrid Honda Civic using only 72% as much fuel as a petrol version in urban use but 85% in highway use.

Achieving this targets for fuel efficiency will require some technical development but, more importantly, it will require legislative and fiscal incentives. Persuading motorists to "downsize" will be difficult in an environment where real motoring costs are not rising, particularly as larger and less fuel-efficient vehicles are driven by the better-off or those for whom motoring is an allowable business expense. At present there does not appear to be the political will to tackle these issues.

Rail fuel consumption

Internationally rail vehicles are becoming more efficient. A comparison of a 30-year old 475t passenger train and double-deck TGV of the same capacity, shows the newer train having half the aerodynamic drag per seat at 150 km/h.[17] However, since rail privatisation, rolling stock development in the UK has emphasised performance at the expense of fuel consumption. As an example, the 10-car HST trains operated on the West of England routes had two power cars, each fitted with a 2250 HP Paxman Valenta engine.[18] On some services these are being replaced by an increased number of 5-car multiple units, each car equipped with a 750 HP Cummings QSK19 diesel engine. Thus for ten cars, the installed power has increased from 4500 HP to 7500 HP, and it would be surprising were there not a concomitant increase in fuel consumption. Legislation, such as for disabled access or crashworthiness, tends to reduce the number of seats on a train and thus worsen the emissions per passenger-kilometre.

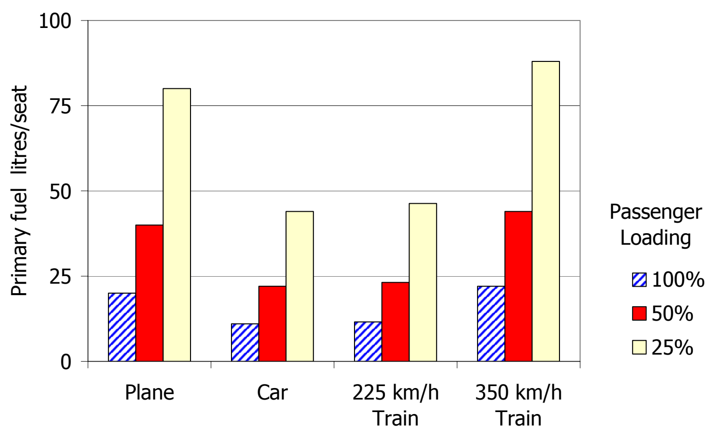
Increasingly trains are running at higher and higher speeds. Energy consumption goes up dramatically at speeds over 200 km/h, although running on newly constructed lines, where trains rarely have to accelerate or brake, improves the figures. The following graph shows the energy consumption of a high speed train running over a new line from London to Edinburgh.[19] Increasing the speed from 225 km/h to 350 km/h saves 45 minutes but almost doubles energy consumption.



Whether or not the CO_2 emissions created by such a train service are greater or less than those caused by a similar number of people travelling in cars or aeroplanes depends on two factors – the passenger loadings of the two alternatives and the fuel mix and efficiency of the power stations feeding the line.

In the past, some studies have been carried out that compared a fully-loaded train with everyone driving their own car. Not surprisingly this showed trains in a good light. At the other extreme one might compare cars with every seat occupied and a half-full train.

A paper to the IMechE in July 2004 [20] calculated the relative energy consumption of different transport modes and presented a calculation of the consumption of primary fuel (for convenience assumed to be oil) per seat over the route London to Edinburgh. The comparison was made between an Airbus A321, a VW Passat TDI and two hypothetical trains, running at 225 and 350 km/h respectively. The conclusions are summarised in the following graph:



This suggests that the primary fuel consumed per seat by a 225 km/h train is much the same as that used by an efficient modern car and at 350 km/h there is little to choose between a high speed train and a modern aircraft.

In July 2004 the Parliamentary Under-Secretary of State for Transport was asked a question on the CO_2 emissions of various modes of transport from London to Edinburgh. His answer is summarised below:

London to Edinburgh	**CO_2 emissions per passenger - journey (kg)**
Aviation	96.4
Rail (Class 91—modern high speed electric train)	11.9
Car	71.0
Coach	9.2

Why is there a discrepancy of about 6:1 between these two sets of data? Part of the reason is because the figures were based on cars with 1.56 occupants (31% full) while trains were a surprising 70% full. They also appears to have taken an average figure for the fuel efficiency of cars while the IMechE presentation specifically referred to an efficient modern diesel car. Finally, he gave figures for present day trains running at a maximum speed of 200 km/h rather than the high-speed trains running at 225 km/h.

This difference between these sets of figures shows how easy it is to change a number of assumptions and radically alter the conclusions. The situation is further confused when you compare electrically hauled trains with diesel or petrol-fuelled cars. For the results presented in April, all energy was converted to kg of oil (on the basis of 1kWh = 8.3 x 10^{-5} tonnes oil equivalent) to ease comparisons, but is this an over-simplification?

The energy supply mix for electricity generation is dominated by coal 33%, combined-cycle gas turbines 28% and nuclear 17%.[21] Working out the carbon emissions from this supply mix is one way to make a comparison. However, you can ask what additional generation would be brought on line to feed the additional load imposed by a new railway and calculate the emissions for that. Alternatively Network Rail could negotiate a supply contract with a nuclear generator or wind turbine operator and claim that all electric trains run on "carbon free" energy. Three different methods of calculation, three very different answers.

Conclusions

Press coverage (not completely impartial) of the April presentation to the IMechE prompted a flurry of activity, calculations, e-mails and meetings. Three important points came out of this:

1. No-one had train energy consumption data at their finger-tips, which confirms that few people considered it to be important.
2. Unlike the situation for cars, there is no standardised method of calculating the amount of CO_2 produced by trains, which leads to wide variations in the assumptions made and the eventual figures.
3. The plethora of different measures (MJ, tonnes oil equivalent, tonnes carbon, grams CO_2 per seat-km, etc.) makes comparison of environmental impact almost impossible for the non-specialist.

UK railways rely on public subsidy. Support for this subsidy is based, at least partially, on the presumption that railways are "a good thing" environmentally. For some lines, such as commuter services into large cities, there is no question that this is true. However the environmental case for building new high speed lines depends on a proper understanding of energy efficiency and carbon emissions which is, in turn, heavily dependent on the future mix of electricity generation. Work at Lancaster is looking at how "green" trains really are in comparison with road and air transport and the directions in which rail development could be encouraged to reduce their environmental impact.

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[2] Transport Statistics Great Britain 2003, table 2.9.

[3] Transport Statistics Great Britain 2002 & 2003, tables 1.1 & 1.14.

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[20] Kemp R. J. *Environmental impact of high-speed rail*. Institution of Mechanical Engineers. Seminar on High Speed Rail Developments, 21 April 2004

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