RAIL IN THE CONTEXT OF CLIMATE CHANGE: STRENGTHS, WEAKNESSES, OPPORTUNITIES AND THREATS

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ABSTRACT

Rail is one of the oldest of our mechanised transport modes, having been in existence in something resembling its current form for almost two centuries. Since the early 20th century, its dominant position has largely been ceded to road and air transport, although it has retained a steady volume, if much diminished share, of the overall transport market, with particular strengths in the commuter market in large cities, medium-distance inter-city travel, and bulk freight. In recent decades, the development of high-speed passenger services has enabled rail to compete very effectively with air travel over distances of up to 800km, and to dominate routes such as London – Paris/Brussels and Paris – Lyon. Similarly, the containerisation of freight services has provided rail with a significant advantage in the intermodal market, as it is very well-suited to the movement of large numbers of containers between ports and their hinterlands.

The issue of climate change remains somewhat controversial, and presents significant political challenges in terms of convincing political leaders and voters that its long-term consequences merit intervention, with the resulting effects on developed-world lifestyles, within the timescale of the typical electoral cycle. However, there is an increasing scientific consensus that the issue and effects of climate change are real, that human activities are a contributory factor, and that efforts are required both to reduce emissions of greenhouse gases and to mitigate the effects of climate changes that are occurring now, and are likely to continue to occur for at least decades into the future, irrespective of the efforts made now to reduce greenhouse emissions.

The transport sector, including rail, is vulnerable to the effects of climate change and is also a significant contributor to greenhouse gas emissions. Rail's vulnerability takes several forms: constraints on horizontal and, especially, vertical track alignments mean that it is typically more dependent on earthworks than other modes, many of which are now quite old, and are thus vulnerable to increased levels and intensity of rainfall; the buckling of rails under the influence of increased summer temperatures is a problem; and low-lying coastal alignments, such as some of those in the south-west of England, are vulnerable to sea-level rise. However, these issues can be addressed with the necessary interventions and investment, and rail is perhaps less vulnerable than other modes to regulatory intervention to reduce greenhouse gas emissions, since it is relatively energy-efficient and, on electrified routes, can already use renewable energy sources.

This paper examines rail's strengths and weaknesses in the face of climate change, and compares them with those of other, competing transport modes; it then examines the opportunities for, and threats to, rail as a result of climate change, and draws some conclusions about the possible future role and significance of railways.

Keywords: rail, climate change, energy, environment, mitigation, adaptation

INTRODUCTION

The issue and the reality (or otherwise) of anthropogenic climate change remain contentious (see, for example, the 'Climate Debate Daily' website at www.climatedebatedaily.com), but the science of climate change appears increasingly convincing. Even in the face of any remaining uncertainty about the subject, the timescales involved (by the time the matter is proven one way or another beyond doubt, it may well be too late to affect the outcome) and the seriousness of the potential implications of climate change are such that it is sensible to apply the 'precautionary principle' and take action to try to prevent the worst of the potential outcomes. This is true for the railway industry as much as (and possibly more so than some) other spheres of human activity.

This paper investigates the implications of climate change for the railway industry, and conducts a review of the railway industry's strengths and weaknesses in the face of climate change, and an assessment of the opportunities and threats facing the industry as a consequence of its potential effects.

Following this introduction, the issue and seriousness of climate change are first reviewed. Rail's strengths, weaknesses and opportunities, and the threats facing the mode, in the context of climate change are then examined. Finally, the conclusions drawn from the work are presented, followed by a list of references.

THE ISSUE OF CLIMATE CHANGE

As stated in the opening sentence of the Executive Summary of the *Stern Review* (Stern, 2007),

> *the scientific evidence is now overwhelming: climate change presents very serious global risks, and it demands an urgent global response.*

There is increasing scientific and political consensus that this is the case. In the transport sector, this is reflected in the UK by the Chartered Institution of Highways and

Transportation's report entitled *Climate Change And Sustainable Transport – the challenge for transport professionals* (CIHT, 2008), and in the US by the Transportation Research Board Special Report 290: *Potential Impacts of Climate Change on U.S. Transportation* (TRB, 2008); the CIHT report refers to the strengths of and opportunities for rail, while the TRB report has a great deal to say about the weaknesses of and threats facing the industry.

Although, as noted in the Introduction, there remains a considerable degree of scepticism about the reality and seriousness of climate change, this is not a convincing rationale for inaction. As an editorial in *The Economist* (18th March 2010) observes,

> *most research supports the idea that warming is man-made. Sources of doubt … have been in large part resolved, though more work is needed [, and while] plenty of uncertainty remains [,] that argues for, not against, action.*

There are two major categories of response to the issue of climate change: mitigation and adaptation (Stern, 2009, pp58, 59; IPCC, 2007, p56). This categorisation is reflected in the following discussion and analysis.

RAIL'S STRENGTHS IN THE CONTEXT OF CLIMATE CHANGE

Rail's general potential strengths in the face of climate change are illustrated in part by its sheer longevity (almost 200 years, now) as a passenger and freight transport mode, in the face of a wide range of other, social and technological, changes, particularly the intense competition that emerged in the 20th century from road and air transport (Profillidis, 2006, pp1-4).

Rail's specific strengths in the context of climate change include its general environmental friendliness relative to competing modes, based on the energy-efficiency resulting from the low rolling resistance of steel wheels running on steel rails, trains' associated ability to coast for considerable distances, and the potential for further improvements through the use of enhanced rail traffic management and driver information systems. Another, related strength is the ability to recover energy through the use of regenerative, or electrodynamic, braking (Profillidis, 2006, p366), whereby kinetic energy that would otherwise be lost as heat is instead converted into electrical energy and returned to the power supply.

Trains' low rolling resistance is due to the lack of friction between wheels and rails, which also means that the gradients on railway alignments must generally be small. This in turn results in high levels of energy efficiency, since steep ascents are avoided, although this may result in increased levels of 'embedded carbon' in the construction of lines and routes, owing to the inflexibility of alignment options, and the need for associated earthworks, tunnelling and viaducts.

These characteristics of rail mean that it compares favourably with other transport modes, in terms of environmental impact. According to Profillidis (p426),

> *within the transport sector, … railways are the least [environmentally] harmful … transport mode and this could prove in the distant future a critical element [and thus an opportunity] for the development of railways.*

In Table 22.1 (p428), Profillidis shows rail's CO_2 emissions per passenger km as being similar to those for bus, at 60g/passenger km (rail's CO, NO_x and hydrocarbon emissions per passenger km are 25% - 40% of those for bus), and half and one-fifth, respectively, of those for car and air travel. For freight, rail's CO_2 emissions per tonne km are less than one-quarter of those for road transport. The comparative performance of passenger rail is shown to be even more favourable in an article by Richard Brown in the December 2009 edition of *Modern Railways* (p59), with rail generating approximately 20g or less CO_2 per passenger km, vs. approximately 130g for car (similar to Profillidis' value), and approximately 175g for short-haul air travel (considerably less than Profillidis' value). However, a word of caution is required here, a recent review has found over 50 carbon emission estimates per passenger km for rail but with considerable variation relating to train type, load factor, assumptions concerning electricity generation, whole life or part life cost analysis and whether or not the carbon dioxide estimate is an equivalent measure to include the effect of all greenhouse gases (Palmer, 2009). If current carbon emissions are difficult to estimate, future estimates are even more problematic as they are determined by the development and take-up of technology which are difficult to forecast but are expected to be lower than current values. Kageson (2009) estimates that for inter city journeys using new vehicles in 2025 CO_2 emissions may be 15g/passenger km for rail, 45g for car and around 120g for air, suggesting that technological progress may be particularly rapid for car.

Given rail's generally favourable environmental performance relative to other mechanised transport modes, another general strength of rail in the context of climate change is its potentially pivotal role in the improvements to public and freight transport services required to reduce vehicle emissions (Tickell, 2008, p148; Friedman, 2009, pp105, 221, 320-325, 403). For the purposes of mitigating the effects of climate change, the extent of the possible requirements for emission reductions is illustrated by Hepburn and Stern (2009, p42): "richer countries will need to have close to zero [carbon] emissions in power (electricity) and transport by 2050." While they admit that this is "no small challenge", their view is that already-available technology could deliver "close-to-zero emissions in power [and thus] for most of the transportation sector", although this would be "costly". Rail clearly has significant strengths and advantages in this respect, since a significant proportion of Britain's railway network, and particularly of its most intensively-used sections, is already electrified, thus providing zero emissions at the point of use, and it is planned to expand the electrified proportion of the network (Department for Transport, 2009).

Beyond rail's favourable environmental characteristics, and its potential role in mitigating the effects of climate change, it compares favourably with other modes in terms of its ability to provide a comfortable, flexible and productive travelling and working environment (Urry, 2007, pp107, 108), with inter-city travel times that compare favourably with the car, and, to an extent (and more so for high-speed rail), with air travel.

RAIL'S WEAKNESSES IN THE CONTEXT OF CLIMATE CHANGE

While rail has many strengths in respect of the implications of climate change, it also has significant weaknesses. In general terms, and not specific to the issue of climate change, perhaps the most fundamental of these are: the limited coverage of railway networks compared with that of roads (particularly since the contraction of railway networks in the second half of the 20th century); the inability of rail to accommodate a significant transfer of traffic from other modes without massive investment in additional capacity, particularly where capacity limits are already being faced, and the inherent inflexibility of rail, sometimes described as a 'single degree of freedom mode of transport' (Profillidis, 2006, p4; Armstrong, 1998, p125; De Fontgalland, 1984, p7), and its inability to provide the 'door-to-door' service offered by road transport.

Other weaknesses include the vulnerability of railway infrastructure and operations to changing weather patterns - the snow-related problems experienced by Eurostar in late 2009 (BBC, 2009a) may be just a foretaste of things to come. These issues can be addressed by engineering means, but will inevitably require significant investment and a long time to implement. The sheer longevity of railway assets, one of the industry's inherent strengths, means that it can take a long time to achieve state-of-the-art environmental performance across the system, and rail's inherent environmental advantages may therefore be ceded to competing modes, especially road.

These weaknesses are not unique to rail, however, and, in the case of the floods that affected Workington, in Cumbria, in late 2009, the road bridges across the River Derwent were destroyed or closed, while the railway bridge remained open (IMechE, 2009). However, much of the rail route along the Cumbrian coast is vulnerable to the effects of sea level rise, as are parts of other coastal routes, such as the Cambrian coast line, the South West Main Line around Southampton, and, perhaps most notoriously, the route along the Dawlish sea wall, in Devon (CIHT, 2008, p93). The vulnerability of the U.S. rail system to coastal flooding is also mentioned by TRB (2008, pp5, 22).

It can therefore be seen that rail has significant weaknesses in terms of its ability to adapt to the effects of climate change, and thus to contribute to the wider process of climate change adaptation. In addition to the issues discussed above, even current levels of investment in rail in Britain are subject to criticism, albeit admittedly from the roads lobby (BBC, 2009b; New Civil Engineer, 2010). The increasing use of yield management on Britain's railways, referred to above, is likely to increase the perception among users that rail is an expensive and/or inflexible means of transport, an impression that is not dispelled by news stories such as the arrival of the first £1,000+ UK domestic rail fare (BBC, 2009c). Referring to a recent UK national rail passenger survey, an editorial in *Modern Railways* magazine (March 2010, pp4, 5) expresses concern about the quoted levels of customer satisfaction, and their implications for the railway industry. The 2008 CIHT report (p20) also notes the struggle "to ensure that acceptable levels of customer satisfaction are being achieved on the rail network."

RAIL'S OPPORTUNITIES IN THE CONTEXT OF CLIMATE CHANGE

From the foregoing material, it is clear that rail has a significant opportunity to use its relevant strengths to contribute to the process of adaptation to climate change, providing it can overcome its weaknesses in this area. As observed by Sperling and Gordon (2009, p43), "the benefits of [and thus the opportunities for] a non-car-centric transportation system are potentially huge." The potential opportunities for rail received a significant commercial endorsement recently, when Warren Buffett purchased BNSF Railway, the second-largest freight railway in the United States.

More generally, given rail's strengths in the context of climate change, the industry should have considerable opportunity to expand both its market share and its actual usage in both passenger and freight (CIHT, 2008, p37), assuming the industry can accommodate such expansion, and successfully address this and the other weaknesses identified above.

Several sets of scenarios have been developed in recent years to identify and assess various issues affecting transport generally, and rail in particular. Of these, the scenarios and associated analyses developed by Network Rail (2009) for its Network RUS and by TSAG (2009) are most explicit about the opportunities for rail.

The Network Rail scenarios (Network Rail, 2009, p5) are based on

> *the degree to which sustainability will be pursued [and] the degree to which the UK participates further in global trade (or whether the economy becomes more decentralised).*

These two 'axes of uncertainty' are used to generate four scenarios entitled *Global Responsibility*, *Local Awareness*, *Insularity* and *Continued Profligacy*. The scenarios are summarised in Figures 1 and 2 (Network Rail, 2009, pp38, 41).

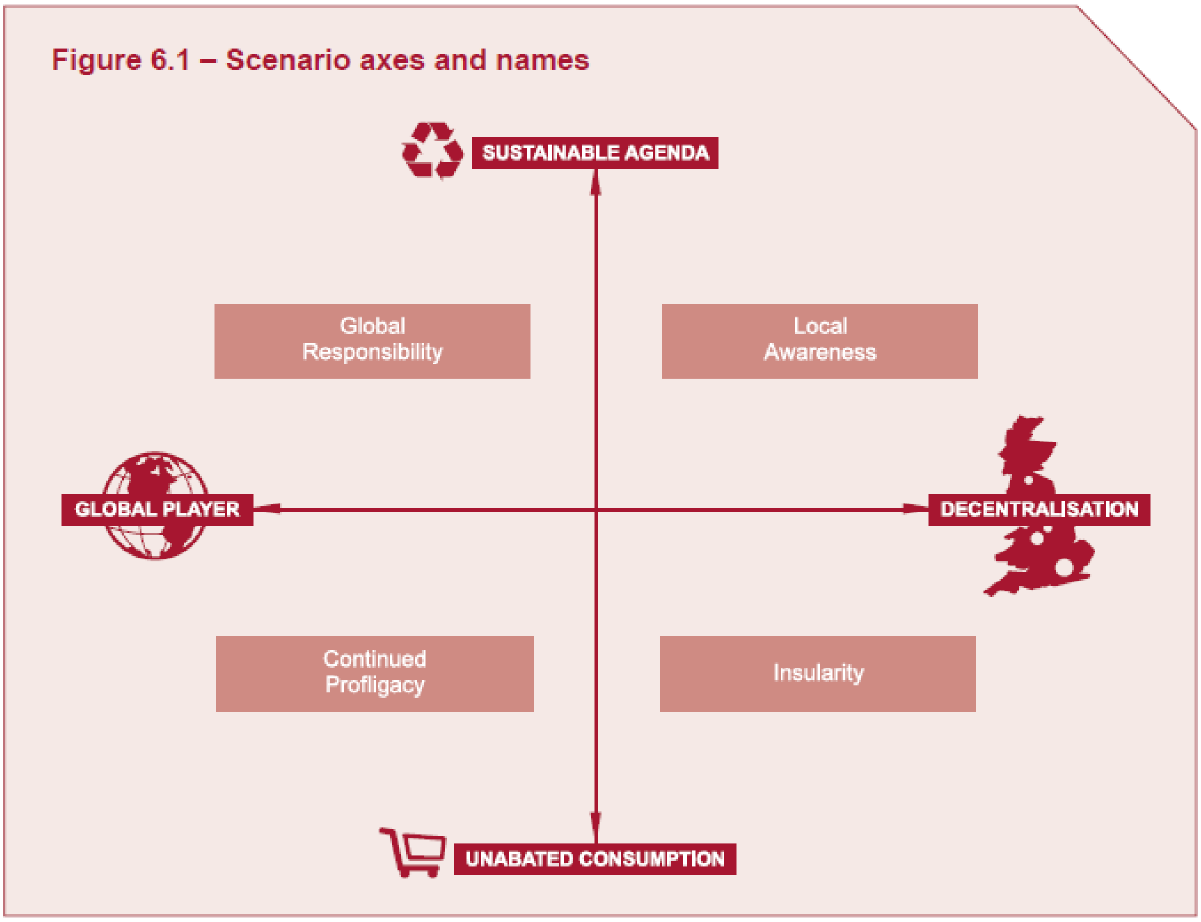

Figure 1 – Network Rail's Axes of Uncertainty and Future Scenarios

The results of the exercise indicate significant growth in long-distance passenger and freight traffic under all scenarios. Passenger growth is predicted to be significantly greater in the continuing globalisation scenarios than for decentralisation, and is not greatly affected by the degree to which sustainability is pursued. Freight growth is maximised by the combination of continuing globalisation and emphasis on sustainability.

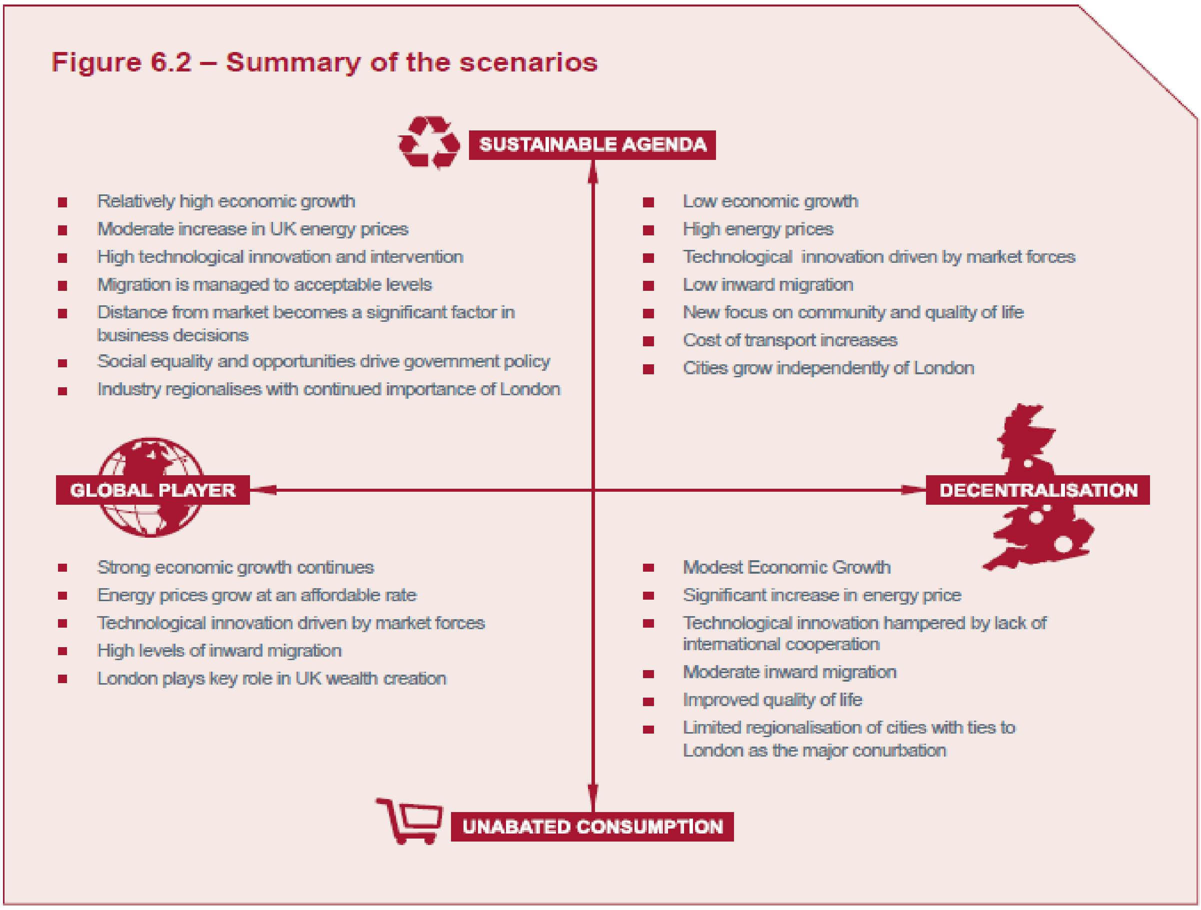

Figure 2 – Network Rail's Scenario Summaries

A similar approach is taken by TSAG, whose four scenarios are summarised in Figure 3 (TSAG, 2009, p19). In this case, the axes of uncertainty employed are "level of co-ordination of the transport sector" (i.e. policy-led vs. market-led) and "amount of travel". The resulting scenarios are called 'Cloud Zero', 'Homeward Bound', 'Gold Stars' and 'Grand Projects'.

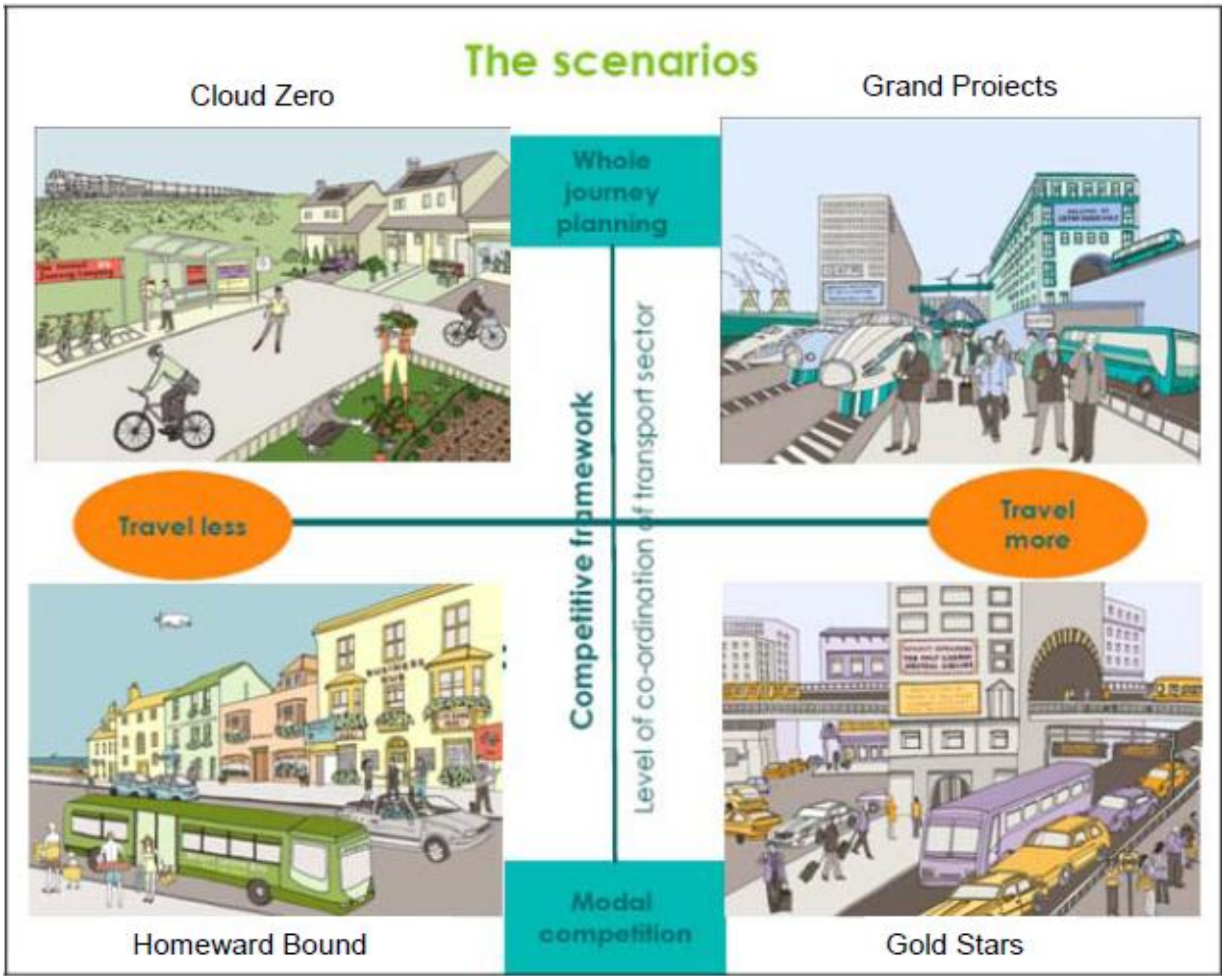

Figure 3 – TSAG Axes and Scenarios

TSAG's (2009, pp20, 21) description of the four scenarios includes the following:

- *Grand Projects represents a world in which the government – nationally and regionally – decide to support the rhetoric of integrated transport planning with integrated investment. … One significant shift is towards rail as the backbone of the long-haul business within the UK.*
- *Gold Stars portrays a world in which transport investment decisions are framed by the ability of competing sectors to deliver improved outcomes in terms of reducing carbon emissions while ensuring that economic activity is supported. In a world where road transport (car and bus) have made huge strides to reduce their emissions, rail's significant advantage is in addressing congestion in urban travel-to-work areas.*
- *Homeward Bound characterises a world in which the government seeks to influence behaviour by imposing taxes on transport choices which have higher carbon emissions. … In this world, the biggest relative change is an increase in the use of rail for leisure, both within the UK and Europe,*

because tax increases have caused a significant fall in aviation demand. Although overall UK travel falls, it is likely that modal share of rail will increase, certainly proportionately and potentially also in absolute numbers of kilometres travelled.

- *In Cloud Zero, which combines reduced travel with policy-driven transport, this is achieved through personal carbon rationing. … Rail's big gains are in the freight sector, because of the high carbon impact of road-based heavy goods vehicles. ... Rail's modal share will increase, but absolute levels of passenger demand are likely to fall.*

It can thus be seen that each scenario envisages different opportunities for rail, although 'Gold Stars' envisages a fairly limited role for the mode, perhaps representing more of a threat than an opportunity (this and other threats facing the mode are considered in the following sub-section). It can also be seen that the opportunities for rail, like (and reflecting) its strengths, are to be found in the mitigation of, rather than the adaptation to, climate change.

THE THREATS FACING RAIL IN THE CONTEXT OF CLIMATE CHANGE

Following on from the preceding section, another set of scenarios was developed by the UK Government Foresight Programme's *Intelligent Infrastructure Systems* (IIS) project. The axes of uncertainty used are (i) the degree of acceptance of intelligent infrastructure and (ii) the environmental impact of transport. The axes and resulting scenarios are shown in Figure 4 (Foresight, 2006, p8).

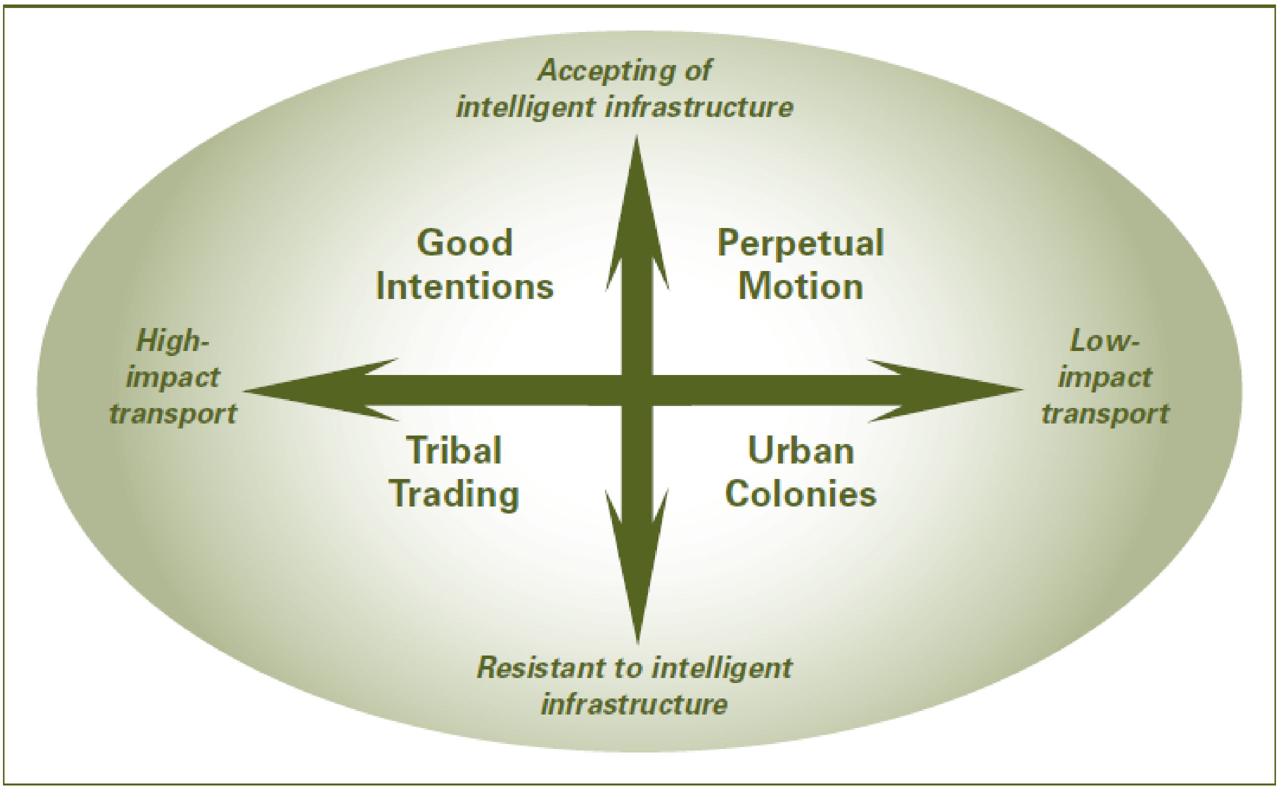

Figure 4 – The IIS Axes of Uncertainty and Scenarios

The nature and source of the IIS project is such that it is essentially 'mode-agnostic', in contrast to the Network Rail and TSAG exercises, both of which focus on rail. It therefore makes relatively few specific predictions for rail, but, while several of the scenarios predict or imply good prospects for the expansion of high-speed rail, it appears in some scenarios that rural, local and, possibly, some commuter services could be under threat, due to improved road-based public and private transport, and discouragement of dormitory towns and longer-distance commuting, even by rail.

Moving away from the scenarios above, rail's commuter role could also be threatened by the expansion and improvement of tele-working technology, although this could reduce the 'peakiness' of rail travel in the mornings and evenings, and provide an opportunity to deploy a more balanced and evenly-utilised supply of infrastructure and rolling stock.

The threats facing the industry reflect its weaknesses, including the vulnerability of railway infrastructure and services to changing climate and weather conditions, the potential consequences of the industry failing to innovate and to modernise its technology and operating practices to match gains being made by competing modes, particularly the automotive sector. The long life of railway assets can actually be a problem in this respect, although equipment can be updated during its operating life. As Sperling and Gordon (2009, p44) caution, "[road] vehicle technology is progressing [and] the vehicle transformation is just getting under way."

Another threat facing the industry is the potential loss of bulk freight traffic in the form of coal, unless ‘clean coal’ generating technology, possibly in the form of Carbon Capture and Storage (CCS), can be developed to prevent coal-fired power generation from being phased out as a result of its contribution to climate change. As observed in the April 2010 issue of *Trains* magazine (Trains, 2010, pp50, 51), in 2008, coal accounted for 45% of US railroad freight tonnage, and 25% of revenue,

> *but the converging trends of global warming, emissions restrictions, and stricter environmental enforcement have the feel of an inflection point, curving the long-term trend for the railroads’ bedrock traffic downward.*

Another, related threat facing the industry is its reliance on such bulk traffic, and its difficulty in handling single wagon-loads of freight efficiently and economically, to enable it to supplement the bulk flows and compete more widely with road haulage (CIHT, 2008, p37).

A further significant threat facing the industry is the sheer cost, in both financial (TRB, 2008, p127) and energy terms, of upgrading and expanding its assets to meet the challenge of climate change. As cautioned by Kageson (2009, p2), “construction emissions for a line of [500km] length may amount to several million tonnes of CO_2”, while Preston (2009, p19) reports that, depending upon the degree of decarbonisation of electricity generation (for traction) achieved, construction may account for between 18% and 70% of total life cycle CO_2 emissions.

This is allied to the fact that the cost base of the UK railway industry is already perceived to be high, as noted above, and the industry is considered in some quarters to represent poor value for money.

It contrast to the opportunities facing the industry, it can be seen that the threats to rail, like (and reflecting) its weaknesses, lie chiefly in the difficulty it faces adapting to the effects of climate change.

CONCLUSIONS

While significant uncertainties remain about climate change and its likely consequences, the science is sufficiently advanced and certain, and the potential consequences sufficiently severe, to adopt measures of both mitigation and adaptation, particularly where the latter will take a long time to implement. This is no less true for the railways than for other undertakings, and perhaps more so, given the industry’s need to adapt to the likely effects of climate change if it is to realise its potential mitigation role, the extensive and vulnerable nature of its infrastructure, and the long life-spans of both its infrastructure and rolling stock.

Rail has considerable strengths in the face of climate change, providing the mode with significant opportunities. These strengths and opportunities lie chiefly in rail’s potential to assist with the mitigation of climate change. However, these strengths will only be fully utilised, and the opportunities realised, if rail’s weaknesses can be addressed and overcome, and at least some of the threats facing the mode can thus be reduced, and, where possible, removed. The industry's weaknesses, and the threats to which it is thus exposed, lie chiefly in the industry's need to adapt itself to climate change, and also to its likely consequences in terms of society's future transport requirements.

In conclusion, rail's strengths and opportunities in the context of climate change lie chiefly in its energy efficiency and potential to be powered by a range of (sustainable) energy sources, while its weaknesses, and the threats to which it is exposed, reside in the extent and vulnerability of its infrastructure, the costs associated with upgrading it to the necessary standards (about which there is some considerable uncertainty), and the possibility that other transport modes, especially road-based, may improve their environmental performance to match or exceed that of rail.

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