Possible Railway Futures

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ABSTRACT

The centuries since the birth of the Industrial Revolution have seen a succession of increasingly sophisticated transport technologies, each offering improvements in speed, carrying capacity and/or operational flexibility. Having spent this time overcoming the physical barriers to freedom of movement imposed on us by the natural world, humanity now appears to face two immense, and related, challenges: declining reserves of fossil fuels, and anthropogenic climate change. These have particular direct implications for the future of energy intensive modes such road and air transport, and thus 'knock-on' implications for other, more energy efficient, modes, such as rail.

Railways provided the second 'great leap forward' in transportation, following hard on the heels of the canal revolution, and were arguably the defining technology of the Victorian age, with their importance peaking in the early 20th century. Since then, and particularly since World War II, their role and market share have diminished in the face of competition from road and air transport, although they retain significant roles in both passenger and freight transport. The last third of the 20th century saw significant improvements in railway operating efficiency, particularly with the switch from steam to diesel and electric traction. The development of high-speed passenger rail travel in Japan and Europe reduced journey times dramatically, and enabled rail to compete successfully with air travel over distances of up to 800 km, to the extent that rail now dominates such markets as London – Paris and Paris – Lyon. In parallel with this, containerisation and the concentration on long-haul, unit-train operations greatly improved the efficiency of rail freight services, as exemplified by the burgeoning rail freight industry in North America, where insufficient network capacity is increasingly an issue.

The Foresight Programme of the UK Government's Office of Science and Innovation recently commissioned a report entitled *Intelligent Infrastructure Futures*, for which four scenarios were developed of how society might be in 2055. These scenarios are: 'Perpetual Motion', 'Urban Colonies', 'Tribal Trading' and 'Good Intentions', each having its own implications for the future of transport. This paper considers the implications of each scenario, and of the underlying/overriding issues of 'peak oil' and global warming, for the possible significance and role of rail transport in meeting our transport needs in the mid-21st century.

1. INTRODUCTION

This paper examines possible roles for rail transport over the next half-century, based on a range of possible technological and social changes during that period. These changes are derived from a range of future scenarios developed in the course of the *Intelligent Infrastructure Futures* project, commissioned as part of the UK Government's Foresight programme.

Some specific predictions of the possible future roles of railways are made in the initial project reports; others are derived from other possible outcomes described in the reports, in conjunction with more general considerations of likely restrictions on the future use of fossil fuels, likely to be imposed (i) in response to climate change (see, for example, Stern, 2007) and (ii) as a direct consequence of 'peak oil' whereby global production reaches a peak (or at least a plateau), before declining, regardless of likely ongoing increases in future levels of demand.

Following this introduction, the background to the issues discussed in this paper is summarised. The UK Government's Foresight Programme is then described, and the Intelligent Infrastructure Systems (IIS) project is introduced, with a description of its origin and aims, a summary of its findings with respect to future requirements for intelligent infrastructure, and a description of the drivers of change, 'axes of uncertainty' and scenarios used for examining 'alternative futures' between now and 2055. Section 4 then describes the scenarios in more detail, and Section 5 considers the implications of the different scenarios for rail transport, rail's potential for satisfying the future requirements for intelligent infrastructure, as identified in the IIS project, and briefly examines the more general implications for rail of climate change and peak oil. Section 6 presents our conclusions, and is followed by a list of references.

2. BACKGROUND

The past 250 years have been a period of enormous social and technological change, exemplified by the succession of transport revolutions that has occurred during that time, i.e. the 'canal age' of the 18th and early 19th centuries, followed by the development and rapid expansion of rail transport in the 19th and early 20th centuries, followed in turn by the development in the 20th century of motorised road transport and commercial aviation, which, particularly since the mid-20th century, have come to dominate much of the transport sector, with road traffic being particularly dominant in the relatively short-haul passenger and freight sectors, and air transport in the long-haul movement of passenger and high-value, low-volume freight, including postal services. With increasing levels of prosperity, and, particularly with the rise of budget airlines like Southwest Airlines, Ryanair and Jetstar, air transport has made increasing inroads into the medium-distance rail and ferry travel markets, too, as exemplified by the contraction of ferry services serving Harwich, on England's North Sea coast, and the withdrawal of passenger rail services in New Zealand apart from a core set of routes serving the tourist market, and commuter rail services in the Wellington and Auckland areas.

Canals still play a significant role in the longer-distance inland transport of bulk freight commodities, although they seem to be increasingly vulnerable to periods of flood and drought, such as those that have been seen in Europe in recent years.

The relative decline of rail during much of the 20th century has in the past few decades been followed by something of a resurgence, particularly in long-distance freight and high-speed passenger services. The mode has also maintained a significant and valuable role in medium-distance passenger transport and in the provision of commuter transport to, from and within larger urban areas. The commuter role has been retained despite the trends in recent decades towards suburbanisation and the development of 'edge cities', and the consequent dispersal of residential areas and employment opportunities, resulting in transport requirements that cannot easily be met by public transport, particularly rail. Despite these recent and continuing successes, however, rail's share of the overall transport market remains small.

Increasingly, however, the longer-term sustainability – in every sense of the word – of our current transport systems is being called into question. Transport is heavily dependent on the availability of affordable fossil fuels: particularly, and almost exclusively, in the case of road and air transport, oil. On the one hand, there appears to be an increasing level of acceptance that oil production will peak within the coming decades, and may already have reached a plateau, with the likely result of comparative scarcity and increased prices, if demand is maintained at current levels, or, as seems likely, continues to increase. On the other hand, there is again, it seems, an increasing degree of acknowledgement that our consumption of fossil fuels, of which transport claims an approximately 20%, but increasing, share, is at least contributing to climate change, the initial signs of which appear to becoming increasingly apparent.

Scenario planning is: *that part of strategic planning which relates to the tools and technologies for managing the future* (Ringland, 1998). It has some pedigree in the rail sector in Great Britain, being used, for example, to identify priorities for rail science and technology developments (Potter and Roy, 2000, Potter, 2007). However, in this paper we wish to examine the wider implications for rail of scenario planning undertaken as part of the Foresight programme and described in the next section.

3 THE FORESIGHT PROGRAMME AND INTELLIGENT INFRASTRUCTURE SYSTEMS

3.1 THE FORESIGHT PROGRAMME

The Foresight programme is run by the UK Government Department of Trade and Industry's (DTI's) Office of Science and Innovation (formerly the Office of Science and Technology). Foresight, together with its associated 'horizon scanning centre', "aims to provide challenging visions of the future, to ensure effective strategies now [by] providing a core of skills in science-based futures projects and unequalled access to leaders in government, business and science" (Foresight, 2002a). Current Foresight projects include *Mental Capital and Wellbeing*, *Sustainable Energy Management and the Built Environment* and *Tackling Obesities: Future Choices.*

3.2 THE INTELLIGENT INFRASTRUCTURE SYSTEMS PROJECT

3.2.1 Project Origins and Objectives

In January 2006, Foresight launched the Intelligent Infrastructure Systems (IIS) project, on which work had started in September 2004. The project's aims are

> *to explore how science and technology may be applied over the next 50 years to the design and implementation of Intelligent Infrastructure Systems that are robust, sustainable and safe*

(Foresight, 2002b). The project's scope includes the "transportation of goods and people and the alternatives to mass movement" and "the future of transportation systems and the application of information technologies and infrastructure" (ibid). Project reports published in 2006 include a *Project Overview* (Foresight, 2006a) and a report on the future scenarios used in the project: *The Scenarios – Towards 2055* (Foresight, 2006b).

The project's presumptions for the future are summarised as follows (Foresight, 2006a, p18):

- *We need to prepare for the post-oil world of personal transport.*
- *We will be seeking to deliver a sustainable solution and we will have the capability to build intelligent infrastructure which can meet all of the pillars of sustainability.*
- *Some technologies may assist us in our decisions on whether we should move, and if we do what would be the best way of getting where we want to.*
- *There will be shocks in the future which will affect our freedom to move and move things, so we need to build an intelligent infrastructure to support people's activities even at times of pressure or be willing to deal with the consequences.*

3.2.2 Intelligent Infrastructure Requirements

Based on these presumptions, the Project Overview (Foresight, 2006a, p2) identifies a need to invest in infrastructure that, over the next 50-100 years, will:

- *Meet a growing demand for transport;*
- *Support economic growth;*
- *Be environmentally sustainable;*
- *Meet the wider needs of all elements of society;*
- *Accommodate future uncertainties; and*
- *Be safe and resistant to shocks.*

In terms of 'intelligent infrastructure', the Project Overview (ibid, p34) identifies four areas where intelligence is important, if we are to maximise the potential benefits of transport investment, and minimise its social and environmental costs in the coming decades:

> *the design of the infrastructure; developing infrastructure that provides us with intelligence; building infrastructure that is intelligent; and the intelligent use of infrastructure.*

These requirements for intelligence are expanded upon as follows (ibid, p10):

- ***Intelligent design**, minimising the need to move, through urban design, efficient integration and management of public transport and local production;*
- *A system that can **provide intelligence**, with sensors and data mining providing information to support the decisions of individuals and service providers;*
- ***Infrastructure that is intelligent**, processing the mass of information we collect and adapting in real time to provide the most effective services; and*
- ***Intelligent use** of the system where people modify their behaviours to use infrastructure in a sustainable way.*

3.2.3 Drivers of Change, Axes of Uncertainty and Future Scenarios

In order to assess possible conditions and requirements over the next 50 years, and to consider "how science and technology might be applied to infrastructure" (Foresight, 2006a, p42), 60 potential 'drivers of change were identified and considered. These include (ibid, p45):

- *Growing demand for mobility – passengers and goods;*
- *Ageing, yet more active population;*
- *Emergence of better physical and virtual management systems;*
- *Growing global energy deficit – increased demand and consumption;*
- *Emergence of radical solutions to climate change;*
- *The end of affluence;*
- *Rising tension between freedom of information and privacy;*
- *Semi-autonomous/autonomous vehicles becoming safer and more efficient;*
- *'Digital natives' – the new generation growing up accustomed to technology;*
- *High-speed rail travel;*
- *Growing impact of climate change;*
- *Complex just-in-time models are vulnerable to external shock;*
- *Demand management of transport provision;*
- *Rising importance of local provision; and*
- *Move towards full-cost accounting.*

The uncertainty surrounding these various issues were 'distilled' into two 'main uncertainties' (ibid, p42):

- *Whether or not we will develop low-environmental-impact transport systems; and*

- *Whether or not people will accept intelligent infrastructure.*

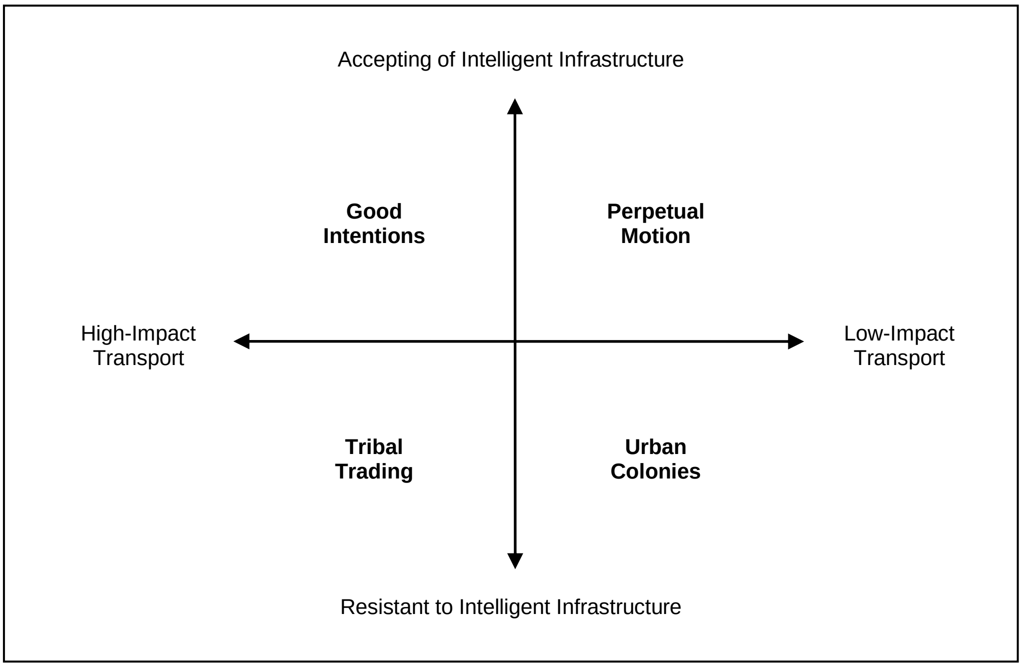
The first of these two uncertainties relates to "the consequences of transport on the environment, economy and society" (Foresight, 2006b, pp7, 8), with, on one extreme, high carbon emissions, ongoing oil dependency and significant waste generation resulting in a high level of environmental impact and associated social impacts of noise, land take and impaired social and community cohesion. At the other extreme, clean-fuel technologies reduce carbon emissions, waste is reduced and manufacturers are forced to lengthen product life. Social impacts are also reduced, although there may still be some social exclusion due to unequal access to transport.

The second uncertainty relates to social attitudes, with, on one extreme, a 'digital native' society accepting of technology that delivers integrated and secure management of personal data and "flexible, adaptive and integrated" systems of physical and IT infrastructure. On the other extreme, intelligent technologies are "in place, but are not integrated", and "terrorism, viruses, identity theft and fear of disruption and instability" cause mistrust of integrated systems, exacerbated by economic uncertainty (ibid). Moreover, a digital divide hinders the role out of intelligent solutions.

These main uncertainties were used as two-dimensional 'axes of uncertainty', as shown in Figure 3.1, which in turn define four scenarios enabling the further consideration of the effects and consequences between now and 2055 of the 60 drivers of change (ibid, pp42, 43). The four scenarios are labelled

- *Perpetual Motion*
- *Urban Colonies*
- *Tribal Trading*
- *Good Intentions*

Figure 3.1: Axes of Uncertainty and Future Scenarios



The authors describe the scenarios as "short-hand labels that capture the essential feature[s] of each possible future", but caution that they are simply

> *pictures of how the future could develop, with no special preference for a particular outcome, nor any likelihood that the real future will resemble any of these 'science fiction' views of tomorrow.*

The four scenarios are described and considered in more detail in the following section.

4. FUTURE SCENARIOS

The four scenarios are described and compared in the project document *Intelligent Infrastructure Futures: The Scenarios – Towards 2055* (Foresight, 2006b). The document notes (p1) that, "for all scenarios, [it was] assumed that climate change would be an important factor", reflecting the fact

> *that transport, with its need for convenient and portable fuels, will find it harder than other uses of energy to switch to low-carbon sources and that, if current trends continue, transport could be responsible for a steadily increasing percentage of all emissions of greenhouse gases.*

Transport's need for convenient and portable fuels also highlights its ongoing vulnerability, particularly for the road and air modes, to the issue of 'peak oil'. Although the scenarios are not based on detailed economic assessments and predictions, three of the four scenarios seem to be based upon the assumption of 'economic business as usual', with the only major constraint on transport being environmental considerations, and the need to address the issue of climate change. This is typified by the *Trends and Drivers in Intelligent Infrastructure Systems* literature review, which concludes in its summary of economic drivers (Foresight, 2006c, p19) that "globalisation is highly likely to continue, bringing with it the need for national economies to remain competitive on the global scale," noting further that "most experts believe that effectively functioning transport systems are crucial to achieving economic prosperity." However, the summary does observe that, while

> *the cost of 'dumb' infrastructure systems [is] substantial and could contribute to lowered economic growth … the possibility of an actual fall in global (or national) GDP is very rarely mentioned, despite the wide ranging consequences this would have.*

Goodwin (2006, p2) quotes this summary, and contrasts the assumed high likelihood of continuing globalisation with views like those expressed by Kunstler (2005, pp17,19):

> *Globalism as we have known it is in the process of ending. Its demise will coincide with the end of the cheap-oil age. … The cost of transport will no longer be negligible [and] the world will*

> *stop shrinking and become larger again. … Relationships among persons [and] nations …will be radically changed [and] life will become intensely and increasingly local. … There will be far less motoring. The future will be much more about staying where you are than travelling incessantly from place to place, as we do now.*

This viewpoint, reflecting a situation in which increased energy costs have a much greater and more immediate social impact than longer-term concerns about the environment, is illustrated by one of the four scenarios, *Tribal Trading*.

The scenarios were used in the project to investigate the possible effects and interactions of the various drivers of change, and their possible influences on five key measures (Foresight, 2006b, p8):

- *Economics;*
- *Society;*
- *Environment;*
- *Safety; and*
- *Robustness.*

A ‘three-horizon approach’ was adopted for the project, in order to divide its 50-year horizon into three discrete periods: 2005-2025, 2025-2040, and 2040-2055. The first period covers the deployment of new, but currently feasible technology; the second the realm of current research; and the third is “beyond the horizon of known science”, focusing on capabilities that are likely to be required by then (ibid, p9). The four scenarios are now summarised and considered.

4.1 SCENARIO 1: PERPETUAL MOTION

4.1.1 Scenario Summary

The ‘Perpetual Motion’ scenario is summarised as follows on page 3 of *The Scenarios – Towards 2055* (Foresight, 2006b):

> *Perpetual Motion describes a society driven by constant information, consumption and competition. In this world, instant communication and continuing globalisation have fuelled growth: demand for travel remains strong.*
>
> *New, cleaner, fuel technologies are increasingly popular. Road use is causing less environmental damage, although the volume and speed of traffic remains high. Aviation still relies on carbon fuels and remains expensive. It is increasingly replaced by ‘telepresencing’ technology (for business) and rapid train systems (for travel).*

4.1.2 Transport Implications

The scenario envisages that, by 2025, the “hypermobile world … has arrived” (ibid, p12), in terms of the mobility of both information and individuals. It is envisaged that much-improved traffic management systems will be in place, with 'automated highways' in place on major commuter routes, and an increasing adoption of hydrogen fuel cells for powering public and commercial vehicles in urban areas.

It is anticipated that, although the environmental performance of aircraft will have improved further (by about 20%), this will be nullified by further growth in air travel, resulting in a campaign in favour of alternative travel methods, and a major reduction in demand for short-haul flights. It is predicted (ibid, p15) that

> *with air travel seen as a less viable option to get to Europe, the ICE [Inter City Europe] rapid train system [will have] become a popular option [with preparations being made] to connect the south-east [of England] and Birmingham to the ICE network.*

By 2040, it is envisaged (ibid, p18) that "the hydrogen economy has now become the reality, and in a way that assuaged the earlier fears of many environmentalists." Long-distance guided road vehicle systems are available, enabling users to work or sleep *en route* to their destinations; ICE rail journeys "are seamless and quick, as well as relatively low-cost in environmental terms [and] further routes continue to be added across the continent"; and "more locally, public transport has mostly been replaced by the Swarm, a type of integrated mass taxi system" (ibid, p19). Despite growth in home working and 'telepresencing' (advanced, three-dimensional video-conferencing), travel demand has not been reduced as much as had been anticipated. A major issue at this stage is the "extent to which public transport can justify itself" (ibid, p21), presumably as a consequence of competition from eco-friendly cars and automated highway systems.

By 2055 in the *Perpetual Motion* scenario, the demand for travel and transport remains high. Although new technologies provide integrated and partially automated transport facilities, and environmental issues have been successfully addressed, it is envisaged that road traffic management will continue to be a problem. In the rail sector,

> *the speed and efficiency of the ICE rapid train system has made it extremely popular, and it now stretches across large parts of Europe, including the north and the midlands of England, and to Edinburgh.*

Although telepresencing has reduced the need for business travel, individual mobility is still highly valued.

Reflecting on the scenario, the report notes (p26) that its "key enabler is the availability of clean low-cost energy", and that, despite major improvements, the overall environmental impact of travel remains high. It identifies (p27) the critical uncertainty about the scenario as being whether sufficient alternative energy sources will be available to provide the

> *sheer scale of energy required in this world, and whether this can be done in a way that reduces carbon consumption rapidly enough.*

It also cautions that, in the absence of such low-impact alternatives, the scenario could easily be transformed into that portrayed in *Good Intentions*, at the “other extreme of the horizontal axis [of uncertainty]”, and that *Perpetual Motion* could also be a precursor of *Tribal Trading*.

4.2 SCENARIO 2: URBAN COLONIES

4.2.1 Scenario Summary

The next scenario, ‘Urban Colonies’ is summarised in the following paragraphs (Foresight, 2006b, p5):

> *In Urban Colonies, investment in technology primarily focuses on minimising environmental impacts. In this world, good environmental practice is at the heart of the UK’s economic and social policies; sustainable buildings, distributed power generation and new urban planning policies have created compact, sustainable cities.*
>
> *Transport is permitted only if green and clean – car use is still energy-expensive and is restricted. Public transport – electric and low-energy – is efficient and widely used.*
>
> *Competitive cities have the IT infrastructure needed to link high-value knowledge businesses, but there is poor integration of IT supporting transport systems. Rural areas have become more isolated, effectively acting as food and bio-fuel sources for cities.*
>
> *Consumption has fallen. Resource use is now a fundamental part of the tax system and disposable items are less popular.*

4.2.2 Transport Implications

The dominant implication of this scenario is that personal mobility is constrained (and the need for it reduced) in order to minimise the associated environmental impacts. It is envisaged that, by 2025, nationwide road pricing and other charges and taxes are in place in the UK, supported by an extensive advertising campaign (based on experience in New Zealand) explaining the rationale behind them. The underlying need for mobility is addressed by increased urbanisation and densification, and by improved planning guidelines, similar to the Dutch ABC system; significant complementary investments have been made in public transport and walking and cycling facilities. Businesses relying on centralised warehousing and complex logistics have faced markedly increasing costs. One of the critical issues to be faced is further enforcement through the planning regime of mixed-use development and improved accessibility for all, reducing the need for high personal mobility and car dependency (ibid, p35).

By 2040, it is assumed that no low-emission means of high-speed air travel has been developed, meaning that cheap and fast long-distance travel is not easily available, resulting in increasingly devolved and ‘local’ business activity, even among large, multi-national organisations. A critical issue is the development of sustainable long-distance transport systems (ibid, pp36, 37).

It is envisaged that, by 2055, the UK has changed enormously since the early 21st century, with cities, especially benefiting from mixed-use development and improved, sustainable transport links. In addition to walking and cycling facilities, intra-urban light rail schemes are widespread, complemented by high-speed inter-city services. Longer-distance travel is more difficult than previously, and expensive, with emphasis on energy conservation rather than on speed – non-polluting sources of energy are expensive. According to the scenario (ibid, p40),

> *large slow-moving 'road trains' are a common sight in their own guided tracks in motorway lanes, controlled by their own information network as they leave the ports for their inland destination.*

While freight transport has benefited from such investments, transport is generally poorly integrated, and road traffic management systems for individual motorists have not delivered the benefits originally anticipated.

In the reflections upon the scenario, it is observed (ibid, pp44, 45) that, in *Urban Colonies*, "the relationship between economic growth and transport will be decoupled", but that there are significant barriers to this, in terms of the existing transport infrastructure being "deeply embedded in existing patterns of vehicle ownership and use", and the likely individual and organisational resistance to change from motorised lifestyles and business practices. It is acknowledged that *Urban Colonies* could easily regress to *Good Intentions*.

4.3 SCENARIO 3: TRIBAL TRADING

4.3.1 Scenario Summary

The 'Tribal Trading' scenario is summarised as follows (Foresight, 2006b, p5):

> *Tribal Trading describes a world that has been through a sharp and savage energy shock. The world has stabilised, but only after a global recession has left millions unemployed. The global economic system is severely damaged and infrastructure is falling into disrepair.*
>
> *Long-distance travel is a luxury that few can afford and, for most people, the world has shrunk to their own community. Cities have declined and local food production and services have increased. Canals and sea-going vessels carry freight: the rail network is worthwhile only for high-value long-distance cargoes and trips. There are still some cars, but local transport is typically by bike and by horse.*
>
> *There are local conflicts over resources: lawlessness and mistrust are high. The state does what it can – but its power has been eroded.*

4.3.2 Transport Implications

The overwhelming implication of this scenario is that transport quickly becomes expensive and difficult, with most people being essentially confined to their own local areas. Infrastructure is deteriorating, and long-distance travel is a widely unaffordable luxury. Cars are scarce, and the final commercial aircraft flight occurs before 2055.

By 2025, it is envisaged that the peaking of oil production (in 2011) has caused massive increases in energy costs, with resulting economic devastation. Conditions are exacerbated by regular occurrences of extreme weather conditions. Cities are increasingly uninhabitable, and travel is difficult, in the UK and in Europe (and presumably elsewhere).

By 2040, travel remains difficult and slow: “energy efficiency matters far more than speed” (ibid, p53). Freight is waterborne, and, although the railway network still exists, rail tends to be used only for high-value, long distance travel, with bicycles and horse-drawn transport being the norm for local journeys. The use of any remaining aeroplanes is a luxury affordable by very few, although there is some progress with airship design. A critical issue going forward from 2040 is to establish “the possibilities for energy-efficient transport, above and beyond human and animal power.”

By 2055, people are living in (ibid, p55) “a world that seems to have stabilised, but the change has been traumatic.” People still travel, but do so more slowly, and over small distances; the scenario envisages a situation where, “in some places, living patterns have reverted to the pre-industrial, with the home and workplace being the same.” Vehicles for local transport use human power, sometimes in combination with electricity, while “the fastest vehicles on the road are steam-powered” (ibid, p56); air travel is a luxury restricted to limited numbers of employees of remaining global companies. It seems (ibid, pp55, 57) that there are still some remaining bus, rail and ‘fast car transit’ services, but these are co-ordinated poorly, if at all.

In the reflections section for this scenario (ibid, pp60, 61), the possibility of “extreme political response”, possibly to secure energy supplies through military means, or to embark on a rapid programme of construction of nuclear power stations (of course, assuming nuclear fusion power stations have not been successfully developed, uranium is also a finite resource, and one likely to be very much in demand). The possibility of “a deliberate turnaround, a correction, a careful easing down [, albeit requiring] structured policy intervention”, is also noted, as an alternative to the ‘overshoot and crash’ nature of the scenario described in *Tribal Trading*.

4.4 SCENARIO 4: GOOD INTENTIONS

4.4.1 Scenario Summary

The final scenario, ‘Good Intentions’, is described thus (Foresight, 2006b, p5):

> *Good Intentions describes a world in which the need to reduce carbon emissions constrains personal mobility. A tough national surveillance system ensures that people travel only if they have sufficient carbon ‘points’. Intelligent cars monitor and report on the environmental cost of journeys. In-car systems*

> *adjust speed to minimise emissions. Traffic volumes have fallen and mass transportation is used more widely.*
>
> *Businesses have adopted energy-efficient practices: they use sophisticated wireless identification and tracking systems to optimise logistics and distribution. Some rural areas pool community carbon credits for local transport provision but many are struggling.*
>
> *There are concerns that the world has not yet done enough to respond to the human activity which has caused the environmental damage. Airlines continue to exploit loopholes in the carbon enforcement framework. The market has failed to provide a realistic alternative energy source.*

4.2.2 Transport Implications

The world portrayed in this scenario (ibid, pp63, 64) is one where personal mobility is constrained by the need to reduce carbon emissions in the face of an already-degraded environment. Individual carbon quotas are in force, and, although intelligent cars minimise emissions and report the environmental costs of their use, "traffic volumes have fallen and mass transportation is used more widely." Energy efficiency has become a major issue for the business community, which employs optimised logistics and distribution systems. Transport provision in rural areas is proving difficult, and "there are concerns that the world has not yet done enough to respond to the human activity that has caused the environmental damage." The market has so far been unable to deliver an alternative to existing energy sources.

By 2025 (ibid, pp64-67), circumstances seem quite similar to those applying today: although road vehicle technology has improved considerably, "the past 20 years have seen limited changes to the UK's transport infrastructure." An ageing national infrastructure is causing concern about the country's long-term economic competitiveness, and "air pollution from traffic-related emissions is damaging London's reputation as a highly-desirable tourist destination." Successive governments have shied away from the electoral consequences of reducing people's mobility in order to address the issue of climate change. Efforts have been restricted to improved traffic management systems, with only mixed results, and considerable resistance from the public and media. Despite significant increases in the costs of air travel, the results here, too, seem to be disappointing, generating considerable criticism and limited benefits. On the UK railways,

> *years of rising fuel costs and underinvestment in public transport mean that the networks are – still – stretched to their limits. Public pressure for investment in public transport is growing and there is mounting concern about the continued use of old, high-SO_2-emission electric traction on regional (and some long-distance) journeys.*

On a more positive note, the recent signing of a Contraction and Convergence Agreement (CCA) by the G10 group of nations is likely to force the UK government to address the situation. Major issues to be addressed in the future include the need to persuade the public of the need for action, and the need for further improvements in infrastructure provision, vehicle efficiency and traffic management.

By 2040 (ibid, pp67-71) the CCA has resulted in continuing economic growth, despite “a significant reduction in the amount of travel being undertaken.” Individual carbon allowances have resulted in a reduction in the number of two-car families, and increases in bicycle sales and home working. The use of biodiesel and bioethanol buses is increasingly popular, and flying has become both a luxury and a socially-unacceptable activity. Car use is closely monitored, and commuting by bus is growing. For UK rail travellers,

> *using the trains is more pleasant and efficient than it used to be after increased investment in latest-generation fuel cells (reducing pollution and improving performance) and satellite positioning systems (improving safety and efficient movement on low-density routes). However, train operators are once more complaining that they are at capacity, despite the increased volumes of traffic afforded by network technology. In the face of threats of price increases, the Government is considering a rationing scheme instead, easily enforceable through people’s smart travel cards.*

For freight, water-borne transport is increasingly popular. More generally, long-term infrastructure planning remains a critical issue for the future.

By 2055 (ibid, pp72-75), the “largely unrestricted personal mobility [of the early 21st] century is now a distant memory.” Carbon quotas are strictly rationed and enforced, and “traffic volumes have shrunk hugely, and will fall further as the carbon ration continues to be reduced.” However, as a result of loopholes in the enforcement framework airlines are now the largest generators of carbon emissions worldwide. Surprisingly little is said in the report about bus and rail services at this stage of the scenario, although both continue to operate.

Reflections on this scenario (ibid, p77) indicate that it is “in some respects the most plausible scenario”, although the caveat at the end of section 3, above, still applies. In essence, meaningful curbs on individual mobility are not applied until the evidence of the effects of transport on climate change is overwhelming, at which point subsequent intervention may not be capable of rectifying the situation.

5. SCENARIO IMPLICATIONS FOR RAIL TRANSPORT

The implications of the four scenarios for rail are considered under four broad categories: high-speed/inter-city services, commuter services, local/rural services and rail freight.

5.1 SCENARIO 1: PERPETUAL MOTION

Despite much-improved systems of road transport, this scenario explicitly envisages the further development and expansion of an integrated trans-

European high-speed rail network, with high-speed rail replacing intra-, and increasingly, international European air travel. These services would presumably replace many of the current equivalent inter-city services, but would run on new, dedicated infrastructure for the 'core' high-speed sections, with high-speed stock using conventional infrastructure at route extremities (as currently happens on some TGV services in France). This could release capacity on some sections of the conventional network for freight, if required. For densely-settled countries with 'clusters' of large urban areas (e.g. the UK, the Benelux countries and parts of northern Germany), there would probably be a continuing role for conventional inter-city rail services, too, since not all routes could economically be replaced by high-speed lines.

Although some doubt is expressed about the continuing justification for public transport under this scenario, it seems likely that there would be at least some continuing commuter role for rail to/from/in large (and densely-occupied) urban areas, given the difficulty of accommodating even automated road traffic on the available highway networks, and the need to provide a suitable environment for pedestrians and cyclists (Foresight, 2006b, p22). Over longer distances, and with suitable rolling stock, rail can provide a high-quality environment in which to work or relax, and is capable of delivering/collecting large numbers of commuters to/from central urban areas over relatively short time periods. Commuter services on some routes might benefit from the release of capacity resulting from the provision of new, high-speed routes.

The continuing viability of local/rural rail services is in considerable doubt, however, under the conditions of this scenario, given the availability and much greater potential flexibility of 'Swarm' public transport and the obvious attraction of potentially self-driving cars.

It seems likely that there would be a continuing (and possibly enhanced) role for rail freight, helped by the potential release of capacity noted above (additional capacity might become available as a result of the contraction of local/rural services, and, if required, with the advent of improved signalling technologies). Given that road traffic management is considered likely to remain a problem, there is a clear incentive to continue moving heavy and bulky cargoes by rail, reducing the number of heavy and relatively slow-moving vehicles using the road network.

5.2 SCENARIO 2: URBAN COLONIES

Rail has an obvious and highly beneficial role to play in the Urban Colonies scenario, with its emphasis on constraint of personal mobility for environmental reasons, and the move towards a high-density urban existence and the increased reliance on walking, cycling and public transport.
This scenario again envisages the development of a highly effective high-speed rail network, ideal for the medium-distance point-to-point journeys generated by a network of high density cities interspersed by sparsely populated rural areas, as exemplified by the existing French TGV network. Again, there is a potential complementary role for conventional inter-city services. There might also be a role for the expansion of sleeper train services, as originally envisaged for the Channel Tunnel, to cater for the remaining longer-distance travel market no longer effectively served by air.

Given the emphasis on densification and mixed-use development, and the reduction of the need for personal mobility, there may no longer be a role for commuter services between dormitory towns and large urban areas, with dormitory settlements either becoming mixed-use themselves, or possibly falling out of use. Long-distance commuting by rail between larger urban areas is also likely to be discouraged. Within larger urban areas, however, there is likely to be a commuter role for heavy rail as well as the envisaged new light rail developments.

Given the emphasis on urbanisation and travel reduction in this scenario, there is unlikely to be an ongoing role for rural railways, but there may be a continuing need for local, 'inter-urban' services in larger, polycentric conurbations.

The scenario envisages the development of automated, slow-moving 'road trains' for use in carrying freight on the motorway network. However, rail already provides such services, moving freight between ports and inland areas in an energy-efficient manner, and seems ideally suited to continue in this role, particularly if capacity on the conventional rail network is released by the development of high-speed services.

5.3 SCENARIO 3: TRIBAL TRADING

In many respects, the Tribal Trading scenario resembles conditions prior to the Industrial Revolution and the advent of rail travel, when society was much less wealthy than is currently the case, with few people able to afford personal transport facilities, and travel being relatively slow, difficult and expensive, and comparatively hazardous.

High-speed rail (as we understand the expression) appears to be an unattainable fantasy under the terms of this scenario, although it does seem that rail is the highest-speed mode of transport that remains available to the vast majority of people, with air travel being restricted to a tiny minority. Such inter-city travel as does remain seems likely to be provided by rail.

Similarly, commuting over anything greater than walking or cycling distance is improbable and unusual, and rail is unlikely to have a formal role in this regard, with the same applying to local/rural transport services.

It seems that freight is mostly carried by water under the terms of this scenario, although there may be a role for rail in the carriage of high-value freight, possibly in trains carrying both passengers and freight.

It might be, if/as society recovers, even slowly, from the conditions described, that rail could provide the sought-for mode of energy-efficient transport above and beyond what can be provided by humans themselves, or by animals. Rail is relatively energy efficient, much of the necessary infrastructure would hopefully remain in place, and history shows that railways can be successfully built and maintained by relatively low-tech, non-energy-intensive methods, using human and animal power. Again, this would in some respects be a return to conditions applying in the early 19th century, at the dawn of the railway age, although the potential for energy efficiency would be much greater, given the knowledge and experience gained in the subsequent two centuries.

5.4 SCENARIO 4: GOOD INTENTIONS

No explicit mention is made of high-speed rail in this scenario, and the conditions described suggest that such a network has not yet been developed in the UK (nor, perhaps, in the rest of the English-speaking world). It seems likely that high-speed rail would continue to play a significant role in continental Europe and Japan. Where genuine high-speed networks do not exist, conventional inter-city services are likely to play a valuable role in this carbon-rationed future, even where relatively little investment has been made.

Rail is likely to maintain a significant commuting role where it is available and suitable, given increasing restrictions on car use. Where local and rural rail services are available and provide suitable travel opportunities, commuters and other travellers who previously used cars might switch to rail in preference to bus services, given rail's comparatively high levels of comfort. Enhanced levels of patronage would probably be essential to ensure the survival of such services in an increasingly emission-conscious world, although their viability would be enhanced by the envisaged improvements in propulsion and network control technology.

It seems likely that rail freight would continue to play a valuable role in such a carbon-conscious world, and in the absence of radically-improved energy sources and other technology. The balance between freight and passenger traffic on congested railway networks would require careful consideration, however.

5.5 GEOGRAPHICAL VARIATIONS

Given that the *Intelligent Infrastructure Futures* project is sponsored by the UK Government, the scenarios and examples given are very much based upon potential prospects for transport within the UK, and between there and continental Europe. They thus represent a relatively compact, heavily-urbanised and densely-populated part of the world, and one which rail is well-suited to serve, with distances being short enough for high-speed passenger rail services to compete successfully with air travel, and long enough for rail to have a significant role in the intermodal, bulk-haul and some other freight markets. In the face of increasing concerns about the environmental effects of transport, there is obvious potential for an increasing advantage for rail in this area and these sectors, and, even in the event of the economic traumas envisaged in *Tribal Trading*, rail has the potential to maintain a significant role in a much-diminished market for transport.

The scenarios are also likely to be applicable to parts of the world with similar development and settlement patterns, such as the north-east corridor of the U.S.A., between Washington D.C. and Boston, much of Japan, eastern China, parts of India, and, possibly, the south-eastern corner of Australia between Melbourne and Brisbane, and the Auckland-Wellington corridor on New Zealand's north island.

In more sparsely populated parts of the world, such as the American West, western China, Siberia and the north and west of Australia, true high-speed rail services are less likely to be justifiable, although there may be some scope and justification for increasing the speeds of conventional passenger services, and, as mentioned above, potential for the revival and/or expansion of sleeper train services. Rail freight is already highly competitive in these circumstances, and has considerable potential for an increased share of the freight market in the face of increasing environmental concerns, capacity issues permitting.

Despite the relatively low speeds available, long-distance passenger rail travel maintains a significant role among less affluent members of society in countries such as China, the former Soviet Union and India, where air travel may be relatively expensive. In the event of a *Tribal Trading*-type situation, with greatly reduced economic activity, prosperity and demand for travel, it could be that a wider cross-section of society would take to the rails as an affordable, relatively reliable and secure mode of medium- and long-distance transport.

5.6 COMPLIANCE OF RAIL WITH REQUIREMENTS FOR INFRASTRUCTURE INTELLIGENCE

As noted in Section 3 above, the IIS Project Overview (Foresight, 2006a, p34) identifies and outlines the need to invest in 'intelligent infrastructure', i.e. infrastructure that is designed intelligently, provides intelligence, is intelligent and is used intelligently.

Arguably, rail already complies with at least some of these requirements, and is well-placed to improve its compliance:

- Rail provides a valuable and central component of an 'ABC-type' planning system, with mixed use development focussed on nodes of a rail network.

- A railway timetable provides basic intelligence to its users about journey timings and lengths, and also about the types of trains provided, including facilities such as buffets and trolley services. Signalling systems can also provide 'real-time' information about train locations and estimated timings when services are running out of course, which can then be conveyed to users by passenger information systems. This can be done in conjunction with advice about alternative journey opportunities, so that passengers can reach their destinations as quickly as possible in circumstances where services are subject to disruption. There is considerable scope for improvement in this area.

- One of rail's inherent characteristics is the comparative operational inflexibility that results from its trackbound nature. However, as noted the preceding point, a considerable amount of information about network conditions is available from the signalling and other operational systems. Considerable work is being done in this area by Rail Reasearch UK and other research organisations to improve the way in which the already-available and additional information can be used to improve real-time adaptations to alterations in service conditions.

- The relatively sustainable nature of rail relative to other mechanised transport modes means that rail travel already constitutes intelligent use of the transport system, particularly where access to and/or egress from the system can be achieved on foot, by bicycle or by another public transport mode. This intelligent use could be enhanced by the use of appropriate pricing and other mechanisms, possibly including carbon rationing.

5.7 CLIMATE CHANGE AND PEAK OIL

Rail has vulnerabilities to both of these phenomena, but also provides a potential means of addressing them both.

Coastal railway routes (e.g. those in the south-west of England, and along the east coast of New Zealand's south island) are vulnerable to the effects of rising sea levels, associated with climate change; and also to the effects of increased rainfall on earthworks, especially embankments and cuttings.

Similarly, any increase in fuel costs associated with the peak oil phenomenon will directly increase the operational costs of diesel-powered rail operations, and indirectly affect electrified railway operations, where the electric power is generated using oil.

However, rail's comparative energy efficiency means that it contributes less to climate change than other mechanised modes, and its ability to operate using a wide range of fuel sources (particularly in the case of electrified operations) reduces its vulnerability to peak oil, and, indeed, gives it a significant advantage relative to competing modes.

6. CONCLUSIONS

Key issues for the future are energy supply, its continuing availability, and the apparent effects of the use of current energy sources on our climate. Rail is both vulnerable to, and provides potential means of dealing with, both these issues.

If affordable, sustainable and readily available energy supplies emerge in the future, thus enabling the widespread provision of low-impact transport, rail is likely to have an enhanced role in the high-speed sector, particularly if an alternative to current aviation propulsion technology fails to emerge. It is also likely that there would be a continuing role for rail freight, and possibly for commuter rail services, even if alternative intelligent infrastructure systems are widely accepted and developed. If these alternative systems are not widely deployed, rail's future role is likely to be enhanced further, providing valuable links to, from, within and between increasingly concentrated urban areas separated by sparsely-populated rural areas.

If these alternative energy supplies do not become readily available, society seems likely to continue along present trends, albeit with growing restrictions on the use of carbon-based fuels. In an extreme version of this case, where we fail to cope with the issue of peak oil, we could face economic collapse. In a carbon-rationed world, with increased emphasis on the use of mass transit and given rail's environmental advantages, the mode is likely to attract an increased proportion of both passenger and freight traffic, and may face capacity issues if necessary investment is not made in infrastructure enhancements. In the event of a severe and long-term economic contraction, it seems at least possible that society might revert to a dependence on rail as a fundamental, strategic transport mode, as was the case between the mid-19th and mid-20th centuries. It is not clear that, in such circumstances, bus, coach and residual car and road freight traffic could justify the maintenance of sufficiently comprehensive road networks to serve all such traffic needs, whereas railways can be built, operated and maintained using relatively low-technology and energy-efficient means.

It seems, therefore, based on the predictions and findings to date of the Intelligent Infrastructure Systems project, that rail has a range of possible futures, ranging from significant, but niche freight and high-speed passenger roles, to an increasingly comprehensive (although possibly reduced in volume and track mileage) and integrated freight and passenger role. In the medium term, at least for passenger traffic the picture seems relatively rosy. Rail Research UK has produced a central forecast of 150% growth in passenger traffic between 2005 and 2035, albeit with a broad range from zero growth to 300% growth (Wardman et al., 2007). However, these forecasts do not consider the kind of economic meltdown envisaged by the tribal trading scenario - the low economic growth case still assumes growth in GVA (Gross Value Added) of at least 1.6% per annum.

The past 50 years have seen a nadir in rail's fortunes, in the face of competition from road and air transport, but the mode has proved to be remarkably resilient, and its fortunes and its prospects have improved considerably in the latter part of this period. This improvement in rail's prospects has occurred in parallel with increasing concerns about the environmental consequences of human activities, particularly with respect to the long-term climatic effects of the use of fossil fuels. The course of the next 50 years is obviously unclear, but rail's prospects seem favourable, especially given its relatively low environmental impact. Assuming the ongoing availability of suitable energy sources, the continued expansion of high-speed rail services is likely, releasing capacity for freight and other services on conventional routes. In the event of energy scarcity and economic stagnation or contraction, rail still has a valuable role to play, making efficient use of available energy sources to provide strategic passenger and freight transport services.

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