Transport and energy use

Book Section

CHAPTER X

TRANSPORT AND ENERGY USE

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THE ENERGY CHALLENGE

Energy use in transport reflects a mix of core concerns that have varied over time and between countries. These could be represented as an interaction between three key groups of factors (Figure X.1). In recent years our growing awareness of the environmental impacts of energy use has attracted considerable attention, but energy shortage and the related issue of the security of energy supplies have been powerful economic and geopolitical factors for hundreds of years. Recently this has been expressed in concerns around the role of high oil prices in triggering the 2008-10 recession, the implications for energy security in the wake of Russia's growing power through its oil and gas reserves and the uncertain political fallout of the 2011 democracy protest movements among Middle East oil producers. Transport energy strategies and policies are all part of this meta picture and, from the global to the local scale, approaches and measures need to address all these issues.

Figure X.1 here

Recent transport energy policies strategies have sought to simultaneously achieve economic, political and environmental sustainability. But in practice, economic and political factors have tended to determine strategies, constraining approaches to address transport's environmental impacts. A distinction can be made between geographically specific impacts of transport's energy use (such as air pollution) and dispersed global impacts (in particular carbon emissions/climate change effects). However, this distinction is lessening as local air quality issues are tending to be subsumed within programmes focused on carbon reduction (e.g. policies seeking a transition to electric road vehicles). Existing forms of transport, with their high dependency on oil, are a major source of local air pollutants, including:

- Carbon Monoxide (CO) – a highly toxic gas that can impair brain function and, in sufficient concentrations, kill. Transport is the major source of CO, with some 90% coming from cars.
- Nitrogen Oxides (NOx) – these cause respiratory problems and contribute to low-level ozone formation and acid rain. Dinitrogen Oxide (N_2O) contributes to global warming. Transport produces about half of NOx emissions. Diesel vehicles are an important source.
- Particulate Matter (PM) - responsible for respiratory problems and thought to be a carcinogen.
- Volatile Organic Compounds (VOCs) - Benzene and 1,3-butadiene are both carcinogens and are easily inhaled owing to their volatile nature. Other chemicals in this category are responsible for the production of ground-level ozone, which is toxic in low concentrations.

To date, the main response to address transport's air quality issues has been the use of technical measures to cut engine emissions coupled with cleaner fuel formulations (Lane and Warren, 2007). In developed countries, this approach has achieved a significant impact. For example, the UK Air Quality Pollutant Inventory Report (National Atmospheric Emissions Inventory, 2011) stated that "overall air quality in the UK is currently estimated to be better than at any time since the industrial revolution." It noted that CO emissions in 2009 were a 75% reduction on the emissions in 1990 and that the change in emissions between 1990 and 2009 "is dominated by the reduction in emissions from the road transport sector caused by the increased use of three-way catalysts in cars." Furthermore, sulphur was cut by 89% as low sulphur fuels were introduced. Similarly tighter European vehicle emission standards in road transport were largely responsible for a 60% cut in NOx over the same period and UK emissions of PM_{10} hydrocarbons declined by 58%.

But despite such improvements, NOx and particulate emissions remain a source of serious concern, with measured levels of both levelling off in many UK cities above acceptable health levels. Some 60 per cent of UK local authorities now have Air Quality Management Areas in an attempt to address this issue. In the USA, despite California's stringent emission standards for cars, air quality for the 14 million inhabitants of the Los Angeles basin currently fail to meet federal standards on around 130 days each year (albeit an improvement on the 226 days in 1988). In emerging economies, where emission standards are less developed, air pollution remains very severe. In Mexico City the summer smog can be so bad that industrial plants are ordered to cut production and schoolchildren are given the month off. For the 2008 Olympics, Beijing famously banned almost half the cities' cars for the duration of the games. In China as a whole, air pollution is estimated to cause around 750,000 deaths annually, although this is a very politically sensitive subject (McGregor, 2007).Even in Britain, the Parliamentary Office of Science and Technology (2002) noted that, looking to 2025, although mathematical models predict that most pollutant levels will continue to fall, targets for NOx, PM_{10} and ozone may be breached in some areas. London is not expected to meet air quality standards until at least 2025. The technical improvements, although substantial, are not enough.

Attention is now moving towards the elimination of such pollutants not by cleaning existing transport fuels and their engines, but by moving to the use of fuels that produce few or no emissions at the point of use. This includes policies to promote electric and hydrogen vehicles, which allows pollutants to be either dealt with during manufacture (e.g. in generating electricity at power stations or producing hydrogen at refineries) or by using sources of energy that produce little pollution at all (e.g. electricity and hydrogen from wind or solar). The 2011 European Transport White Paper, (Commission of the European Communities (CEC), 2011), envisaged that within 20 years internal combustion engine cars will simply not be permitted in cities. The move towards a fuel shift strategy very much brings together action to cut transport's local and global environmental impacts. It is also one that has the potential to link to the powerful political driver of energy security. But how viable is such a technical transition to a low carbon transport future?

The public policy aim of a transition to a low carbon future by the middle of this century is a particularly difficult challenge for the transport sector. This was highlighted in the 2006 UK Stern Report (Stern, 2006), where it was noted that, between 1990 and 2002, transport was the fastest growing source of carbon emissions in OECD countries (a growth of 25 per cent) and the second fastest growing sector in non-OECD countries (36 per cent growth). Rather than declining over the next 40 years, the trend is for transport CO_2 emissions to grow, particularly in non-OECD countries, where their share of global emissions is anticipated to increase from one third to one half by 2030.

Along with other countries, the UK Transport sector has failed to cut CO_2 emissions; indeed it was only the recession that meant that emissions in 2009 were the same as 1990 (previously they had risen above 1990 levels). With other sectors reducing their CO_2 emissions, the proportion coming from transport has grown from 15.6% in 1990 to 21.7% in 2009. Over 90 per cent of the UK's transport CO_2 emissions come from road transport (Table X.1). Passenger cars remain the biggest source of CO_2, but road freight emissions are significant and those for light vans have risen substantially. Rail produces only 1.7 per cent of transport's CO_2 emissions, despite recent substantial rises in passenger-kilometres and freight carried.

Table 1 here

Within this overall trend of little change in CO_2 emissions, it is notable that emissions from cars have dropped slightly, but there has been a strong rise in emissions from light duty vehicles (coinciding with the rise in internet shopping deliveries). Table X.1 covers domestic emissions but excludes some sources, including international aviation. The 2009 UK report on climate change emissions (DECC, 2011), noted that between 1990 and 2009, CO_2 emissions from UK-based aviation (this covers both domestic and UK-based international flights) had more than doubled to 33 million tonnes carbon dioxide equivalent. It also noted that emissions at altitude have a greater global warming effect, and allowing for this means that they now represent 11 per cent of the UK's total climate change impact. At currently predicted growth rates, the aviation sector will constitute about 33 per cent of total UK climate change impact by 2050. So, even if all other sectors meet government CO_2 reduction targets, air travel is a key environmental issue for the twenty-first century (Bishop and Grayling, 2003).

Energy security and energy shortage were issues that attracted much attention in the 1970s, but came to be overshadowed as the environmental impacts of transport emerged as a major global concern. Until recently, energy supply has not been an immediate problem. According to BP, the ratio of world oil reserves to production have remained largely static in the twenty years to 2004, with there being around 40 years of reserves (BP, 2005). But reserves are only part of the issue. The concept of 'peak oil' is attracting increasing attention, with projections that global oil production will reach a resource-limited maximum (or 'peak') sometime between now and 2030 (for a review of projections, see Boyle and Bentley 2008). Potentially, though, when production of oil actually reaches its peak is less relevant than when demand exceeds supply, which appears increasingly likely in the wake of the rapidly growing economies of China and India. The former Chairman of Shell, Lord Oxburgh, succinctly summed up the issue when he stated that "There isn't any shortage of oil, but a real shortage of cheap oil that for too long we have taken for granted" (ITPOES, 2008).

This conclusion is reflected in the subsequent long-term rise in oil prices. In early 2007, the price of a barrel of Brent Crude was around $70 By mid 2008 the price had risen to $140, but rapidly dropped to around $50 as the recession hit. Since then, the price has steadily risen again to stand, at the beginning of 2012, at around $110 a barrel. Short term economic factors produce price volatility, but there are all the signs of a long term rise in price as globally demand approaches the limits of supply. Providing energy for transport is becoming expensive, involving difficult, costly and potentially riskier situations. The latter is illustrated by the 2010 Deepwater Horizon disaster in the Gulf of Mexico (at the time of writing, BP had spent $14bn in its spill response and cleanup operation and has set aside a further $20bn for damages claims).

Thus economic drivers are set to make energy an increasingly prominent factor in 21st century geo-politics. This is typified by the USA's 2007 Energy Independence and Security Act (Govtrack, 2009) with the stated aim to pass: "an act to move the United States toward greater energy independence and security, to increase the production of clean renewable fuels, to protect consumers, to increase the efficiency of products, buildings, and vehicles, to promote research on and deploy greenhouse gas capture and storage options, and to improve the energy performance of the Federal Government, and for other purposes." Although citing environmental factors as support issues, this policy's core desire is to reduce reliance by the USA on hydrocarbon fuels from politically unstable regions. This is what is emphasised in USA politics, epitomised by George W. Bush's preference to label hydrogen as the USA's 'freedom fuel' to symbolise its potential for energy security.

However, energy security and shortage can be less compatible with environmental requirements. The easiest and most secure way may not be to develop clean energy. This is typified by the burgeoning interest and development of oil shale reserves. In environmental terms, oil shale is an extremely 'dirty' fuel. Brant et al (2010) notes that fuel-cycle carbon dioxide emissions from oil shale derived liquid fuels are likely to be 25 to 75% higher than those from conventional liquid fuels, and the processing also requires major water use. But oil shale is abundant and obtained from politically secure areas (with the USA and China having large domestic reserves). Oil shale (and also shale gas) can economically outcompete renewable energy. Thus it is difficult to see how environmental concerns will moderate such a powerful economic and political combination. Much the same can be concluded from China's extensive use of domestic and Australian coal for electricity generation.

For sustainable transport, the strategic energy challenge is to simultaneously achieve a low carbon transport future that also ensures adequate and secure supplies of energy. Although it is crucial to cut transport's CO_2 emissions, a sustainable transport energy approach is likely to be entirely sidelined unless it can also deliver economic, political and social sustainability.

Transport energy futures

The issues discussed above have led to a particular meaning emerging for the term 'sustainable transport'. This is not defined purely in terms of environmental sustainability, but has become a conceptual and ideological mantra moulded by the wider concept of 'sustainable development'. Sustainable development is the ideology that carbon reduction is not a constraint on growth but is an opportunity to be realised through 'green' economic growth. For transport, this philosophy is epitomised by successive CEC policy papers on transport. Stead (2006) reviewed the 2001 CEC White Paper on Transport (2001), and the subsequent mid-term review *Keep Europe Moving* (CEC, 2006), noting "The use of the term 'sustainable mobility' in the title of the mid-term review of the Transport White Paper serves to highlight a key dilemma of European transport policy, namely how to reconcile the free movement of people and goods, one of the basic pillars of the European Union, whilst at the same time protecting the environment and improving the health and safety of citizens".

The 2011 CEC Transport White Paper, *Roadmap to a Single European Transport Area* (CEC 2011), reiterated the same philosophy (and dilemma), seeking "to build a competitive transport system that will increase mobility, remove major barriers in key areas and fuel growth and employment. At the same time, the proposals will dramatically reduce Europe's dependence on imported oil and cut carbon emissions in transport by 60% by 2050." This viewpoint was also reflected in the 2011 UK White Paper, *Creating Growth, Cutting Carbon* (DfT, 2011). Subtitled Making Sustainable Local Transport Happen, this policy White Paper sets out a vision 'for a transport system that is an engine for economic growth, but one that is also greener and safer and improves quality of life in our communities'. Thus transport planning, policy and management are increasingly responding and being moulded by the conceptual mantra of 'sustainable development'. But although we may be on the cusp of a transition to a very different type of transport energy future, quite what future this could be and how it will come about is a matter of great uncertainty. A number of scenarios is possible.

In terms of how it might look, one 'sustainable transport' future could be the widespread use of low carbon vehicles in the context of a continued rise in mobility amidst population dispersal - i.e. roughly business as usual but with clean technology vehicles. This sort of future was articulated over a decade ago by Tickell and Wright (1998) who envisaged a 2030 vision of green hyper mobility, on the basis that with car *'emissions cut to nearly nothing … the main argument against roadbuilding has been swept aside'*, so there is a massive rise in car use, further roadbuilding and suburbanisation, but congestion remains intense, being managed by advanced information technologies. Alternatively, there could be a sustainable transport future of active travel demand management with cities and towns reconfigured around high capacity electrified public transport systems, where walking and cycling dominates and car use restricted to a minority of trips (Fig X.2). This is an approach perhaps epitomised in the seminal study by Newman and Kenworthy, (1999). Either end of this spectrum (and anything in between) could be claimed to represent 'sustainable transport.' This poses a key question: could 'sustainable transport' manifest itself in a series of different ways, or can only certain combinations of measures deliver a low carbon energy future?

Figure 2.X

This is a crucial question because we appear to be entering a new stage in the transport energy debate. Despite rearguard actions from those who benefit from fostering climate change denial, it is clear that we cannot continue transport's hydrocarbon intensive regime for much longer. Quite aside from climate change, energy economics, supply and security issues will require an alternative approach. We now need to explore questions around what sort of transport regime represents a viable energy future and how the transition to this future could be achieved. In terms of the magnitude of change, the 2011 EU Transport White Paper (CEC 2011) envisages a 60% cut in transport's CO_2 emissions by 2050. An 80 per cent cut in all transport's CO_2 emissions by 2050 has emerged as the benchmark definition for a 2050 low carbon society as articulated in the UK Low Carbon Transition Plan (DECC, 2009). Under the 2008 Climate Change Act, Britain has set legally binding 'carbon budgets', aiming to cut UK emissions by 34% by 2020 and at least 80% by 2050. This can be taken as a reasonable working definition of what kind of environmental improvement is needed within the wider concept of 'sustainable transport'.

3. Exploring transport energy futures

A list of greener transport initiatives is not difficult to compile, but how far they take us towards a low carbon and more energy secure future is debatable. The comprehensive E4tech report for the UK Department for Transport (E4tech, 2006), reviewed a range of vehicle technologies (including battery-electric, hybrid electric and fuel cells) and a range of related fuels (gasoline, diesel, bioethanol, biodiesel and hydrogen). This study concluded that, compared to conventional petrol and diesel-engined cars, hybrid cars can cut carbon emissions by around 20 per cent. The use of low carbon fuels offers greater improvements; bioethanol can cut CO_2 emissions per vehicle kilometre by 25 per cent, biodiesel by 45 per cent and hydrogen by 40 per cent or more. These fuels also have the potential to address fuel security concerns, although whether they can be produced in a sufficient volume is open to question. In addition, any carbon improvements very much depend on the production methods used. International studies (e.g. EUCAR et al, 2002) have produced similar results to those reported above, but almost all these technologies appear to fall short of the required 80 per cent cut in all transport's CO_2 emissions.

In terms of fuel switch, in 2002 the UK Government set a target that low carbon cars should represent 10 per cent of all car sales by 2012 and in 2005 announced the Renewable Transport Fuels Obligation, requiring suppliers to source five per cent transport fuel sales from renewable sources by 2010/11, although in 2009 this target was cut to 3.5 per cent[1] (The actual figure was 2.5% in 2009). This formed a major part of transport's contribution to the 2006 Energy Review (DTI, 2006). The promotion of electric road vehicles has achieved prominence in the last few years, and it is notable that the commitment to support low-carbon battery electric cars was the only transport policy measure to feature in the 2010 Conservative/Liberal Democrat Coalition pact. A longer term transition path has now begun to emerge through the 2009 Low Carbon Transition Plan (ibid) and the 2009 NAIGT report on the future of the automotive industry, which anticipates cleaner internal combustion technologies being joined by an initial widespread uptake of Battery Electric Vehicles (including 'plug-in' hybrids) followed later by hydrogen Fuel Cell Vehicles (NAIGT, 2009).

It is significant to note that the emphasis in all these recent reports and strategies is on switching to low carbon fuels. An alternative technical approach is to use fuel more efficiently. This is actually how hybrid cars cut carbon, but there is a greater potential than the 20-30% improvements that they achieve. Over a decade ago, Wemyss (1996) in his technological review considered that advances in vehicle technologies should allow cars to achieve a fuel consumption of 1.9 litres/100km (150 mpg) within 10 years. That represents an 80% reduction in fuel use compared to the average fleet performance today. Yet, although there has been some progress in the fuel economy of new vehicles, there are still no cars on the market that achieve anywhere near this technically possible performance. It appears that, although car manufacturers had developed a number of energy efficiency technologies, these remained unapplied until the European Commission introduced, in 2009, its CO_2 emissions regulation (EC443/2009). This regulation sets a sales-weighted CO_2 target for new passenger cars; it specifies an average target of 130g/km by 2015 (a 9.8% reduction on the 2010 level), proceeding to an average of 95g/km in 2020.

The result of this regulatory action, which replaced a voluntary agreement with car manufacturers, can be seen in the sudden appearance of a range of 'eco' petrol and diesel cars incorporating a variety of fuel efficient technologies. Up until 2007, there had only been a gradual improvement in

[1] For details see http://www.renewablefuelsagency.gov.uk/aboutthertfo

new car test CO_2 emissions[2] - in the ten years from 1997 to 2007 test CO_2 emissions were cut by 13%; yet in only three years to 2010, CO_2 emissions were cut by a further 13%. The change from a poorly enforced voluntary agreement of the 1990s to the 2009 EU regulations and prospective fines seems to have stimulated real action from the car industry.

Notwithstanding such improvements, these strategies essentially represent a supply-led approach envisaging a technical fix scenario of 'business as usual with clean vehicles'. There also exists a separate range of measures that involve a demand management approach, advocating modal shift from cars to more energy efficient forms of transport including light rail and innovative public transport systems, public shared bicycle schemes, car pooling, car clubs and teleworking/shopping. This is often coupled with proposals for planning controls to produce settlement patterns and conditions that will cut trip length, favour sustainable modes and disadvantage car use. Such an approach involves very different processes and understandings to that needed and used for a technical-fix based approach.

In his comprehensive review of this and other approaches, Banister (2005, Chapter 6) cites case studies of cities that have achieved a 10% drop in car use through approaches utilising planning controls and public transport development. The key thing about such an approach is that it seeks to 'lock-in' energy efficiency through travel patterns and behaviour rather than relying on massive technological and fuel system improvements. A further demand management approach is that of pricing mechanisms. Economists have long argued that the core problem is the under-pricing of the environmental costs of road and air transport and that marginal cost pricing should be adopted (Pearce, 1993; Maddison et al, 1996; Glaister and Graham, 2003) and *Green Budget Europe* (http://www.greenbudget.eu.) has spearheaded the case for ecotaxation reform within the EU. The arguments and evidence for a tax neutral programme of green fiscal reform was presented by the 2009 report of the UK Green Fiscal Commission, including a detailed briefing paper on transport taxation (Green Fiscal Commission, 2009). Pricing mechanisms are seen as supporting changes in travel patterns and behaviours, but need to be applied with a political sensitivity that is difficult to represent in econometric models. In practice, fuel taxation protests and successful lobbying for fuel tax reductions indicate that pricing can be a difficult policy to pursue.

Overall, the sustainable transport energy debate is very much around the relative roles of technical measures to promote cleaner fuels and fuel economy as opposed to modal shift and other demand management measures. What combination of factors is used involves a very different set of social

[2] In practice, on road fuel economy is around 20% poorer than under vehicle type tests.

and economic adjustments. This issue has been explored by a number of researchers (e.g. EPA, 1998; Kwon and Preston, 2005 and Potter, 2007) who conclude broadly that there are substantial problems in seeking to achieve sustainable transport by using any one of these approaches in isolation. For example, using technical measures in isolation means that to even achieve a relatively modest 40% cut in CO_2 emissions from cars (while not addressing behavioural demand-generating factors), would require doubling fuel economy to around a fleet average of 5 litres/100km and the widespread uptake of low carbon fuels that cut the carbon intensity of road fuels by 60 per cent. This would require very substantial fiscal or regulatory actions to achieve such a substantial shift in vehicle purchase patterns. Politically this would be extremely difficult to achieve in the timescales required.

Equally, the studies show that, alone, even a substantial modal shift to public transport cannot attain a sufficient CO_2 reduction even assuming a politically 'heroic' reduction in car use. The need for a combined strategy is clear. If everything depends on one group of measures, then economic, social and ecologically sustainable transport become unattainable, even if improvements are pushed to technically and politically unrealistic extremes. At the very least, low carbon fuels must be introduced in conjunction with substantial improvements to fuel economy. Merely substituting petrol gas guzzlers by hydrogen guzzlers is no sustainable solution. The most viable combination is the integration of technical improvements with demand management that reduces trip lengths, promotes trip substitution and modal shift. This would counteract rises in transport costs and so help political, economic and social acceptance. Such a scenario is represented diagrammatically in Figure X.3.

Figure X.3 here

Despite the case for a combined approach, there is a real danger that it may be politically easier to develop some technical measures (e.g. fuel switch) more readily than demand management. Any success of technical measures could result in the neglect or abandoning of demand management policies, particularly as the latter are perceived as politically difficult. In reality the magnitude of the challenge is that while 'quick wins' are being implemented, the foundations of longer term and more tricky measures need to be put into place. Transport policies at the local, national and international level need to blend technical improvements to vehicles with modal shift and other aspects of travel behaviour, such as trip length, frequency and vehicle occupancy. Transport's energy challenge is of such a magnitude that, unless substantial progress is made on all these fronts, we will inevitably fail to achieve environmental, economic and social sustainability.

4 Towards an energy efficient transport system

The above analysis suggests that we should be seeking a transition to a transport system that is inherently energy efficient and one that is adaptable to future challenges. This could involve a variety of configurations that combine vehicle technical improvements with demand management. At the same time, the future may not necessarily be 'business as usual' plus low carbon cars; the transport energy future may be far more open than we think. New transport technologies and service systems are emerging, and developments in IT have already had a major impact on travel behaviour (e.g. the growth in web based shopping and home-based teleworking – see Chapter X).

These developments are likely to affect different places in different ways. For major cities there may be an emphasis on high capacity public transport systems, roadspace reallocation to buses, cyclists and pedestrians and demand management through road and parking pricing. Behavioural measures to reduce and manage travel needs, might include electronic substitution for commuting and business travel, distance access to services and education, workplace and leisure travel planning and a variety of new product-service systems such as car clubs and city electric car hire schemes (e.g. the Paris *Autolib*, see Willsher, 2011). For suburbs and smaller towns, some elements of such 'big city' formulations would be inappropriate. Here different sorts of clean, energy efficient transport systems will be needed rather than a lower-specification version of big city systems. Trams, metros and other high capacity public transport systems are inappropriate and unaffordable, but there are newer transport systems emerging that could work very well in such contexts. For example advanced guided bus systems can provide the coverage and flexibility needed for cross-suburban travel or, as being applied in Cambridge, to provide a city link corridor serving a mix of established and new settlements.

There are also important emerging designs and technologies that have the potential to provide entirely new sorts of transport service. Demand Responsive Transport (DRT) is well suited to the dispersed pattern of transport demand found in suburbs, towns and rural areas. There are examples of successful systems in a number of countries and in some places in the UK. Several Canadian, Dutch, French and German suburban-style towns have entirely replaced their conventional bus routes by semi-scheduled DRT systems (Enoch et al 2004). In the UK niche markets have emerged, including in Bicester where there is the Chiltern Railways shared taxi link to the station that has provided a popular alternative for car users. In the Netherlands shared 'Traintaxis' are available at most rail stations. Advances in IT now make it possible for a hybrid taxicab/minibus DRT service to provide a considerably better service than conventional bus or even light rail services, but the main barriers seem to be regulatory and financial, in that existing institutional structures do not recognise such a service system.

Personalised Rapid Transit (PRT) perhaps represents a vision of a long term low carbon public transport system that has all the characteristics needed to provide a high quality low carbon service in suburbs and towns (Rogers, 2007). PRT offers a level of service that comes close to the convenience of the private car. The small automated battery electric vehicles run on lightweight guideways that make up a network taking people directly between their origin stop to their final destination stop. The sort of service PRT provides can be thought of as akin to a driverless taxi service. The vehicles guide themselves automatically and, being automated, such PRT systems offer an on-demand 24/7 all year service. People do not wait for a service to turn up, but the service is there when they arrive at a station. The first PRT system in the UK has been built at Heathrow Airport to link the car parks to Terminal 5 (ULTra PRT, 2011), and a number of systems are close to market application in several countries throughout the world (Figure X.4).

Figure X.4 here

Although systems like advanced DRT face institutional barriers and PRT has yet to be proven outside the sheltered confines of an airport operator, the potential is there for future transport systems to be very different to those of today. It is not just a matter of new technologies and designs substituting current vehicles, but of different business models for a new product-service system. For example, low carbon cars have a different cost structure compared to petrol and diesel cars. They are more expensive to buy and, for electric cars, battery packs are costly; however this is counterbalanced by lower running costs. This cost structure is more suited to leasing packages rather than outright ownership. It is also suited to the development of new service models like public car schemes. This means that a possible future is one where many people may not buy one or two multi-purpose vehicles, but have a ‘mobility package’ whereby they have a lease car, plus the availability of specialist vehicles for specific uses coupled with ‘add-ons’ like discounted rail or public transport passes through integrated smart cards. If internal combustion-engined cars are to be phased out in cities, car access may be through schemes like Paris’ *Autolib* city car hire scheme rather than individual car ownership. Much wider options are opening up to obtain car use, and the distinction between ‘public’ and ‘private’ transport could well become blurred.

These sort of technical and service system developments, together with behavioural measures that allow people to explore transport alternatives, suggest that customised packages of measures will need to vary by different types of settlements and patterns of travel demand. We could have a much more diversified transport future. However, the transition to a flexible and appropriate sustainable transport system requires more than developing a range of service and technical designs. There is a need to a change the process by which transport services and policies are implemented. As noted above, institutional, regulatory and assessment structures are built around the existing models of transport provision and make it difficult, if not impossible, for new design configurations to emerge. This is a largely unrecognised, but crucial part of the formula to deliver sustainable transport.

This institutional inertia is deeply rooted in the way transport policy is conceived and articulated. In almost all countries, both transport and energy policies have for long been supply-led processes. For example, energy policy has been about building increasingly centralised power stations and choosing the primary fuel used. It is about organising centralised production marketed to an exogenous dispersed demand. The technology may change (e.g. from coal generation to nuclear or renewables) but the process, the actors involved and the approach does not. Around this core logic has been built a professionally-oriented policy structure centred upon a small group of actors with civil engineering project management skills. This is how governments 'do' energy policy.

Equally, until recently, transport policy has evolved around a similar centralist logic and socio-technical regime structure. It has been about engineering skills to implement a supply-led solution of roadbuilding. As with energy policy, transport policy has been built around interactions with, and the management of, the specialist professions to deliver transport projects. Indeed, even when the need for transport demand management emerged in the early 1990s, this was done in a way that was compliant with the logic of the socio-technical regime. So instead of building roads, the civil engineering project approach shifted attention to building new metro and tram systems and upgrading the railways. It was used to build Britain's first high speed rail line (HS1) and is being used now as Crossrail in London and HS2 proceed. The supply-led technical approach has simply shifted onto different things to supply.

Even this relatively simple shift in focus has proved problematic. For example, the UK has not had the standardised processes to deliver cost-effective tram networks, particularly in the context of our privatised public transport systems. This has led to many schemes failing and tram systems falling from favour after only a handful were built in the largest cities. As noted by Hodgson (2011) the 2000 Ten Year Plan envisaged 25 new rapid transit lines to be delivered, but by the 2004 Future of

Transport report, such light rail schemes were off the agenda. No new schemes have been authorised since Nottingham in 1994, with the exception of Edinburgh's politically motivated tram system, which is severely delayed, cut back and considerably over budget (Lowe, 2010). The main reaction to the difficulties in getting tram systems built in the UK has been to try instead for cheaper and lower performance guided bus schemes, but these too have suffered from similar problems of funding shortfalls and cost overruns. The Cambridge system (albeit now operating well and the largest guided busway in the world) was delivered two years late and at least a third over budget.

This highlights a key institutional issue that shifting the focus of a supply-led approach also requires a change in the regulatory and professional structures of transport policy. In the UK public transport privatisation and deregulation in the 1980s and 1990s produced an institutional context that makes major new public transport investments risky and expensive. Other countries, France in particular, have a policy context of state transport operations coupled with diverse funding mechanisms. Thus it has been much easier for France than for the UK to shift its supply-led approach to public transport systems. This institutional context also helps to explain why innovations, such as DRT services, struggle in the UK. Our system of deregulated bus operations is so structured around conventional 1980s style of registered services that it makes innovations (such as the taxi-bus fusion that works elsewhere) difficult to introduce other than for small niche markets.

Indeed, it is notable that, rather than addressing the key barrier of the institutional and regulatory structures, policymakers in the UK have sought to find projects that can be implemented within the existing structure. This probably means that many existing transport solutions (such as trams and DRT) will see little application in Britain and there is a real danger that retaining our old structures could also jeopardise the viability of many of the new innovative systems and technologies needed to radically decarbonise the transport system.

Such situations have been the subject of analysis in the literature around the transition process to sustainability. For example, Geels et al. (2008) argue that purely technical approaches are limited to incremental innovations and only slowly dismantle the unsustainable patterns of the production and consumption system. Such an approach typically seeks technical improvements that reduce environmental aspects without affecting the core production and consumption system. Even energy efficiency has also been done largely in a supply-led manner. There have been public information campaigns, but these are peripheral to the supply-side core approach of regulations and voluntary agreements with industry to improve vehicle fuel economy, backed up by central taxation 'nudges' to stimulate takeup. All these are essentially an adaptation of the centralist supply-led logic. It is what can be delivered within the approach of engaging only with the small core of actors who make up the supply system. Engagement with users is alien to the way the regime operates.

On moving towards transport demand management measures such as travel plans and new product-service packages, a real clash of practice and logics occurs. The management of travel demand is a process that requires engaging with end users and finding ways to work with them to accept responsibility for their travel behaviour. This requires a totally different set of skills to those in supply-led capital projects, and ones that are very undeveloped amidst transport professionals. It also requires a transport policy approach that recognises that, to deliver sustainable transport, transport policy processes and structures need to be reformed.

From this analysis, it can be concluded that a more comprehensive socio-technical approach is needed to address transformative change at a system levels (Geels, 2005). This comprehensive approach includes the emerging technologies as well as production processes and management/policy practices, which are entwined in relationships of technological innovations and socio-economic arrangements. Geels and Schot (2007) claim that transitions can be explained by using multi-dimensional levels. The key factors identified in this chapter suggest that a such a multi-level approach needs to include actions that feed from the *product level* (new low carbon technologies) into the generation of *new service and mobility models*; these cannot succeed without a shift in the system's *institutional structures*. This last level is possibly the greatest and most neglected challenge; both institutional and regulatory structures are needed that facilitate (rather than hinder) innovative service and mobility models and transport policy and professional skills/organisations that understand and value such approaches. Only with such a multi-level systems understanding resulting in effective action at all levels can sustainable transport be a realistic proposition.

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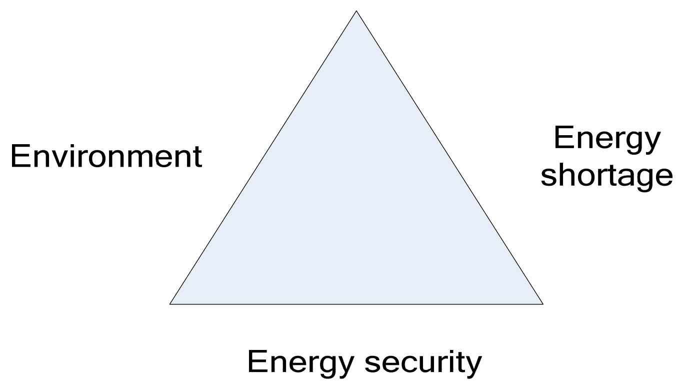
Fig X.1: Transport's energy challenges

(based on Berridge, 2010, Fig 1-1)



Environment	Energy shortages	Energy security
• Reduction in greenhouse gases (CO_2, NOx, SOx) • Reduction in local air pollutants • Desire to use renewable energy • Desire to meet emissions goals (Kyoto, Copenhagen etc.)	• Peak oil constraints • Hydrocarbon gas supplies increasingly far from point of use • Emergence of rapidly developing economies greatly increasing World's energy requirement • Need for long term energy solution	• Minimising reliance on imported energy • Changing political climate increases dependence on energy from unstable regimes • Non geographic solutions sought

Fig X.2: A modern tram running through the car-free streets of central Strasbourg.

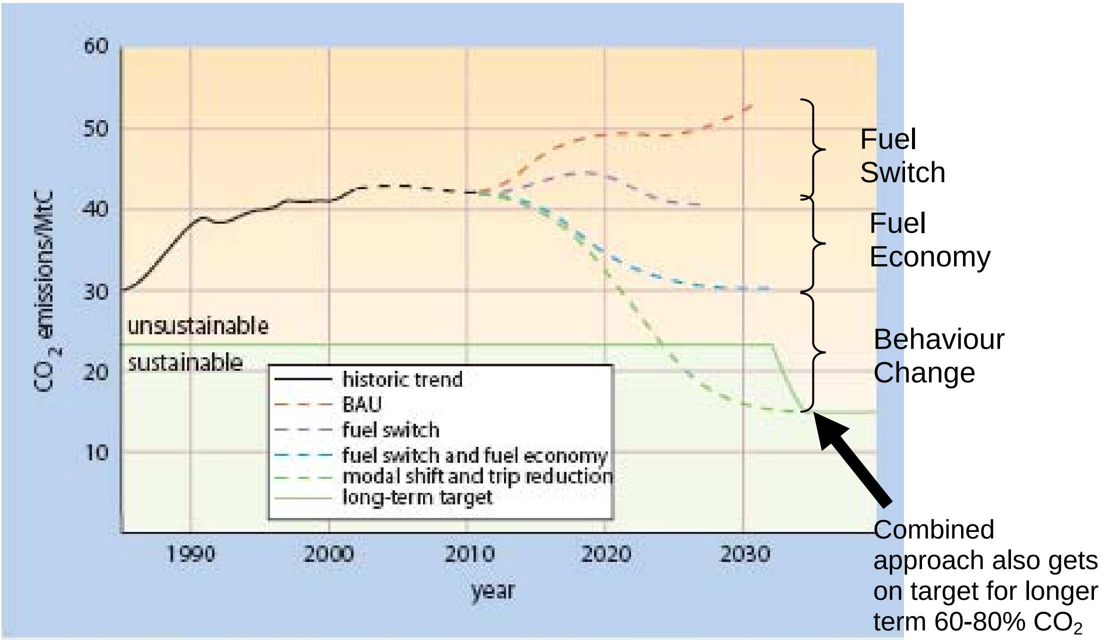


Figure c.5 Ground transport carbon dioxide emissions 1970–2004 and possible 'sustainable' projections (source: DEFRA, 2004, Figure 7; DTI, 2006)

Figure X.3: Ground transport CO_2 emissions and possible 'sustainable' projections, including a combined measures scenario (Source: Warren, 2007, p161)

Fig 5: A Heathrow PRT 'pod' descending from the elevated guideway to a car park station

Table X.1: UK CO_2 emissions by source (Mt CO_2) 1990 and 2009

		1990	**2009**
Aviation	Civil aviation (Domestic)	1.4	2.0
Road	Passenger cars	73.1	70.9
	Light duty vehicles	9.4	15.3
	Buses	3.8	5.3
	HGVs	24.0	21.0
	Mopeds & motorcycles	0.6	0.6
	LPG emissions (all vehicles)	0.0	0.3
	Other (road vehicle engines)	0.3	0.1
Railways	Railways	2.1	2.1
Shipping	National navigation	1.8	1.5
Other Mobile	Military Aircraft and shipping	5.3	2.5
Other Transport	Aircraft - support vehicles	0.3	0.5
Transport Total		**122.1**	**122.2**
Transport as % of total		**15.6%**	**21.7%**
Total UK Emissions		**781.6**	**563.6**

Source: Department of Energy and Climate Change (2011)