HIGH SPEED RAIL

AND

CO_2

Optimising Rail Network Capacity and Connectivity to Maximise Modal Shift and Emissions Reductions

A study by

Alan Brooke

Executive Summary

Introduction

The 2008 Climate Change Act has committed the UK to cut CO_2 emissions to 20% of current levels by 2050. Reductions of such magnitude seem certain to affect all aspects of modern life – not least the ability to travel – and will demand radical action on the part of Government, to put in place the necessary structural changes. In the transport sector, the greatest potential for reductions lies with a step-change modal shift from road and domestic aviation to lower-emitting rail, and this creates a requirement for massive Government-led interventions to create the necessary additional rail network capacity.

This would seem to demand that all current Government transport projects – of which the HS2 initiative for UK high speed rail development is pre-eminent – should be configured to deliver maximised CO_2 emissions savings. But the Government's own projections[1] show that HS2 will deliver overall CO_2 reductions of no more than 0.3% of total transport emissions over the same period. This seems strange, given the 'green' image of rail travel, and its fundamentally low-energy, low-emitting characteristics.

This also begs several obvious questions. If HS2 – the principal intervention in long-distance surface transport up to 2050 – is not to deliver the required major savings in CO_2 emissions, then which project will? Does the low level of predicted savings reflect the true 'green' credentials of high speed rail? Or do these low predictions reflect structural flaws in the HS2 proposals and underlying philosophy?

Aims of Study

From these questions, the central aims of this study naturally follow:

- to gain an understanding of the various factors that drive the 'carbon footprint' of high speed rail, and of their relative magnitudes;
- to realise the true potential of high speed rail (or simply 'new rail') to deliver step-change reductions in CO_2 emissions, in the context of current and growing environmental concerns;
- to develop a methodology for comparative assessment of potential modal shift, and consequent emissions reductions;
- to allow better-informed and more relevant choices to be made in the development of a UK high speed rail network.

Consideration of Alternative Schemes

The HS2 proposals could not be examined in isolation; to gain the necessary perspectives and make comparative judgements, an alternate 'exemplar project' was considered. The clear choice for this alternate was the High Speed North scheme, published in 2008 by the 2M Group of London and South-East Councils.

HS2 comprises a high speed system serving principal Midlands, Northern and Scottish cities, with dedicated loop connection to Heathrow. High Speed North serves the same communities, but with its Heathrow connection provided by development of a regional 'Compass Point' network focussed on Heathrow. See Figure X1 on following page.

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[1] Item 4.2.28 / Figure 4.2c of the 2010 HS2 Report to Government sets out predicted emissions savings over a 60 year period, resulting from implementation of HS2. These range from 26.6MT reduction (most optimistic) to 4.6MT reduction (median) to 25.0MT increase (most pessimistic). This is noted as amounting to "a range of -0.3% to +0.3% of UK transport emissions", with the conclusion drawn that "HS2 would not be a major factor in managing carbon in the transport sector". No vision is offered of what other surface transport intervention (in the absence of HS2) might deliver the legally-committed 80% CO_2 reduction target of the 2008 Climate Change Act.

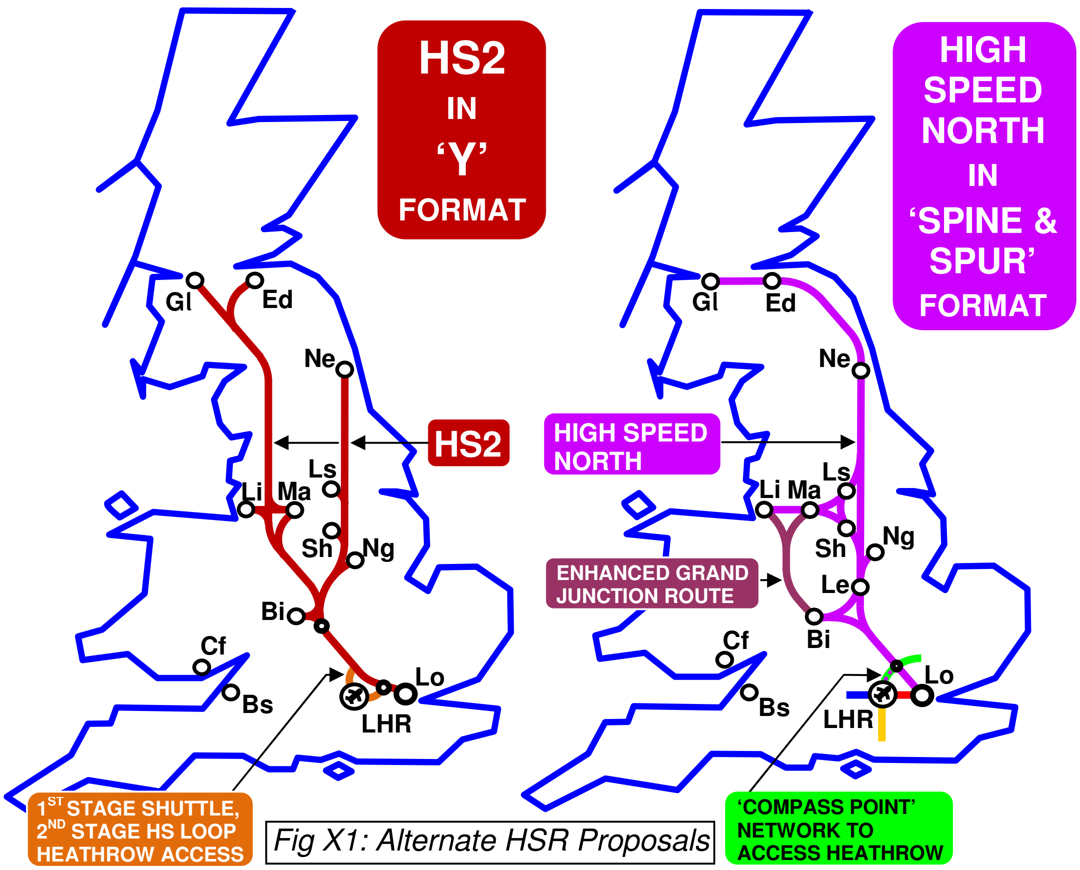


Fig X1: Alternate HSR Proposals

Findings

Key findings of this study are as follows (reference to section of study in ***bold italics***):

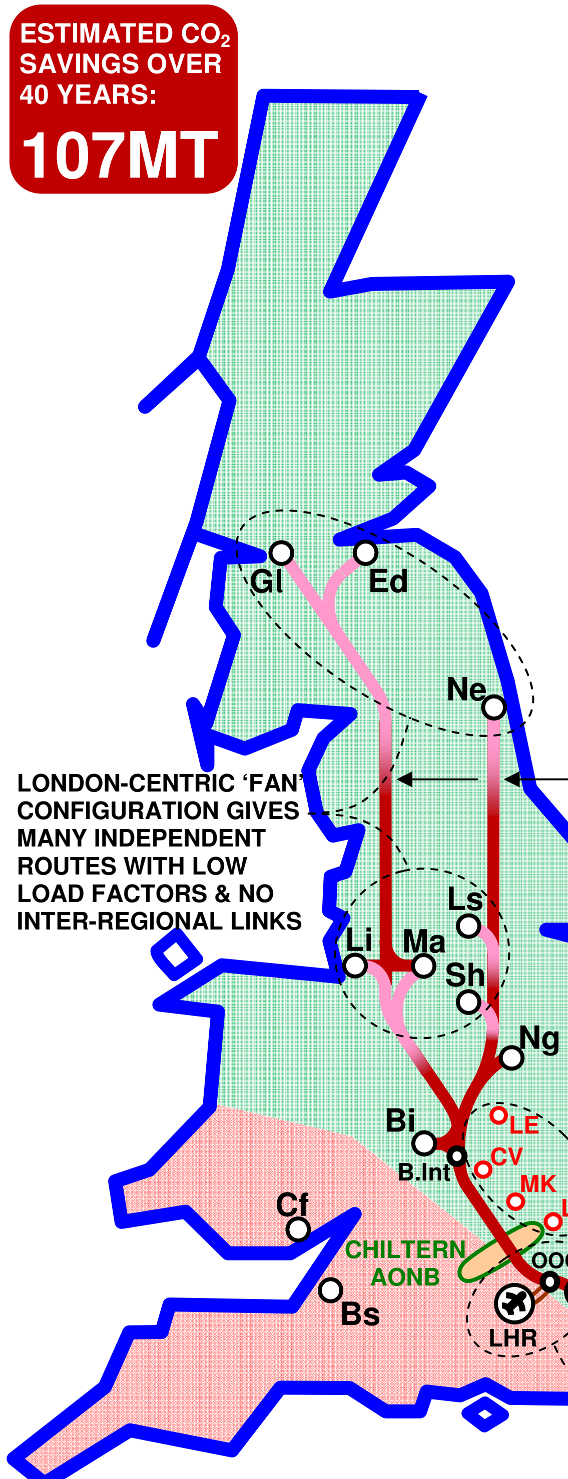
- Potential CO_2 savings are far greater than has so far been predicted. HS2 could deliver up to 107MT savings over a 40 year period, and reduce annual transport emissions by 5MTpa. But High Speed North's environmental performance is superior by an order of magnitude. Savings could be up to 593MT, with annual emissions cut by 24MTpa. (Refer ***Section 4.10*** and ***Figure X2***).
- The 24MTpa potential savings generated by High Speed North would make a valuable contribution to the UK's legally-committed CO_2 reduction obligation, both in the transport sector (21% of 112MTpa) and overall (5.5% of 440MTpa).
- High Speed North's superior environmental performance stems from its alternative 'spine & spur format', optimising against the following key criteria:
    1. Optimised network coverage with comprehensive interconnection – *it is only possible to generate major modal shift along any particular intercity corridor if new capacity is provided along that corridor*. ***(4.6)***
    2. Pace of implementation – *environmental controversy through HS2's unnecessary Chiltern route will delay achievement of CO_2 reductions and damage the 'green' credentials of high speed rail*. ***(4.7)***
    3. Integration with the existing railway network and other transport systems – *to maximise CO_2 reductions, a single integrated and enhanced network is essential, accessible to as much of the UK population as practicable*. ***(4.8)***
    4. Maximised operational efficiency in respect of both speed and network configuration – *modal shift gives maximum CO_2 savings when rail's own carbon footprint is minimised*. ***(4.9)***

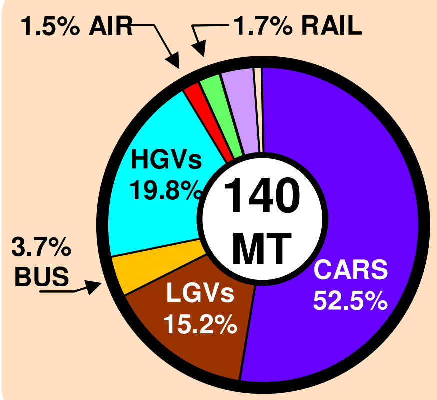
- All these advantages are achieved with:
  1. Lesser route length – *hence lesser cost to construct.* ***(4.2** & **4.3)***
  2. More communities connected and greater capacity provided – *hence greater benefit.* ***(4.5** & **4.6)***
  3. Greater network connectivity, integration and efficiency (ie higher attained load factor) – *hence lower operating costs and higher economic returns.* ***(4.8** & **4.9)***
  4. Lesser environmental damage through closely following established transport corridors such as the M1 – *hence greater public support and quicker implementation.* ***(4.7)***
  5. Superior and more comprehensive rail connections from Heathrow to its entire UK hinterland – *hence greater spread of economic benefits from proximity to hub airport.* ***(Appendix F)***
  6. Comprehensive interregional links, avoiding London-centricity of the 'Y' – *hence greater potential for regional development.*
- From all of the above, it is possible to infer a Benefit-Cost Ratio (BCR) for High Speed North that is vastly superior to that of HS2, for which a BCR of around 2.0 has been calculated. In approximate terms, High Speed North's lesser cost (£34bn vs £39bn) and greater connectivity/capacity imply a BCR of circa 4.0.
- Against all of these comparisons (which apply at every stage of development, see Section **4.7** and Figures **4.11** & **4.12**), there appears to be no justification for pursuing the current HS2 proposals.
- The principal reason for HS2's vastly suboptimal performance appears to be a politicised requirement to achieve 'high speed rail access to Heathrow'. As discussed in ***Appendix F*** (see also diagrams in ***Appendix G1***) this exerts a massive westward gravitational pull on the route of HS2, drawing it from the ideal M1 corridor to an excessively west-sided route that:
  1. cannot avoid the Chilterns (with consequent delay and controversy).
  2. inevitably develops into the 'Y' system (with consequent poor interregional links, and inherent operational inefficiency).
- The predication of the HS2 route upon Heathrow results in hugely reduced economic performance, and potential to cut transport CO_2 emissions. ***Appendix F*** identifies 330MT of HS2's performance shortfall of circa 500MT (with respect to High Speed North) as attributable to undue prioritisation upon Heathrow.
- The remainder of HS2's performance shortfall appears to be due to its adoption of an 'exclusive' mode of operation, preferring to standardise upon double-decker rolling stock too large to fit onto the UK classic network, and neglecting the self-evident requirement to achieve optimum integration. This prevents access to crucial main line hubs such as Birmingham New Street, and causes intermediate cities such as Coventry to be bypassed, and blighted. ***(4.8)***
- High Speed North's philosophy of fully integrated operation between high speed and classic network, with a fully 'UK-appropriate' model of high speed rail, allows the benefits of the new railway to be projected beyond its physical extent (ie the principal conurbations) to the 'second tier' cities such as Coventry, Leicester and Milton Keynes. Moreover, it both maintains the integrity of, and provides huge enhancement to the existing UK railway network. ***(3.6** & **4.8)***

The key conclusion is that the transport planning process underpinning the HS2 proposals is fundamentally unfit for purpose and inappropriate to contemporary environmental concerns ***(5.6)***. A more integrated 'railway engineering' approach, based upon the '4 C's of capacity, connectivity, CO_2 and cost, appears to be essential.

Essence of Argument – Bite-Sized *(with reference to relevant section)*

1. There is a legal, moral and environmental imperative to make radical cuts in CO_2 emissions – to 20% of current levels by 2050. *(2.1)*
2. In transport, the majority of the reductions will come about through step-change modal shift, from road and air to rail. *(3.1)*
3. Such modal shift would approximately quadruple current railway traffic levels, and would demand corresponding increases in network capacity. *(3.1)*
4. Construction of new railways to supplement existing main line routes (ie 2 new tracks alongside 2 existing tracks) will provide an approximate fourfold increase in capacity to enable the modal shift and consequent emissions reductions. *(3.2)*
5. Capacity and connectivity, rather than speed, are the key factors by which CO_2 emissions are reduced. *(3.3 & 3.4)*
6. To establish the emissions reduction potential of high speed rail, two 'exemplar' projects are chosen, each with fundamentally different network configurations ie the 'Y' of the HS2 proposals, and the 'spine & spur' of High Speed North. *(3.5)*
7. To maximise emissions reductions, any proposal (high speed rail or otherwise) must be optimised against the four following criteria (8, 9, 10 & 11):
8. The network must be configured to enable modal shift on the maximum practicable number of interconurbation corridors. *(4.6)*
9. Greatest emissions reductions are delivered through earliest practicable implementation. *(4.7)*
10. Full integration between classic and high speed networks is essential, to maximise the scope of journeys for which modal shift might be effected. *(4.8)*
11. The 'value' of the modal shift must be maximised, through optimum operational efficiency. This consideration covers both the running speed of trains, and the configuration of the network (by which load factor might be optimised). *(4.9)*
12. High Speed North comprehensively outperforms HS2, with projected CO_2 savings of 600MT over a 40 year period (while HS2 might achieve 100MT). *(4.10)*
13. High Speed North also outperforms HS2 on more conventional criteria, with reduced costs from shorter route length and more efficient operation, and increased benefit through the greater number of communities connected. From this, a superior benefit-cost ratio can be inferred. *(5.5)*
14. Comparative assessment of benefit-cost ratios indicates that High Speed North might achieve a BCR of 4.0, as opposed to the predicted 2.0 for HS2. *(5.5)*
15. The primary cause of HS2's vastly sub-optimal performance seems to be the political imperative to achieve high speed rail access to Heathrow. This dictates both a Chiltern routeing and a London-centric Y-shaped network. *(App F)*
16. High Speed North's spine and spur is fundamentally more efficient than HS2's 'Y', with CO_2 emissions lower by 330MT and interregional links also achieved.*(App F)*
17. The 'Y' also fails to achieve direct access to Heathrow's central terminals. High Speed North accomplishes this through utilising the existing Heathrow Express system, transformed into a 'Compass Point' network, extending to both the high speed line and the classic northern main lines. *(App F)*
18. The remainder of HS2's performance shortfall can be attributed to its proposed 'segregated' (or 'exclusive') mode of operation. This inevitably limits its coverage and restricts accessibility. *(App F)*



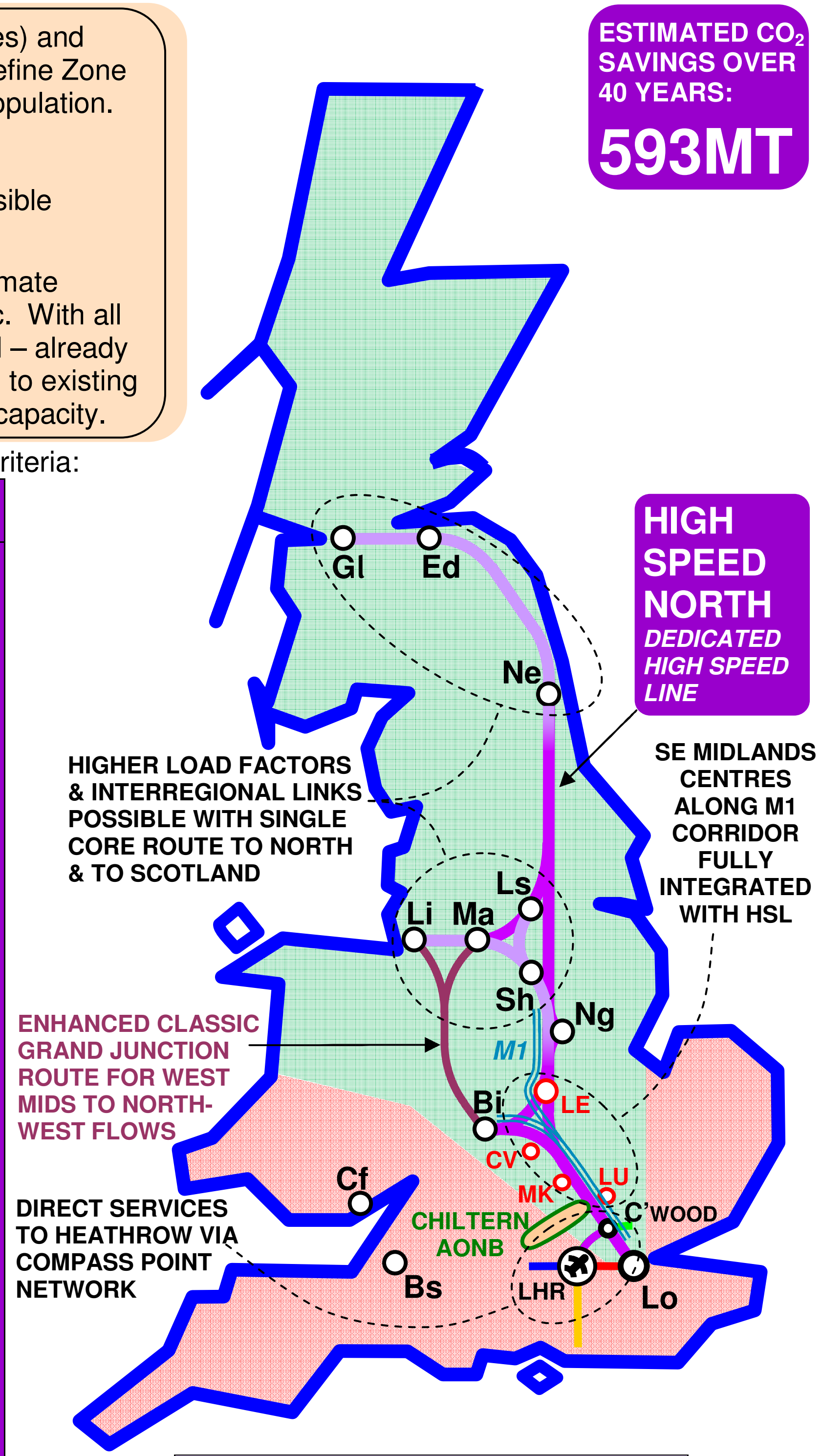


89% of current UK transport CO_2 emissions (ie all roads except buses) and domestic aviation) are potentially convertible to rail. Green areas define Zone of Influence of northern high speed line, with 40M of 60M total UK population.

Target CO_2 emissions = 140MT x 89% x 40/60 = 85MTpa

UK HSR development should be configured to achieve greatest possible reduction below 85MT, through modal shift to lower emitting rail.

Major modal shift – compatible with radical requirements of 2008 Climate Change Act – will result in approximate fourfold increase in rail traffic. With all inter-conurbation rail corridors – along which HSR might be provided – already under significant capacity pressure, 2 new high speed tracks parallel to existing comprise best means of achieving required step-change in network capacity.



Maximised emissions reductions can be achieved through optimising the following criteria:

No / Ref	Criterion	High Speed 2	High Speed North	HSN CO_2 saving
1A / 4.6	Maximised modal shift between conurbations	Potential modal shift limited by London- & Birmingham-centric 'funnel' configuration with no connectivity on Transpennine axis and little overall between Northern and Scottish centres	Spine & spur configuration of HSN covers all existing main line axes incl. Transpennine and CrossCountry to enable full inter-connection between all Midlands, Northern & Scottish conurbations.	92 MT
2B / 4.7	Quickest Timescale to Completion	Network completion delayed by controversy of route via Chiltern AONB and through rural areas to north. Greater route length also takes longer to build.	Much lower environmental intrusion along M1 corridor & shorter total route length allows quicker completion at lesser cost	117 MT
3C / 4.9	Greater Operational Efficiency : Speed	360kph operating speed applied as standard across new-build sections of network, with no flexibility due to restricted 2-track route through Chilterns.	4-track London-Leicester section allows differential speeds: 240kph London to Midlands 280kph London to North 320kph North to Scotland	47 MT
4D / 4.9	Greater Operational Efficiency : Load Factor	Configuration as London-centric fan limits load factor with relatively weak flows to individual destinations	Concentration of services onto strong core routes allows higher load factors & more viable services	52 MT
5E / 4.8	Maximised integration between classic & high speed network	Operation as 'exclusive' railway limits integration of HSR with both conurbations & secondary centres. Major risk of blight to bypassed communities eg Coventry, Leicester, MK & Luton.	Network fully integrated with existing intercity network to serve secondary centres. National connectivity much greater. Potential for modal shift & emissions reductions greatly increased	172 MT
6F / 4.11	Superior Heathrow access	No direct airport access so interlining flows still need domestic flights for long-haul connections	Efficient spine & spur configuration & allied Compass Point network allows direct services from all regions	24 MT
7G / 4.12	Carbon Footprint of Infrastructure	400kph design speed needs straighter alignments with higher embankments, longer tunnels and increased CO_2	Emissions reduced through: Shorter route length Lower 320kph design speed Lighter engineering	6 MT

Extra million tonnes of CO_2 saved over 40 years by High Speed North compared with

HIGH SPEED 2	
Length of new build	1092km
Estimated cost	£39bn
Emissions saved (40 yrs)	107MT_{CO2}
InterConurb Emissions score	163 (73%)
InterConurb Connectivity	76 (60%)
Conurbation Pairs connected	19 (42%)

PERCENTAGES RELATE TO MAX POSSIBLE INTERCONURB CONNECTIVITY

HIGH SPEED NORTH	
Length of new build	935km
Estimated cost	£34bn
Emissions saved (40 yrs)	593MT_{CO2}
InterConurb Emissions score	224 (max)
InterConurb Connectivity	127 (max)
Conurbation Pairs connected	45 (max)

Fig X2: Comparative Economic Performance of HS2 and High Speed North

Author's Foreword

Railways have always fascinated me, both personally and (as a still active but long-retired strategic planner) professionally also. Everything about the railway is highly deterministic, with millions of passengers travelling on tens of thousands of trains each day, all working to an intricate timetable. Every aspect of running the railway is planned in fine detail, yet the network we enjoy today has happened almost by accident, through a series of often ad-hoc and sometimes capricious developments.

One of the great "What if's" of life is to consider how the railways of Britain might have developed, with the benefit of a guiding masterplan. Such an overview was never possible in the chaos of the 19th century 'Railway Mania'; but in the 21st, with a belated political commitment to creating a new high speed rail system, and with the benefit of hindsight, the opportunity to 'do it right' has at last arisen.

To have the chance is one thing; but to take it is another. The beginnings of the HS2 project were not auspicious, its launch tacked onto the then Government's ill-fated commitment to expansion of Heathrow Airport (and to all appearances a political 'sop' to the environmental lobby). Much detailed work followed, with a controversial route through the Chiltern Hills seemingly gaining favour very early on. With the publication of the HS2 proposals in March 2010, and with the opening of the official Government Consultation in February 2011, the intention to route the new line through the Chilterns has hardened into a firm line on the map, and the controversy has intensified.

This opposition to HS2 is not just confined to environmentalists and residents of the Chilterns; over the past year, as I have delved into the machinations of the HS2 project, I have become aware of a considerable undercurrent of disquiet among railway professionals, engineers and operators who have been involved with the railway for their entire working lives, and who have a much deeper understanding than I could possibly possess. They see capacity and connectivity as the priorities, rather than extreme speed and fast links to airports that will be achieved largely to the exclusion of all else; and in my deliberations on UK high speed rail development, I have come to the same conclusion.

Donning my strategic planner's hat, I have attempted to pull back from the controversy in the Chilterns, and to examine instead the more fundamental questions:

- What do we hope to gain from high speed rail?
- Would these gains be proportionate to the cost and effort, and relevant to contemporary concerns?
- Is a route through the Chilterns, with all its attendant controversy, the best way of realising these gains?

The fundamental rationale behind HS2, taken very simplistically, appears to be economic gain from improved transport. There is nothing wrong with this, *per se*. But I am old enough to be able to remember a time when there were greater priorities than simple economics, and the need to preserve civilised life in the face of evil and brutal dictatorships took precedence over all else. The threat of climate change (just one of mankind's many excessive and unsustainable impacts on this planet) is of a similar magnitude to that posed by the wartime crisis, and the world is slowly waking up to this fact. Politicians have been heard to describe climate change as "the greatest threat to civilisation since the Second World War", and the 2008 Climate Change Act now gives the force of law to a commitment to reduce CO_2 emissions to 20% of current levels by 2050.

Yet the awakening is slow, even within the Government that is charged with putting in place the necessary structural changes to turn its own Climate Change Act from aspiration to realisation. Quite how slow became apparent as I worked my way to the end of the HS2 reports, to the section entitled 'Impact on Carbon Emissions' (Item 4.2.22 *et seq*), within

‘Part 4 : Business Case’. I came upon the crucial passage (Item 4.2.33 on P178), which stated:

> *Overall this* (ie the foregoing paragraphs - AB) *suggests that the impact of HS2 on carbon emissions will be between an increase in emissions of 26.6MT CO_2 and a reduction of 25MT CO_2 over 60 years. The key drivers of this range are the carbon intensity of electricity – which drives the size of emissions from HS2 trains – and the response of airlines to reductions in aviation demand. Perhaps the most important point to note is that this is equivalent to a range of -0.3% to +0.3% of UK transport emissions. So HS2 would not be a major factor in managing carbon in the transport sector.*

This begs a plethora of questions, for instance why HS2 is targeted only at the aviation sector, and ignores the vastly larger contribution of the roads sector to UK CO_2 emissions; or why it is presumed that high-emitting domestic aviation will be permitted to continue, in the face of a growing environmental crisis. Yet the most telling point is the apparent disconnect between the desire to establish high speed rail (and not just any high speed rail, but the fastest in the world) and the wider ambition for emissions reductions. Can it be acceptable for HS2, the principal intervention in UK long-distance surface transport in the first half of the 21st century, not to be *a major factor in managing carbon in the transport sector?* Because if HS2 does not bring about the required CO_2 reductions, it is difficult to see what else will.

Even allowing HS2’s stated (but never technically justified) ambition to operate trains at 360kph (possibly rising to 400kph), with all the attendant high energy use and CO_2 emissions, it seemed strange that the fundamental low-emitting characteristics of railways could not be harnessed to deliver worthwhile environmental savings. This gave me the cue for this study. If I were to start not from the ‘business as usual’ precept of HS2, but from a more fundamental, quasi-wartime need to engineer a railway system to deliver the necessary CO_2 reductions, what might be achieved?

It was clear from the outset, that the potential for high speed rail to deliver optimum reductions in CO_2 emissions was dependent upon a multitude of variables aside from simple high speed. Modal shift, primarily from road to rail, was the key driver, and capacity, network coverage, ease of implementation, integration with the existing network and operational efficiency were the vital issues that had to be considered. However, I could find little evidence in the various HS2 outputs that sufficient attention had been paid to these matters. It therefore appeared necessary to consider not just the HS2 scheme but also a second ‘exemplar’ project which might capture these issues better. The clear choice for this second exemplar was the High Speed North scheme.

As I embarked upon this study, it became apparent that I would have to tackle two basic issues: carbon accountancy and railway network design. For the former, there is a wide array of environmental statistics available, but little rigorous and established practice in ‘joining them up’; for the latter, I could find nothing in the way of a textbook that might guide the design of the undoubtedly complicated system that a new railway network must comprise.

There is nothing in the HS2 outputs that gives confidence that they had access to such a textbook (and indeed, there is much to indicate the opposite). For my part, I found myself in the unexpected position of having virtually to write this textbook, to develop the methodologies and the metrics that would define in quantitative terms the performance of an environmentally optimised railway system. The extent to which I have succeeded is of course for the reader to judge.

I make no claim to absolute accuracy; the statistics available are simply too approximate to enable any fine degree of exactitude to be attained.   But even with all the approximations taken into account, it seems reasonable to conclude that either of the schemes under consideration could deliver far greater environmental benefits than have so far been predicted.   Over the 40 year currency of the 2008 Climate Change Act, CO_2 savings measured in hundreds of millions of tonnes seem feasible.

In a comparative sense, with even-handed application of the same methodologies to both schemes, the achievable accuracy is much greater, and the contrast between the two candidate schemes utterly clear.   The figures that I have developed indicate that the High Speed North proposals can deliver emissions reductions at least six times greater than those achievable with HS2.

There might be some consolation for those backing HS2, if the issue of engineering for optimum environmental performance were somehow contra-indicatory to those of business performance and operational efficiency, for which HS2 has presumably been designed   But all indicators appear to point in the same direction; an environmentally-optimised system must be operationally efficient, and that in turn indicates good business performance.

It therefore seems reasonable to enquire how, and why, HS2 appear to have got matters so badly wrong.   As ever, the fault seems to lie not with the individuals involved, but with the process and remit to which they were working.   Overall, it can be broadly characterised as a corridor-specific transport planning exercise, to which the engineering detail was then added, and the sub-optimal outputs are plain to see.   It is clear, to myself at least, that a more fundamental broad-scope and systems-oriented 'railway engineering' approach (as taken by High Speed North) is a far more appropriate way forward.

It remains for me to thank those who assisted me in the production of this magnum opus.

I am grateful for the support and advice offered by my many contacts within (or retired from) the railway industry, for providing me with the perspectives necessary to make objective critiques of both candidate schemes.   I should stress that this assistance essentially comprised educated interpretations of material in the public domain, with no privileged or confidential material ever offered to me.

Mindful of this issue, I deliberately refrained from approaching those close to the HS2 process.   There was in any case no need for 'inside information'; there was sufficient in all the published outputs of HS2 to fully clarify the scope and potential of this scheme.

It was necessary to gain a greater understanding of the High Speed North proposals, and I would like to express my gratitude to senior figures associated with the 2M Group of London Councils, who were able to offer substantial clarifications in this respect.   Particularly valuable was the opportunity to view comprehensive route plans (of necessity confidential) which indicate clearly that the proposals are a) feasible and b) achievable at a fraction of the environmental cost, or impact on residential property of the rival HS2 scheme.

Final thanks must go to my family, especially my granddaughter Amanda, who has provided invaluable technical advice, and assistance with proof reading and preparation of the many plans and illustrations.   The 'Best Friends Forever' analogy (Item 4.6.2) is hers; it explains far better than I ever could, the somewhat unlikely, but true proposition, that transport CO_2 emissions are, for the purposes of interconurbation transport within the UK, largely independent of distance.

I hope that this document sheds some light on the currently opaque world of high speed rail.

Alan Brooke

May 2011