Delivering a Sustainable Transport System – DfT consultation on planning for 2014 and beyond.

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The Focus of the Submission.

The document, DaSTS, set out clear goals. The goal of cutting greenhouse gases features strongly in the title and intent of the document. Improving the transport system, which includes eliminating congestion is another strong goal. Safety, equality of opportunity and other goals are clearly set out and further pushed into a series of challenges to be met in various specific areas of transport. This invites the obvious next step of asking which modes of transport best meet these goals. They can only be met through forms of transport which drastically cut greenhouse gas generation, broadly by trains and coaches. Coaches, which give a 90% cut in greenhouse gases per passenger km, and could therefore, at least in passenger transport, meet the Government's target directly, are not considered in DaSTS. Yet coaches also also offer an expansion in transport capacity by using road space fifteen times more efficiently than cars, meeting another of the goals. They cut congestion, which presently wastes some £20 billion annually, as each coach hoovers up a mile of car passengers and clears roads. They are safer, integrate with other modes and abundantly meet all the other goals and challenges set out in the DaSTS document, yet they are not explicitly considered as a major mode. Though this focus does not neatly fit the later terms of the consultation document, meeting the goals is central to the thrust of this submission. The mode of coach transport must be central to sustainable transport and its planned development.

I. Clarifying the Goals and Challenges.

This submission focusses only on passenger transport and looks mainly at modal changes with slighter comments on the other three steps of the planning process. First, we consider the goals. They are carefully stated. The first is reliable and efficient transport networks to support economic growth. This is against a background of road congestion and other inefficiencies in the system which add something like a fifth to the overall private transport budget. The second is a radical cut in CO_2 and other greenhouse gas emissions to tackle climate change. Elsewhere the Government has unequivocally committed itself to something like an 80% cut in greenhouse gases, and clearly this 80% cut must be reflected in the transport sector. This is not a marginal change and must result from either using green energy sources which do not add greenhouse gases to the environment or using more efficient forms of transport. It is this latter option on which this study focusses. **We require a five or tenfold cut in fuel use for passenger transport; there is no way round this necessity.** A tenfold increase in the efficiency of moving passengers through economies of scale is what both coaches and trains offer. At present, railways are close to maximum capacity without big

infrastructure work, but coaches allow unlimited expansion. **Coach transport is being ignored in public policy at present, yet it is the only way of meeting the Government's declared policy commitment. The decimation of greenhouse gas emission by coaches offers the chance of meeting both of the DfT's primary goals, of an 80% CO_2 cut and a substantially *expanded* passenger transport system. No other mode can do this.**

The goal of health and safety has been addressed thus far by increased vehicle safety and stronger control on drivers' use of alcohol and speed with some success, but it faces a growing problem. Vehicles are increasingly travelling close to one another on congested roads at considerable speeds and this, and the congestion of parked cars, is adding to sources of accidents year on year. We shall look at the possibility of substantially emptying roads and reversing this trend with substantially greater safety. The goal of equality of opportunity is further addressed by focussing on those without cars, some 30% of the population. Finally, the quality of life is addressed by falls in traffic, congestion, noise and transport expenditure. This proposal thus suggests a way forward which meets all of the goals identified in this long-term review with very positive outcomes, improving safety and health, giving equality of opportunity especially to those without cars and improving the quality of life and convenience of the traveller, while expanding passenger transport provision and decimating the present CO_2 output per passenger of cars. This may seem an impossible claim to make, but it relies on the sheer physical efficiency of mass use of a substantially more efficient mode of transport.

II. Other Challenges to be addressed.

The challenges set out in the DaSTS document are a valuable list of the kinds of priorities which transport policy should have, and it will be clear that the strategic suggestions below meet these in abundance. For example, coach transport aids safety. Passenger coach transport used extensively in the corridors not only cuts accidents because the vehicles have a proven record of greater safety than cars, especially with seat belts, but also by eliminating cars o the road through transferred passengers and clearing the roads of congestion, they offer the possibility of greater safety in car travel. Yet these immediate challenges do not go to the critical issues faced in transport policy on which the next direction hinges. Below are set out four such challenges. The Outer-Urban failure in public transport in cities and conurbations is obvious. There is no public road transport in most of these areas and people use cars by default. The failure to address the possibility of superseding the car in much longer distance transport is addressed, because that is still the major challenge in transport policy. Congestion, the shortage of road space, is addressed by economizing on road space, not by building more of it. Finally, the complexity of transport passenger corridors is addressed since this is one of the focusses of DaSTS. It is suggested that only coaches can cope with this complexity.

1. The Outer-Urban failure in public transport.

Railways operate substantially as carriers from city centre to city centre. This is partly reflecting the size of Britain's cities in the 19th century when the railways were established and they cut through areas of suburban traffic with superb efficiency. Yet the result is that they

cater for only one kind of inter-city movement – from centre to centre. Bristol Parkway and a number of other stations introduce some possibility of movement out from the suburbs, but the ability of railways to pick up journeys from the city periphery, where most people live, is very limited. Most travellers accept that they must go in to a city centre station in order to go out by rail to another city or town. This process may take a hour or more and adds to the journey time. Curiously, coaches operate a similar pattern with city centre coach stations, on the model of Victoria Coach station. Again there are some exceptions, like Milton Keynes Parkway, but they are very limited. Even more dramatic is the bus networks. They ply between city centres and suburbs, with the occasional orbital movement, but when they hit the outer suburbs, normally a terminus peters out as the fields appear. In fact buses are planned only for journeys into the cities and not for journeys on to other destinations. There is, at present, no way of moving from the urban bus networks out into longer public transport journeys by road. The outer reaches of urban bus routes stop as fields appear. As a result most journeys which involve moving out of the city or conurbation from the suburbs have to be made by car. The suburbanite has no alternative. Below a systematic way of gathering journeys from outer conurbations on to other towns and cities, using coach orbitals, is presented which addresses this gap. It allows the bus routes to be used for outward journeys as part of an integrated system and thereby doubles their effectiveness.

2. Better than the Car.

When New Labour came to power in 1997 the avowed aim, declared by John Prescott and others, was to substantially decrease car journeys. The car caused high CO_2 pollution, high levels of congestion and was seen as the main cause of transport problems. The evidence has been available for decades. The aim of cutting car journeys is no less urgent now - even more so given our increasing awareness of global warming and the Government's unequivocal commitment to an 80% cut. Yet the policy on the car has been slowly sidelined. Why is this the case?

The process began with the revolt over petrol prices in September 2000. The power of the car lobby was recognized and the Fuel Tax Escalator was dropped. Shortly after that the Government decided that the car lobby was too powerful, and curbing motoring was dropped as public policy. The Conservative Party has taken the same route, and so, implicitly have the Liberal Democrats. Alienating car drivers is too powerful a way of losing votes. The next development was Road Charging, a valiant and logical attempt to ration road space and address congestion. It was accepted as public policy, incurred a lot of research and development spending and was then dropped because it was seen as provoking a car lobby revolt of fearful proportions. This inconsistency – on the one hand car transport has to be tackled, but on the other hand car users cannot be directed by public policy – dogs transport policy and has caused its virtual paralysis. Everyone knows that various proposals amount to doing very little about anything, and the recession is a welcome relief because it at least edits down traffic for a while.

And car drivers have a point in that for a vast majority of the journeys they undertake, there seems to be no alternative. Longer commuting, outer conurbation and orbital

movements, non-rail intercity journeys, cross country movements cannot be done other than by car. The slogan, “There is no alternative” undercuts the possibility of addressing our present car dominance in passenger transport, which constitutes some 80% of all passenger miles. By and large we seem to accept this impasse. Yet still the problem remains and this review will have to face it directly, or by neglect. This study will suggest that there is an alternative – comfortable, fast, frequent on-off coach transport.

In reality the position of the car user is far less stable than this scenario presents. First, millions of users already choose and prefer journeys by train, underground, coach and bus to those by car. Second, cars have costs. They face congestion on a vast scale. They need parking. They offer the very inefficient pattern of driving 1.5 people to their destination, an extraordinary waste of person hours nationally. Driving frequently means high levels of stress. Cars are expensive in purchase, insurance, tax, petrol, parking, garaging, maintenance and security. For many people they are also extraordinarily inefficient, needing to be owned and maintained for perhaps two or three journeys a week. As a result they take much of a day a week’s work to finance, no small economic commitment. If an alternative were available many families would be happier with one less car or even no car.

But this problem is not just personal, but also structural, a matter of basic engineering and physics, as a comparison between cars and coaches makes clear. A coach with 30 occupants (normal occupancy at present) requires six wheels and one engine. Cars carrying the same number of people require eighty wheels and twenty engines (ignoring spare wheels). The same cars require vast amounts of body weight and generate twenty systems of wind drag, requiring profligate levels of energy. We know that the advent of peak oil and the oil demands of the new emerging economies will make the long term profligate consumption of petrol untenable and very expensive for the car driver. This is a dying industry. We assume that its successor may be an electric or some other type of car, but nothing can match the improvement in efficiency offered by the coach. Car driving is expensive because there are no economies of scale of the kind that come from grouping journeys; it is structurally expensive. By contrast, coaches group journeys. Stagecoach manage an average occupancy of *sixty* on their shuttle service between Oxford and London during the day. That saves a pile of a hundred and fifty wheels required to be driven along the M40 by the equivalent number of cars each coach trip. The economies are obvious and the prices are cheap and attractive. Thus, there is a better form of transport than the car for many journeys. It is just not available and has been marginalised in public policy, investment, infrastructure and road use priority. It is possible to improve on owned and used cars for a high proportion of journeys.

Being better than the car requires some radical changes. Cars win in a variety of areas – convenience, lack of journey planning, comfort, luggage, availability and speed of journey. The question is whether these qualities can be matched or bettered by a national public system of road tranport? As yet, this is not even attempted. This study suggests how it may be – with low levels of national investment, cheaply, with enormous gains for families, promoting equality of opportunity and with the possibility of safer, car edited communities. Moreover this is not an anti-car policy, because it actually offers continuing car users better

conditions on roads freed from congestion. But for this change to take place, it must be a matter of public policy, planning, infrastructure and national priority.

3. Congestion.

Everyone is an expert on congestion. We know the patterns. There are instruments for avoiding it. The Highways Agency carefully documents it. There are obvious points and times – motorways, the M25, the extended rush hours, the accident likelihood and so on. There is widespread agreement that you cannot build roadspace enough to end the problem. This is highlighted by a salutary calculation involving the M25. A car at 60mph needs 77metres minimum according to the Highway Code (4m for the vehicle, 18m reaction time and 55m braking distance). This is roughly 50 metres per person. At 70 mph the figure rises to 100m per car and nearly 70 metres per person. These are *minimum* figures and in bad weather they can be doubled. This means that only about 32 people can occupy a mile of motorway. The M25 is 118 miles long, and allowing three lanes each way solely for cars – really a lane or more each way is occupied by light and heavy goods vehicles – the maximum car passenger capacity of the whole of the M25 with four lanes at 60 mph is only 23,000, enough to fill one end of the Emirates stadium. Actually, the capacity is often far lower than this because of lower car occupancy rates at rush hours, weather, goods vehicles. The inevitable result is congestion or standstill, so that the M25 even becomes that famous car park.

Congestion costs are complex personal and business calculations, depending substantially on how highly people's wasted time is valued, but the best estimates suggest £20 billion. Phil Goodwin comments on this decade, "The effects, using the current Government method of measuring congestion, and a long established method of valuing it, would be that the widely quoted figure of an annual cost of £20 billion would increase to £30 billion by 2010."[1] This is no mean amount. Let us assume it is 2% of GDP of sheer inefficiency. Addressing this systemically would make us all potentially better off. Coaches offer the logical and obvious solution. They increase the efficiency of road space use by an amazing factor of fifteen or more. Thirty people in a coach at 60 mph might need 100 metres, or three metres per person. Thus, a person in a coach at 60 mph requires as much road space as a person in a stationary car. The coach capacity of the M25 moves from under 25,000 to over a quarter of a million. Wherever coaches are used intensively, roads are cleared. Already, with relatively light use, the M40 coaches soak up 10-15% of the London-Oxford car traffic. That congestion needs addressing we all agree. Coaches used extensively offer the only practical hope of so doing.

4. The Major Transport Corridors.

The Department for Transport's document DSTS identifies the importance of the major UK transport corridors. They carry vast numbers of passengers and large amounts of freight. It is here that congestion mainly occurs. They are the arteries of the transport system and rightly command attention. Recently, new high speed train links are being considered, and this paper does nothing to question this possibility. Yet these train links cannot get close to perhaps the vast majority of passenger movements in these corridors. The ORBIT study of the M25 showed that the typical M25 movement was only for a few junctions. The London

metropolis generates a complex interaction with satellite cities and communities which are reflected in more complex journeys than can be made by high speed trains. This is a widespread phenomenon, whether we look at the Western corridor, Birmingham and the North West, or the East Anglian links down to London or the Ports. Always, a high proportion of the passenger movements are a complex which defies the simple route patterns of high speed trains.

This is another reason why coaches are so important. Both through allowing fast orbital movements and through a strategic system of motorway based transfers they are able to provide both the fast underlying journey time and the flexibility of route transfer that the road system alone provides. It is the construction of this passenger network in these major corridors that is the main focus of the rest of this paper. The underlying understanding is that this system is complementary to fast inter-city rail routes, allowing a fuller complex of journeys to be undertaken, and that it can soak up a high proportion of present longer distance car journeys in a major shift of market choice. This is such a decisive change that it needs presentation in the next section.

III. The Coach as the key mode.

This section does not immediately arise out of DaSTS. Indeed, it arises out of what the document does not do. While the goals focus on cutting greenhouse gases and improving the network, most of the document ceases to be goal-orientated. Given these goals, the next stage is to ask what modes of transport effectively deliver the goals. Coaches are the only powered mode of transport which can successfully replace the car. They offer extravagant cuts in greenhouse gases. They cut congestion and economise on the use of road space. They complete the public transport system. Therefore they cannot be ignored. In this section they are considered as part of this strategic review.

Why Coaches are marginalised.

Everybody understands that transport is multimodal, that the modes need linking and journey needs vary with modes. Car journeys will continue both in urban and inter-city journeys on a substantial scale. Yet it seems possible that millions of monotonous journeys undertaken at speed, or in congestion, by one or two travellers in a car could be transferred to coaches. Yet coaches at present offer a very poor choice. This is not necessarily the fault of the operators who work within parameters they cannot escape from. Coaches are infrequent; they usually need booking, maybe running every hour. They are slow. A study of National Express or Stagecoach timetables will reveal average speeds of 30 mph, with the occasional journey falling below 20mph. The reasons for this are urban and inter-city congestion, waits for interchanges, complex journeys and other such factors. Many of us have been passed on a motorway by a coach and there is no inherent reason why the journey of this kind of vehicle is slow. Coaches have also been uncomfortable, though they have improved markedly, and perhaps most important the end to end journey given the links often reduces the through journey speed well below 20 mph. Moreover, coaches do not constitute a system. For example there is no way from Cambridge of going up the A1 and travelling North. The

journey just is not possible. There are some hubs, like Victoria Coach station, but they are surrounded by congestion and waits. Other journeys link places, as for example the X5 Oxford to Cambridge coach does, but the result is that an 80 mile journey takes three and a half hours.

This situation is merely the end result of decades of marginalisation by all the governing parties. Trains and buses are subsidised but not coaches. The infratsructure of trains involves vast expenditure, but coaches must stop where they can, an add on to a bus station. The Department of Transport has no policy on coaches, publishes no papers on them, does no research, collects almost no data and it is even difficult to establish what the public use of coaches is from UK statistical information. Challenges to the DfT on these issues have produced no response, probably because ministers and senior civil servants do not travel by coach and do not think about travel by coach. This is merely the mental outcome of the dominance of car transport and the long-term marginalisation of the coach and its relegation to the domain of the poor and time rich who cannot travel any other way. Though this reaction may be understandable, in terms of national transport policy it amounts to a dangerous prejudice, because it rules out the mode of transport which can decimate fuel consumption, address congestion and links the other modes which allow effective public transport. Clearly for coach transport to grow quickly, it must change quite radically.

Coaches and CO2

It has long been clear that coaches are far more fuel efficient than cars, but how much? The Houghton Royal Commission on Environmental Pollution gives the following figures. Coaches use 0.3 megajoules per passenger kilometre, while small cars use 1.4 and big cars 2.8. (p199) Using a weighting of two small cars to one big car that gives a figure of 84% for the savings in energy, and therefore in CO_2 emissions, from the transfer from car to coach. We will call this 80% to use a conservative figure. In another study Roderick Smith gives figures for London-Bristol which work out at 84.5%, London-Edinburgh at 87% and London-Manchester at 88.3% which further show the 80% fuel saving on these journeys is probably an underestimate.[2] Another estimate comes from the 2008 Guidelines to Defra's GHG Conversion Factors.[3] In the Passenger Transport Conversion Tables the average figure for petrol car CO_2 generation is 0.2070 kg CO_2 per unit km. The similar figure for diesel cars is 0.1979 kg per unit. The overall figure for the average car is 0.2042. Using the current occupancy rate of 1.5, this reduces to 0.138kg CO_2 per passenger for petrol cars, 0.133 kg for diesel cars or 0.136 for the average car. The figure for coach transport, the national average of National Express coach use, obtained from their Corporate Responsibility Report is 0.0290 kg CO_2 per passenger km. Interestingly, this figure is about a half of that for the National Rail network, making it the most efficient form of public transport, though trains travel faster. This gives the overall saving per passenger arising from using a coach at 79% of the CO_2 generation over using a car. It seems safe to conclude that *immediately* coaches save 80% of the fuel used by passengers in cars, and I have long used this figure.

But this 80% figure is a serious underestimate for a whole number of reasons. It includes the present use on coaches in heavily congested city centre areas which the proposed

reforms would avoid. Given Stagecoach average about 60 people per coach, twice the national average, on its London-Oxford coaches for much of the day, even more ambitious saving in fuel and CO_2 generation is possible. These factors alone can push the figure up to 90%. But other factors come into play. First coaches cut congestion by allowing other road users more room. It is quite difficult to estimate how much energy a coach saves through eliminating congestion in cars that remain on the road, because it varies with time and location. If each coach removes half a mile of car traffic at 30 mph, then it may induce savings in the fuel consumption of forty or more cars. Even a slight saving for each car would amount to a substantial bonus to the coach's actual consumption of say 1-5% over the car. Further, coaches economize on road space by a factor of fifteen to twenty and therefore cut out the need to build more roads and the surrounding infrastructure. Road building requires large amounts of energy, but given the lifetime of roads and motorways, one would guess that the impact per passenger is quite small. In addition, as we know, new roads, especially motorways tend to generate more car traffic, and their overall effect is therefore to increase CO_2 consumption. If we include other car related building of car parks, traffic management systems, we could say that another saving occurs here.

More important are the energy costs going into the construction of vehicles. We are talking about using coaches on a scale that will allow the elimination of some car and second car ownership. Let us suppose that a coach in service leads to a reduction in car ownership of one in five of the passengers. When a substantial national coach system is up and running, this proportion could be exceeded. This means that six cars do not need to be bought. Each car involves substantial amounts of energy. The immediate energy use in the *assembly* of cars is equal to something like a year of car operation energy use, but this figure seems too low, for energy goes into refining the metal, extracting chemicals and other raw materials which occur before and beyond assembly, and there are other manufacturing costs associated with using cars, like garage maintenance, spares and vehicle disposal. It seems likely that the energy use would push towards two years in a lifetime of ten, that is 16.7% of overall fuel consumption for a fifth of the passengers, or about 3%. Another estimate puts the energy cost of constructing cars at 10% of their total consumption.[4] That would give us a figure of saving energy of 2%. So here is another 2-3% of saving.

There is a further saving which it is easy to miss, a kind of fuel multiplier. We consider the fuel saving at the pump, but substantial amounts of energy have gone into getting the fuel to the pump. It includes drilling, well and pipeline construction, tanker movement, refining and distribution to service stations. Much of this is actually used oil, both at the well-head and in transport. This is often called the "well to tank" phase, and it amounts to about 15% of the total energy cost. [5] Over oil in the ground, the efficiency of coach travel is thus boosted further to the tune of 3%. Simply put this is the bonus of radical fuel economy. Though the savings do not occur directly in the cars, they are no less real in relation to global warming. Immense effort has gone into biofuel *substitution*, actually with calamitous results for the poor, subsistence agriculture and rainforests, while the proper policy should have been radical fuel *economy*, such as the coach allows.

There are other energy savings from substantial coach use, like reductions in policing costs, accidents, pollution costs and noise control systems, but the underlying reality is that coach travel though the simple processes of gathering journeys, economizing on engines, body weight, wind drag and road space is far more economical than cars. When these factors are taken into account, it seems a responsible conservative estimate to say that coaches decimate fuel use and CO_2 generation over cars; they offer savings of 90% per passenger km. **Overall, this makes coaches the most fuel efficient form of public transport, rivaled only in some situations by rail. We cannot refuse to recognize its importance as a mode of transport in the national system.**

Coaches as a Distinct Mode.

This study thus suggests that coaches have a distinct modal role which has not functioned for decades of undertaking mass movements of passengers on the road system, linked to local delivery points. It requires no new technology, but just some infrastructure and system priorities. Thus far coach journeys largely ape trains though with less success. In cities they move to performing the task of buses. They remain partly unintegrated with other forms of transport. The key is therefore to create a national system which achieves convenience, speed, comfort and accessibility allowing this mode to match and beat the car and open up the share of this mode, linked with others. This requires a national infrastructure which must be implemented by national government. The companies and regional authorities are not big enough to do it. Fortunately, once a viable system is available, the market share will tend to continually rise as people transfer to this mode as its frequency, reliability and ease of use improves. The underlying system can be described in a few simple points.

A National Coach System.

- **Create a national network of motorway coach routes in the main transport corridors with transfer stations at junctions roughly every twenty miles.**
- **Create orbital coach services round the M25, Manchester and Birmingham with a necklace of transfer points to the radial motorways.**
- **Create coach stations, possibly on a carousel design, with flat entry and exit and facilities at junctions allowing easy transfers to other coaches or local buses.**
- **Guarantee a frequency of five minutes on the orbitals and ten minutes on the motorways, higher at rush hours, to keep waiting times low.**
- **Establish a fleet of quality coaches with facilities, comfort, flat entry and exit to stock this development.**
- **Establish local bus, train, underground, coach and bike links with the national network to allow easy door to door movement. Use local transport hubs as feeder centres.**

- **Establish ticketing, information, pricing policies which make the marginal cost of using coaches lower than cars.**
- **Establish systems of coach priority which allow guaranteed coach movement when roads are congested or blocked.**

Such a system would need to cover some 2,500 miles of routes initially, although it could even be rolled out area by area and it could start with as few as 2,000 coaches. Its capital costs would be well below most major transport initiatives because in the main it would be using existing motorways. With perhaps a hundred coach stations at £5 million each and finance for some depots, road modifications and information systems the capital costs nationwide would not be much more than £1 billion. A fleet of 2,000 coaches would cost less than £500 million. And it would generate the capacity for 20 million passenger km per day. As an immediate policy option it has no rival; a national system could be up and running in five years.

From this it could grow, with the right pricing policy, to absorb 20-40-60% of longer distance car travel, increasing convenience and improving performance. The pricing policy would need to make sure that the marginal cost of coach travel, which has an underlying greater efficiency than car, and therefore a lower cost, was lower at the margin than car travel. When many of the fixed costs of car travel like purchase, insurance, tax and garaging are paid, the marginal cost of using the car on the road tends to be little more than the cost of petrol. Because this is not always matched in public transport, the overuse of cars relative to their efficiency tends to continue. By meeting some of the cost out of taxation, national or local, or through a general levy, the pricing system would reflect the incredible benefits that coaches bring, not only to coach users, but also to all road users, and the mode would establish its proper place in the economy of transport. Coach lanes would readily become a good use of road space and coach priority would become an easier highways task.

There are many other detailed aspects of this development, which are discussed elsewhere and cannot be covered in this short document, but it seems incontrovertible that gathered road journeys, represented by coaches, are the inevitable outcome of all the trends evident in the world economy – peak oil, metropolitan crowding in China and India, global warming constraints on fuel use, population growth and the necessary economies in metal use and manufacture which the world now faces. This must be a growth industry, and the UK Government should not ignore its importance to our manufacturing base. The money going to redundant car manufacturing units would be better spent seeding coach manufacture.

I therefore present this focus to the strategic consultation for their consideration. This paper does not even set out the details of the major orbital systems and the operation of the coach motorway network, though they are covered in other papers. It merely underlines the clear conclusion that the only feasible way to meet the goals set out in DaSTS and develop a sustainable transport system is through the large-scale development of coach transport in the UK.

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[1] Phil Goodwin "The Economic Costs of Road Congestion." (London: ESRC Transport studies Unit, UCL, May, 2004) Summary.
[2] Report David Witt, Prof. Roderick Smith, The 19th Jenkin Lecture, 23rd Sept. 2006 "Railways: - The Technical Challenge of their Renaissance." http://www.soue.org.uk/souenews/issue6/jenkinlect.html
[3] http://www.defra.gov.uk/environment/business/envrp/pdf/ghg-cf-guidelines-annexes2008.pdf
[4] John Heywood Scientific American Sept. 2006 37
[5] John Heywood Scientific American Sept. 2006 37