Wendover HS2

ACTION AGAINST CHILTERN HS2 ROUTES

Financial analysis of HS2

multiplying an unknown by an uncertainty for 75 years

Dr J Savin MBA

Prepared for Wendover HS2

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Financial analysis of High Speed 2 Stage One

This document summarises the work of the Wendover HS2 Business Group (WHS2) on the High Speed 2 Limited (HS2 Ltd) proposal for a high-speed rail link between London and the West Midlands, know as High Speed 2 (HS2). An ancillary spreadsheet model (WHS2 BCR Analysis) is available for use with the report at www.wendover-hs2.org.uk . This allows readers to test the business case assumptions quickly without any knowledge of financial modelling.

It is very important to note that this analysis is based on **the actual numbers used by HS2 Ltd** to prepare its report published in March 2010. We look at the overall national financial case for HS2 to how it has been constructed and whether it is as robust as it has been claimed by certain politicians. Our view is that, as UK taxpayers, major proposals of this nature should be clearly explained. This will enable people not familiar with transport planning jargon and advanced financial analysis to assess the strengths and weaknesses of the case. Instead, we have from HS2 Ltd an unbalanced document full of hyperbole, spin and numerical obfuscation. In most cases, these numbers are unknown quantities multiplied by uncertain factors and accumulated over 75 years.

The document is in four sections.

Overview: this is a descriptive and largely non-numerical summary of the report.

Section 1: the background to the method used in transport planning and forecasting is explained with relevance to the HS2 Ltd case. The aim is to explain why some of the numbers in subsequent sections are so large. A key section in this part of the report relates to the passenger demand to use HS2 to access Heathrow airport. HS2 Ltd has been inconsistent in its treatment of Heathrow because it has two separate computer models and has chosen to use the higher set of numbers - even though these are unrealistic. The political fascination and obsession with Heathrow is anachronistic but is clearly substantial. Yet, no one can produce a business case for connecting Heathrow to HS2.

Section 2: the individual financial components making up the Benefit Cost Ratio (BCR) calculation are examined and tested for realism. The BCR is critical to the acceptance of the business case. It is generally expected that a project must have a BCR greater than 2. Demand for rail transport is not an explicit element of the BCR but it underlies most elements of the BCR. Hence demand and the compound growth assumptions are examined. We find that HS2 Ltd has claimed all new passengers and may claim over 90% more passengers than is realistic, or physically possible.

Section 3: uses a spreadsheet model based on the HS2 Ltd figures. This allows us, and you, to add, remove or adjust various BCR values. The underlying demand estimates can be also be adjusted. We include financial elements that are excluded by HS2 Ltd from the BCR calculation: the interest on the large debt that HS2 Ltd would incur in building the line; the substantial profits the two operating companies will expect; and carbon emissions

Wendover HS2 would like to thank all those who have contributed to this report including from the HS2AA associated groups and in particular Bruce Weston.

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How did HS2 Ltd get the "right" BCR outcome

In 2007, the then government published a transport White Paper which found solidly against a high speed line. The concept was deemed too expensive and too inflexible given the long build time.

In 2009, an unelected Minister had a different view. He demanded a plan that ran a line out to the west of London, connected with Heathrow and then ran north, initially to Birmingham. The basis for this constrained route selection remains obscure. All strategic studies of these issues have concluded that a line running direct from London to Manchester and Leeds with a Birmingham spur is the only viable option. This is because there is hardly any demand for a Heathrow HS2 connection and Birmingham, is well served already with a short journey time.

We can only presume that election considerations and arguments over the Heathrow third runway were crucial to this decision. HS2 might have made Heathrow seem more acceptable, it pandered to West Midland marginal seats and it appealed to Labour's Northern supporters. It could also be spun as a green project. These considerations will be of rather less interest in 2085. It is not ideal to build an expensive line for marginal, short-term political reasons.

To give these arbitrary plans momentum, the unelected Minister set up a new company linked to but at arm's length from, the Department for Transport: HS2 Ltd. This had the sole remit of justifying the selected arbitrary route. The aim was and is backed by consultants and contractors with regional cheerleaders, especially in the West Midlands.

HS2 Ltd had a problem however. The costs of building the line were clearly going to be high because of the tunnelling out of London and the engineering needs of crossing some hilly and sensitive landscapes through the Chilterns. There was the further problem that the line would be too far south for easy alignment with the important London-Manchester corridor. This required it to cross floodplains and sensitive Midland greenbelt land. Finally, it did not save much time, as London-Birmingham is a short, well served route. The stage one proposals do not reach Manchester and Leeds where most extra demand is likely to arise. How then to build a business case and get the all important BCR to an acceptable level?

The first thing to do was get a massive demand forecast. The transport planning system is geared to small scale projects with fast payback. It recognises that forecasting more than seven years into the future is risky since its models are fundamentally linear relying on past economic trends. These tend to work in stable economic conditions for a limited period as, generally, transport demand rises with GDP although as we showed in Section 2, this correlation is far from perfect. It is a difficult problem.

HS2 Ltd had a solution. The long period need to agree and build the line would allow projected demand to grow. An extra seven years worth of demand growth after the line opened in 2026 could then be added till 2033. In reality, any forecast made on the basis of HS2 Ltd parameters is worthless after c 2016. HS2 Ltd took a high GDP growth estimate and then increased rail demand about 23% faster than GDP. To 2033, this increases demand 131% relative to 2008.

A big issue that has to be avoided is if demand is c 105,000 people per day on the West coast line in 2025 (now c 48,000) how are they transported till 2025 without a lot of extra investment? And, what happens to that investment if 80% of them then use the new line?

The solution has elements of genius. The case is developed in terms of "uncrowding". That is, the freed, empty, capacity is valuable. So the higher the demand before HS2 opens, the bigger the uncrowded benefit and the more people that can pay to use HS2. It's a win-win, for HS2 Ltd. Further, this benefit happens every year till the project plan ends. It is a form of economic perpetual motion.

Even better, whereas Treasury rules keep costs flat, benefits can grow, in this case at 2% year till 2086. This inflation adds an extra 43% to the benefits in the BCR. All non-cash inflated benefits count

100% as cash under the project evaluation rules. Taxpayers are being asked to pay cash now to get the intangible benefits of empty trains after 2026.

HS2 Ltd still did not find this enough. Although HS2 itself only increases the 2033 demand by 3.9%, all these extra, 61,000 passengers are claimed, even those who cannot travel on HS2. We find that HS2's figure might be might be over 90% too high. In particular, HS2 claims many air passengers. Most of these passengers can only come from Scotland. Yet HS2 Ltd only finds 1,000 air passengers a day from its other models. Budget airlines are unlikely to be unduly troubled.

Sadly for HS2 Ltd the other benefits have not been as productive, although as they can still be inflated, they can still useful to prop up the BCR. Air benefits are negative but fortunately tiny, road benefits are insubstantial and the others, like access, waiting for trains, are prosaic and obscure.

Embarrassingly, the regional benefits are highly localised and in some cases negative. This is inevitable since, as far as we can tell, these relate to extra local rail capacity. How relevant this really is to most Birmingham and West London businesses is unclear. A shortcut on something called Imperfect Competition is useful here. This is simply 10% of the indirect business benefits as, in theory, the emptier the trains in 2026 due to HS2, the more local business profits rise. Again, these are inflated till 2085. It sounds arcane but they are valued at £1.6 billion in the BCR.

Having got as many non-cash benefits as possible, HS2 Ltd then needed to minimise the bottom of the BCR calculation. If benefits had to be high, costs had to be low. It is standard in planning to increase the anticipated costs by a standard amount (optimism bias) to reflect the uncertainties of forecasting. HS2 Ltd argues that it has done detailed planning so the costs are more accurate and the bias lower. This makes the costs substantially lower. Instead, we apply realistic rates.

Fares offset costs in the BCR method. Hence, whilst costs need to be low, fares need to be high. HS2 Ltd had a problem on this. Firstly, its models are too crude to handle sophisticated fare schemes and competition from other than travel modes especially the, presumably, empty West Coast line and budget airlines. It accordingly assumed that legislation and government regulation will prevent competition for customers. This is hardly an advertisement for a "robust" business case.

Policy is that regulated fares, particularly London commuter rather than long-distance business, rise by RPI+1%. HS2 takes full advantage of this formula up to 2033. This increases the value of fares relative to level costs and so has a greater offset effect. Nonetheless, higher fares are an issue for HS2 since they depress demand, and lower demand damages the crucial top line non-cash benefits.

HS2 Ltd had some other awkward cost items. Its solution was to ignore them in the BCR. Firstly, there are the profits of the operating companies that will run the trains and maintain the track. These are nearly £1 billion in the BCR. Secondly, the cost of finance is a problem. HS2 Ltd is extremely vague on where the money is to come from suggesting a levy on all rail users and free money from taxpayers. We have assembled all HS2 Ltd's yearly figures into one model so we can see the debt mountain generated. The interest charge could have a BCR value of £15 billion.

The last thing HS2 omitted is the environment. Carbon is explicitly valued in the plan. HS2 would be a net carbon emitter increasing by 0.5% the UK's transport emissions. HS2 Ltd offsets these by claiming that domestic air traffic is reduced. This is misleading in two ways. Firstly, the claimed reduction in flights (c 90 per day) is contradicted by the Heathrow number: 1000 daily (6 flights). Secondly, any landing airport slots will be reused for long-haul and EU flights. The UK as a whole will see no CO_2 reductions. Indeed as HS2 goes fast and speed takes hugely more energy, we have added in 23% more CO_2 to our carbon calculation.

Section 1: Background aspects

This section looks at the methodologies used assesses the business case presented by HS2 to using the original spreadsheet numbers obtained under Freedom of information requests. It attempts to use Treasury Green book principles and WebTAG guidance as used by the transport planning industry. There are a number of major differences with the way that a private sector organisation would analyse a similar project. There are also some major adjustments made by HS2 and also adopted in this report.

Benefit cost Ratio (BCR)

The actual BCR produced by HS2, and realistic one produced by us, will be discussed later. The BCR is a fraction:

- **Top:** intangible promises like based time savings and distant economic growth; and;
- **bottom** consisting of real cash costs, offset by hypothetical fares from unborn travellers.

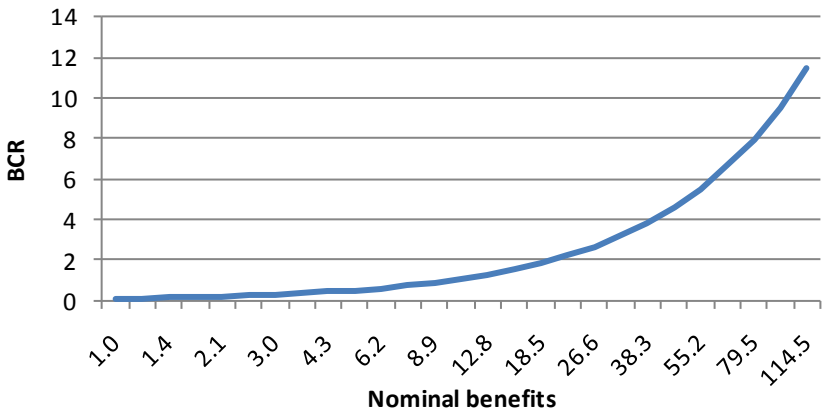
The top elements are all theoretical based on economic theory and partial surveys of travellers. To a scientist, what is amazing is these are based on little hard data, lots of theory and no validation.

The bottom elements are more "real" since although there will be large errors, these at least relate to cash people might pay, the numbers of users and the construction costs. These elements are the ones that can be retrospectively measured. In HS1's case, the user and fares estimates were major error sources, at least 200% overestimates.

A BCR of less than 2 implies that the returns will be very marginal. Under 1.5, projects are not viable. The BCR is a tool used to rank projects. Projects with higher BCR values should be preferred. In politics, however, flashy projects with low BCR may have higher utility than small, cheap and boring incremental improvements with very high BCR's

Exhibit 1.01 shows the shape of any BCR curve: almost flat at the left; very steep on the right. Although the curve has the same ratio properties throughout, if an absolute number on the BCR is a "target" rather than just a ratio, it could be misleading because the BCR curve as an absolute number becomes steep very quickly so small increments in benefits rapidly increase the apparent result. Below 1, the reverse is also true: small decreases in benefits only marginally decrease the ratio in absolute terms, but the ratio is the same. Because of our innate tendency to view a number as an absolute and because a small decrease in costs and a small increment in benefits can have a big apparent BCR change, BCR is a poor tool for assessing project viability. There is a tendency to understate cash costs (bottom) and overstate intangible benefits (top). Risk-adjusted, discounted cash flow analysis is a more rigorous tool. Any forecast is always massively error prone.

Exhibit 1.01: generalised shape of a ratio-based curve



Present Values

The use of present values is widespread in finance but has caused to confusion, which HS2 has not rushed to resolve, about the actual build cost of the project. The idea is that money in 2085, the end date of the HS2 project, is worth less than money in 2009, the calculation year. To compare money from different years in the BCR, based on 2009 values, a discount rate is used and applied to the cash and benefits of each project year.

This works like a negative interest rate. If you put £100 in the HS2 discount account, you get £96.66 back after one year. By 2085, you have £6.62 left. Properly speaking, if someone offered to pay you £6.62 now or £100 in 2085, you would not care, they are the same in HS2 terms[1].

The discount rate used, called the "Social Time Preference Rate" is set out in the Green Book[2]. It has the following elements:

STPR = catastrophe risk + (margin utility of consumption x GDP growth)

The Treasury estimates that the chance of any UK government project being written off due to massive floods, large meteorites, plague, earthquakes, volcanoes or other unpredictable events is 1.5% per year. The marginal utility is basically "do we value increases in wealth": yes we do and it equals 1. That leaves GDP growth which since the 1950's has been around 2%.[3]

3.5% = 1.5% + (1 x2%)

Note that the STPR has absolutely no relationship to interest rates as set by the Bank of England[4] it is a guess at risk, set very low, and another guess at future wealth creation. There is no inflation element so it only works if all prices are at base year values. However some benefit values are inflated, see Value of Time (VoT). A realistic rate should take account also of forecasting errors and data uncertainty, perhaps in the range 10%-15%. In effect, the STPR says that nationally, we are happy to get a 3.5% return on the huge HS2 investment. This seems a low threshold given the high uncertainty and enormous risks of the project.

The Green Book has a discussion to the effect that for very long-term projects, the STPR, which we will call the discount rate as everyone else does, should be lower. The work of Gollier (2002) is cited[5] and from 2055 in the HS2 calculations, the discount rate used drops to 3%. Hence, benefits in the period 2056-2085 are more valuable in the BCR. The use of lower future discount rates passes the burden on the HS2 investment to future generations.

Discounting requires precision about financial years and we have noted some apparent inconsistencies in the way that different HS2 spreadsheets treat this. The discrepancies are particularly noted in 2026 when the line is supposed to open in January. This could encompass three months of the 2025-6 financial year or 12 months of the 2026 calendar year. HS2 seems to use both, inconsistently. If this is correct, it will create errors of a few hundred million.

Price and benefit base year

Benefits and fares are based on 2002 prices, with the proviso that they are then inflated, see Value of Time. To adapt 2002 prices to 2009, a GDP multiplier of approximately 1.2 is used. Benefits are all

[1] The rate is 3.5% or specifically for any particular year, it is the value of money to the power of the number of years so the value in any year since the start (n) is given by that year's value*(1 - 3.5%)^n. The values for all the years are then added up to get the Present Value.
[2] http://www.hm-treasury.gov.uk/d/green_book_complete.pdf
[3] HS2 Ltd uses 2.75% in its demand projection
[4] In private business, a discount rate reflecting expected returns on capital invested is used, not the STPR. This means that businesses, in theory, do not make investments that give returns lower than the cost of borrowing money or of shareholder returns required to fund them. This rate is directly affected by Bank of England decisions. The discount rate is also affected by the riskiness of the project and high risk projects might use 12% or higher annual rates.
[5] However, Gollier, a French economist, then advocated in 2003 that "it is efficient to take a discount rate that is increasing with time". More recent work (2009) attempts to reconcile these approaches by assuming that future generations make appropriate investment decisions. In other words, if we mess up the HS2 investment, our grandchildren can pay more to sort it out. Good luck!

given in the BCR at private sector values, that is, if they have been calculated in ex-tax public sector values, they are multiplied by 1.209 which is the amount of indirect tax in the economy.

Where present values are calculated to 2002, they are converted to 2009 present values by use of a further 1.27 multiplier, this is the discount factor.

This gives an overall multiplier of 1.536. For example, fares are calculated to a present value 2002 of approximately £10 billion. They are then multiplied by 1.53 to get the 2009 present value fare figure of £15 billion. This figure is used in the BCR calculation.

Conversion to	*2009*
Discount Rate Adj	*1.2722793*
Price Base Adj	*1.2075024*
Total Adj	*1.5362802*

Value of Time

In transport modelling, one needs to allocate passengers between different transport modes.[6] One therefore needs to know if people prefer to walk, cycle, or take taxis relative to alternatives. These values are economic, based on hourly salary rates for employed people, and on preference values, what someone tells a researcher they might pay, for other travellers. Models use these to allocate between transport modes. For example, people hate walking so walking has a high rate so less walking increases GDP! If a transport mode fare costs less than the preference time value of walking, people will use the transport. VoT rates are in WebTAG guidance[7] and shown in Exhibits 1.02 (working time) and 1.03 (non-working time).

For economic gains, it has been long pointed out that this is confusing two things: 1) a preference value for allocation relative to fares and 2) hard cash in the economy. Many sophisticated arguments based on perfect market concepts are deployed to equate the two and it is DfT policy that the two are the same. That is, if a business traveller saves 30 minutes due to HS2 making the rail system more efficient, that equals £11.09 (36.96p x 30). That is then taken as the gain to the employer, and so to the economy, in 2002 prices. The income distribution affects values. Rail passengers tend to be better paid than other transport users (other than air) and this is reflected in the value of time. HS2 disproportionately benefits higher income groups.

Exhibit 1.02 Working value of time by mode 2002 prices (pence per minute)

Vehicle Occupant	Resource Cost	Perceived Cost	Market Price
Car driver	21.86	21.86	26.43
Car passenger	15.66	15.66	18.94
LGV (driver or passenger)	8.42	8.42	10.18
OGV (driver or passenger)	8.42	8.42	10.18
PSV driver	8.42	8.42	10.18
PSV passenger	16.72	16.72	20.22
Taxi driver	8.08	8.08	9.77
Taxi/Minicab passenger	36.97	36.97	44.69
Rail passenger	30.57	30.57	36.96
Underground passenger	29.74	29.74	35.95
Walker	24.51	24.51	29.64
Cyclist	14.06	14.06	17.00
Motorcyclist	19.78	19.78	23.91
Average of all working persons	22.11	22.11	26.73

Source: DfT WebTAG Table 1

Exhibit 1.03 Non- working time values, 2002 prices (pence per minute)

Purpose	Resource Cost	Perceived Cost	Market Price
Commuting	4.17	5.04	5.04
Other	3.68	4.46	4.46

Source: DfT WebTAG Table 2

[6] See Mackie, PJ et al (2003) Value of travel time savings in the UK.
http://eprints.whiterose.ac.uk/2079/2/Value_of_travel_time_savings_in_the_UK_protected.pdf
[7] http://www.dft.gov.uk/webtag/documents/expert/pdf/unit3.5.6.pdf

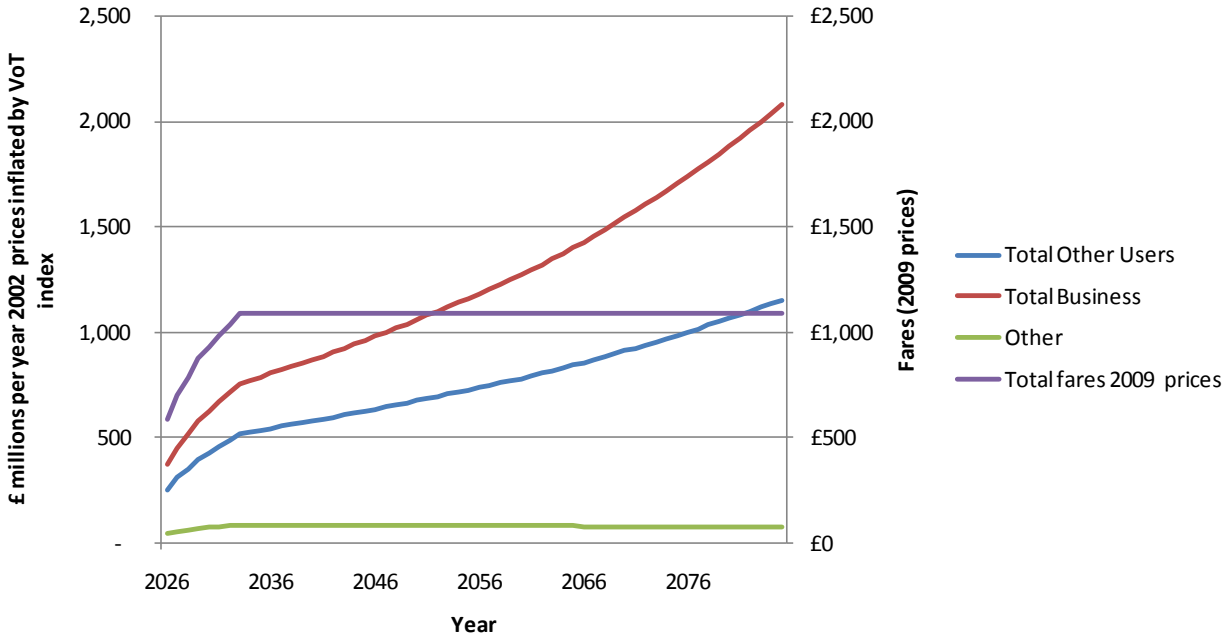
The ivory tower idea that time saving benefits due to HS2 directly increases company profits and GDP on a 1:1 basis is a theoretical economists ideal not validated in the real world. At the micro-level where these transactions happen, prices and wages are sticky. In a modern knowledge economy, time does not directly equal output.

The biggest trick in planning, a convention since the 1980's so not unique to HS2, is to increase the Value of Time with rising incomes, taken as the projected GDP increase. Hence, although the base VoT rates are in 2002 prices, these are inflated at 2% per year till 2085. We noted that in 2002 prices, a 30 minute business time saving was worth £11.09 in 2002 prices but, due to the growth in GDP, the employer of the business traveller's grandchildren will gain £57.37 in 2085 in 2002 prices.

For HS2, VoT growth increases the present value of business benefits by 143% and the non-business benefits by 104%. The effective discount rate is 57% lower for these non-cash benefits compared to costs because the GDP inflated increase cancels the GDP deflator in the STPR.[8]

The effect is shown in Exhibit 1.04. The lines curve upward due to the effect of compounded growth. We argue that increasing benefits in this way over long periods is an imprudent assumption.

Exhibit 1.04: non-cash benefits by passenger group per year vs cash fares



Source: HS2 Ltd. Key: Other = carbon emissions and road safety effects. Carbon is a negative benefit so this drops over time; other users are commuter but mostly leisure passengers. Values are in £ billion per year at 2002 constant prices inflated by VoT growth. Note that fares are capped at £1,089 million per year after 2033 since forecasting more then 7 years into a project is deemed too risky – however, this project starts 17 years after the forecast was made. As absolute benefits are about the same level as fares at the start, using a VoT inflator makes them much more significant as the project progresses. Running the project for 90 years would boost them even more.

Oddly, HS2 does not seem to use time saved by travelling on HS2 in the BCR although this is calculated the spreadsheets. This may be because passengers pay fares so this would be double counting. Hence, we do not know how the spreadsheet figures were calculated. The values are:

- The PV of business HS2 time savings is £3.68 billion;
- The PV of leisure HS2 time savings is **negative**: -£1.82 billion.

[8] Hence, benefits are discounted at 1.5% whereas costs are discounted at 3.5%. This does not sound much but over long time periods, it is a crucial difference in the BCR calculation.

The net £1.86 billion present value seems a poor return on £17.8 billion of investment (PV).

The value of time is also used to calculate other "benefits" maybe with even less GDP relevance. These are:

- time spent waiting for trains
- time spent boarding trains
- access to trains
- crowding on trains
- "uncrowding" on trains – we think this is freed up rail capacity, that is not using West Coast Main Line capacity seems to have a value. The residual WCML will have only c 20% loading if HS2 Ltd is correct.
- reliability (one minute more reliable equals 3 minutes real time so a one minute increase in business time reliability is almost £1 per passenger in GDP; note, assumptions on HS2 's improved reliability are used to calculate the switch from conventional to HS2).

2009 fixed prices vs real construction costs – the hidden bill

Construction costs are calculated in 2009 public sector prices. These values are then discounted to get a 2009 present value figure. This is then multiplied by 1.209 to reflect the indirect tax in the economy. These are then discounted by the STPR to give the £17.8 billion used in the BCR calculation. Note that this PV figure includes both construction and post 2050 renewal costs.

BUT: this is not the **actual cash** Treasury bid figure. Treasury rules require that the public sector cash cost is inflation adjusted by 2.5% per annum and that this forms the basis of the actual budget settlement. It is logical because contractors want to be paid in that year's money not in discounted pounds. This cash figure is approximately £25 billion; we have used the actual inflation adjustment of 3.1% for the current financial year so this is slightly higher than the figure HS2 Ltd uses but is coy about. This £25bn cost **does not** include renewal costs (since these occur from 2050).

In addition, the £25 billion is at ex tax prices. In the BCR these are adjusted to private sector rates by adding the tax burden of 20.9%. This then gives a cumulative actual investment of over **£30 billion**, Exhibit 1.05. However, even these figures may be over-optimistic.

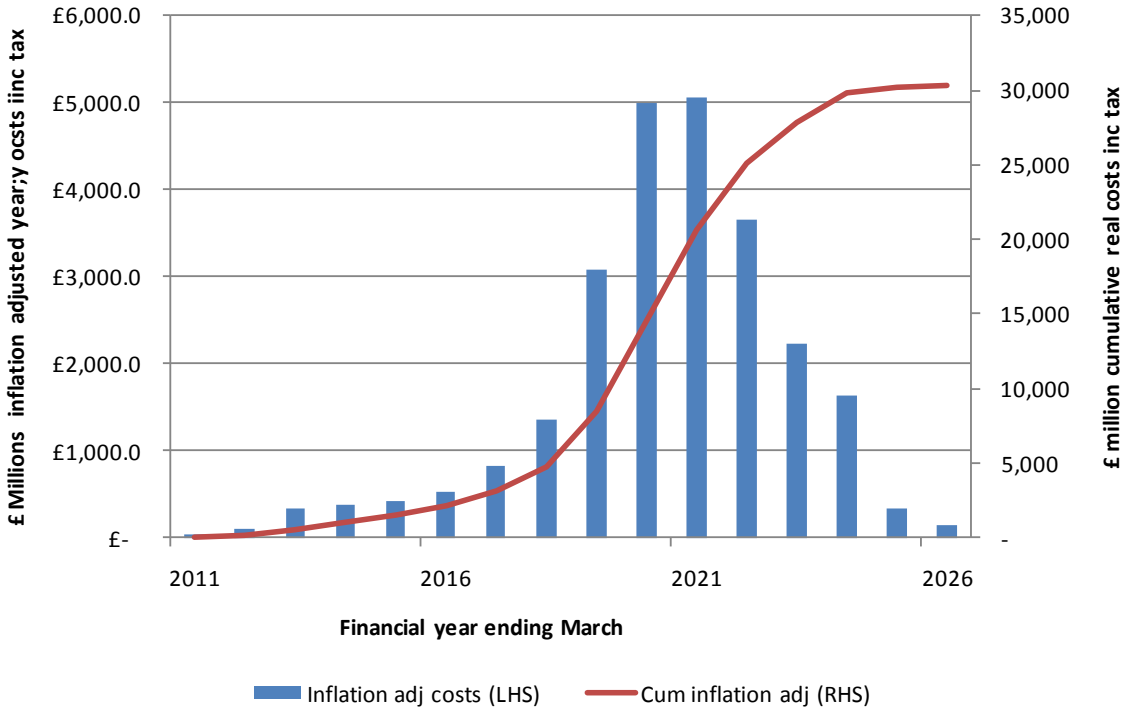
Optimistic on Optimism bias

In initial assessment, costs are usually underestimated so an arbitrary optimism bias is added, presumably based on bitter experience. There are three levels of optimism bias in projects. An early stage project is required to increase its cost estimate by 60%, a project which has received conditional approval and therefore has a higher level of planning has a 40% uplift and projects which are in the ordering stage use 18%.

The Network Rail review of high-speed line options used 60% optimism bias as no specific route was costed in detail. Although at the time of writing the government has not approved any specific route, HS2 Ltd has carried out survey work principally on Route 3 and used a 40% optimism bias; this is intended for projects which have received conditional approval. A private sector figure at a realistic 60% bias, with inflation indicates a track and station cash cost of £29.6 billion, Exhibit 1.06.

HS2 Ltd assumes that 16 high-speed trains will be bought "off the shelf" at £25m each and attract 18% optimism bias (£29.5m "budget", £35-£40m realistic). The 45 "classic compatible" trains, not yet designed, are assumed to cost 50% more than HS2 trains (so a detailed plan there): £37.5m "budget". A 40% uplift was then used giving £50m each, £60m may be realistic. Note that these are all public sector rates, that is without the indirect tax factor. Using the comparable private sector rates adding inflation and using a realistic optimism bias indicates a rolling stock cash cost of £5.1 billion. It is a lot for 61 trains.

Exhibit 1.05: actual and cumulative cash costs at private sector rates of initial construction



Source: Wendover HS2

Exhibit 1.06 summarises the possible real cash costs of construction. It probably lies in the region of £30-35 billion. Note this is the cash total on the final invoice not a present value or a 2009 value.

Exhibit 1.06: inflation adjusted construction costs with realistic optimism bias.

	Base estimate £ million	Opt. Bias	Number (Units)	Public (ex tax)	Private (inc tax)	Inflation adjsusted
Track	£11,795	60%	NA	£18,872	£22,816	£29,628
HS2	£25	40%	16	£560	£677	£876
Compatible	£38	60%	45	£2,700	£3,264	£4,222
Total				£22,132	£26,758	£34,725

Source: HS2 Ltd basic figures, Wendover HS2 estimates

Cash flows and Cost of Money

Apart from the Treasury discount rate, it is assumed that all money is free. HS2 Ltd explicitly refers to "subsidy" in its spreadsheets. This is also clear from its report to government. As we have built an overall cash-flow model, we have the option of adding in the cost of finance. This should be done to assess the opportunity cost, what could be built instead, and in case private sector funding is used. We suspect that work on this has been done by HS2 Ltd but it has not been disclosed.

National Modelling

In attempting to model a high-speed line in the UK, HS2 did not have a novel task but it did have a difficult one. In addition, there was a problem because the (then) ministerial diktat was that the line had to have an interface to Heathrow on the presumption that it would generate significant passengers for the airport, as it turns out a false assumption.

Because of this ministerial limitation on the choice route, HS2 ltd had to optimise the benefits to give the best possible case for constrained route. This is cheerleading for a weak option not impartial consideration of the optimal route alignment. As a Network Rail New Lines study showed[9], going north from London directly is cheaper but this option was not considered by HS2 Ltd since they could not link a direct route to the North West and Midlands, both East and West, with Heathrow.

The modelling process occurred in five stages.

The demand for transport into the distant future was calculated using EDGE. This model cannot assign different modes of transport. To do that required three further models which can assign demand amongst different modes but which cannot predict it:

- PLANET Long Distance (PLD) sometimes called the strategic model. Most of the demand figures come from this model which also provides the data on air forecasting;
- PLANET South (PS) is a detailed model of the London commuter network;
- PLANET Midland (PM) is a model of the West Midlands rail network but with less emphasis on commuting since the majority of that within the region is by car.

All these models are highly sophisticated using a variety of mathematical techniques. They appear to be run iteratively as the models determine many of the parameters related to demand so that the model output becomes stable. These types of models can be internally consistent but divorced from reality. Because three models needed to interact together and take demand forecast data from EDGE, only two days in separate years were forecast; this is the minimum required under WebTAG. Unfortunately the years available are 2021, five years before HS2 opens, and 2031. HS2 therefore took a 2021 base year and started demand projection then but only use the results for modelling from 2026. For other numbers, 2031 seems to equate to 2033.

Note as only one day in each year was run it is extrapolated to a whole year. High annualisation rates seem to be used. That is, the train frequency is almost the same at weekends as weekdays. These rates vary with model used (PLD/PS/PM) and type of passenger.

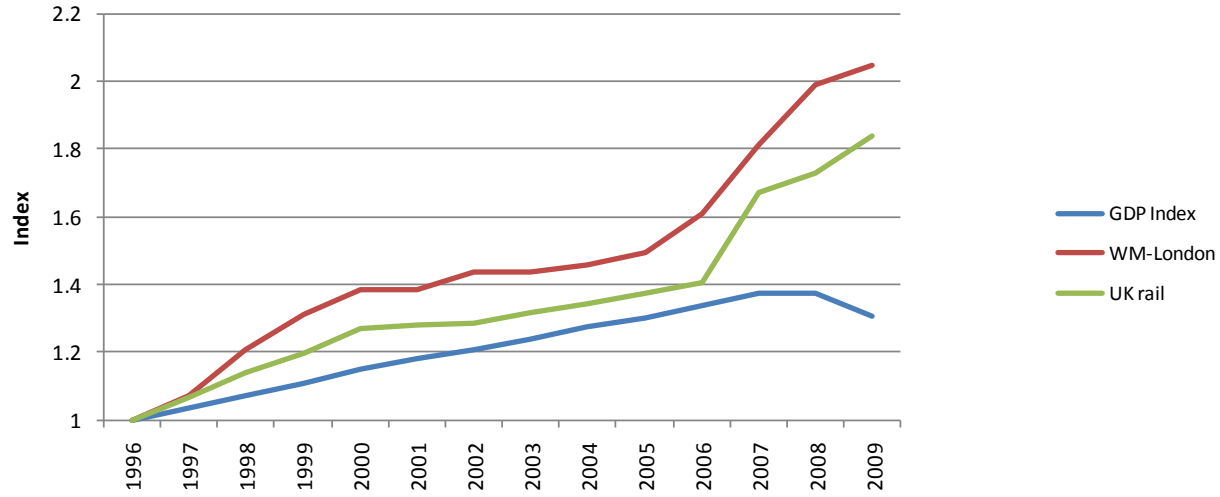
Forecasting rules require that demand projections are capped after seven years of project operation. This means that the fares and demand do not grow after 2033 on a 2026 start.

Demand

Exhibit 1.07 shows historic rail demand for the UK (excluding London commuting which is c 60% of rail) indexed to 1996 – the first year of easily accessible data.[10] We have also plotted the demand from Birmingham to London and a GDP index, in this case in 2006 real prices. The Compound Annual growth rate for GDP was 2.93 to 2007, as this proved unsustainable, it should not be used as an indicator of future performance. The CAGR rises in rail passenger numbers were 5.5% and 4.85. Data after 2008 is plotted but the basis of passenger data collection was altered in 2008 so the historic series is disrupted. There is no question that rail has been more popular. However, in this period, there was a major upgrade and service improvement on the WCML and privatisation gave a greater range of fare options (mostly confusing).

[9] http://www.networkrail.co.uk/documents/About%20us/New%20Lines%20Programme/5883_Strategic%20Business%20Case.pdf
[10] All historic rail data used comes from the Office of the rail regulator 2009 report.

Exhibit 1.07: Historic Rail Demand



The demand models are all built on the idea of elasticity. That is, if GDP rises by 1%, the demand will alter by the GDP change multiplied by a factor. The basic rail factor assumed is around 1.2, so rail rises 20% faster than GDP. In fact, the HS2 Ltd models compute a range of elasticities for different groups from different regions travelling other regions. This is all computer generated and gives a mathematically self-consistent model. However, it needs to be validated against the real world. A set of values so generated is shown in Exhibit 1.08. For example, demand between central London and Birmingham is expected to grow 2% for each 1% rise in GDP. The Glasgow rise is more impressive: 2.6 times the rate of GDP growth.

Exhibit 1.08: Demand elasticities used in 2031 HS2 modelling

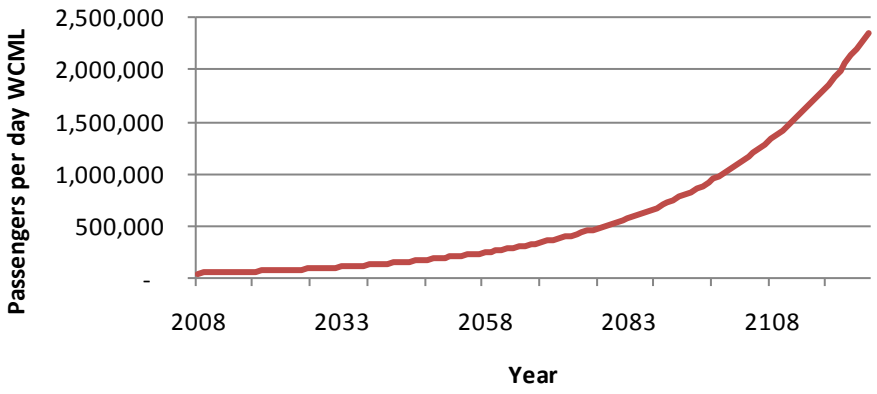
2031 With recession (EDGE Run 2) growth factors for Business (B), Commuting (C) and Leisure (L) journey purposes						
PLD zone	Name	Central London	Bham	Manchester	Leeds	Glasgow
117	Central London	B: 2.229 C: 1.592 L: 1.907	B: 2.068 C: 1.464 L: 2.202	B: 2.443 C: 2.408 L: 2.588	B: 2.411 C: 2.2 L: 2.552	B: 2.629 C: 2.829 L: 2.77
5	Bham	-	B: 1.432 C: 1.236 L: 1.54	-	B: 1.578 C: 1.63 L: 1.58	B: 1.549 C: 1.549 L: 1.552
130	Manchester	-	B: 1.599 C: 1.747 L: 1.603	B: 1.514 C: 1.372 L: 1.62	B: 1.608 C: 1.818 L: 1.613	B: 1.575 C: 1.541 L: 1.582
105	Leeds	-	-	-	B: 1.504 C: 1.365 L: 1.601	B: 1.562 C: 1.525 L: 1.566
37	Glasgow	-	-	-	-	B: 1.406 C: 1.094 L: 1.496

Source: HS2 Ltd Baseline forecasting report

These numbers are stated with great confidence by HS2 Ltd but they are an extrapolation of historic data, of variable quality, to infinity (and beyond). Exhibit 1.09 plots the unconstrained growth in WCML passengers using an elasticity of 1.24 and a typical GDP growth of 2.75% (there are no future recessions, demographic shifts or technological changes in transport planning). This means growth of c 3.4% a year. One hundred years after HS2 opens, over 2 million people a day will use it. By the year 2222, the entire population of the UK (c 60 million) will travel on HS2 every day. Advance booking is recommended. You can run your own simplified version of this in the associated spreadsheet model.

For this reason, HS2 demand is capped in models from 2033 at 145,000 passengers per day - although the model runs to 2085 to build up the fare and non-cash, inflated benefit values.

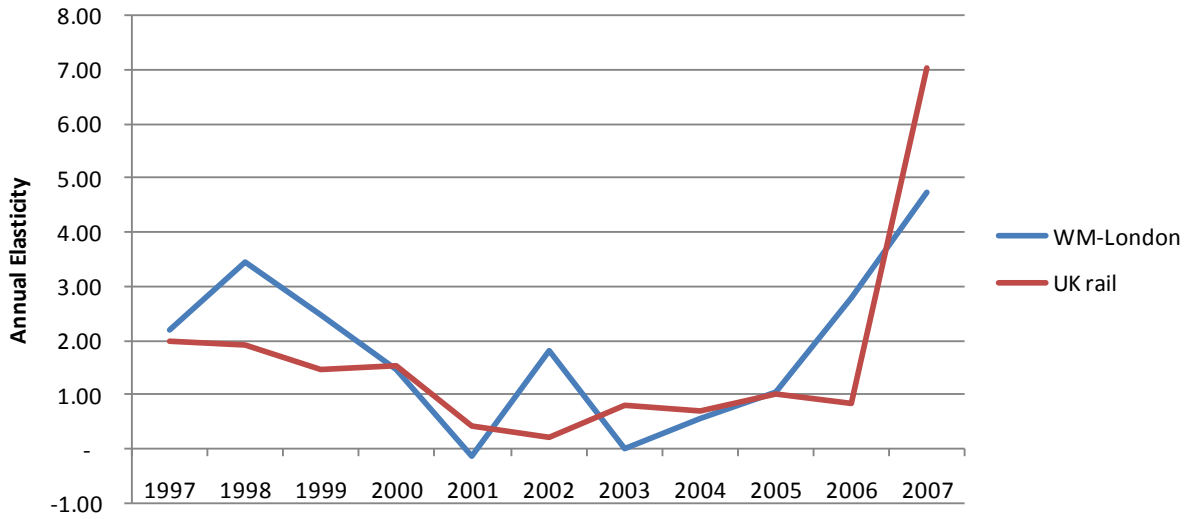
Exhibit 1.09: Growth in WCML rail demand



Source: WHS2 based on transport planning best practice.

How reliable are these elasticity values given so confidently to three decimal places? HS2 Ltd do not seem to know, there are no errors bars on the report. We are not transport planners but have tried to test the consistency of the elasticity function given the limited data available to us. Exhibit 1.10 takes the data in Exhibit 1.07 and plots the year on year growth in rail relative to GDP growth- the elasticity.

Exhibit 1.10: calculated demand elasticities for UK and WCML rail



Source: WHS2

The values vary widely and have been negative in some years. This indicates that a wide variety of factors influence rail growth. The correlation with GDP is 0.45 for WCML and 0.26 for UK rail as a whole (1 is a perfect match, 0 is no match at all; note that correlation does not mean causation). Rail use had a sudden spurt from 2005-6 as the debt-fuelled economic boom drew to a close. In 2003 and 2004, it grew at less than GDP and in 2001, it reversed. The statistical measure of this is standard deviation. We calculate, on the very short data run, that in any year, the demand for travel between London and Birmingham will grow between up to 4.8% or fall by up to -0.93% relative to GDP with 95% confidence. Until transport planning develops some sophisticated behavioural models, it will not advance beyond elaborate, but fundamentally simplistic, linear extrapolations.

The models also, of course, need to assume GDP growth. Knowing future GDP is inherently impossible and good economic models show a range of outcomes for next year.

HS2 is based on multiplying an unknown by an uncertainty for 75 years.

Heathrow Modelling

The final model that is particularly important in terms of route selection is the Heathrow analysis. This has been done on a separate spreadsheet. It does not seem to feed into the BCR so is discussed here rather than in Section 2. Strategically, there is meant to be high demand for HS2 from air passengers. There isn't. The Malwhinney report commissioned by the 2005-10 government was clearly an attempt to reverse this analysis. [11] It failed.

A discussion document on the development of the Heathrow model is provided in HS2 technical appendices. We have requested a copy of the model. However, HS2 itself does not have a copy of and the contractor has proved recalcitrant in delivering it under Freedom of Information.

Given that the Heathrow and the west London connection are critical to the route selection, it seems surprising that HS2 has not studied this model in great detail; maybe it gave the wrong answer. We have also noted discrepancies in the assumptions from PLD about air transport that do not appear to correlate with high-speed access to Heathrow.

The basic assumption about the Old Oak interchange are:

- It enables wider access to greater London via Crosssrail
- It links HS2 to Heathrow, again by Crossrail
- It provides a connection to the Great Western line allowing some use of HS2 by travellers from Wales and the SouthWest. However, as HS2 note, the assumption of no fare premium is not likely to occur and this will depress passenger numbers.
- It limits HS2 congestion at Euston. The tube connections to Euston are already clogged although HS2 makes light of the increase in numbers (+3%). Euston will have to handle in excess of 105,000 passengers in 2025 before HS2 starts.

Exhibit 1.11 shows the flows of passengers from an Old Oak interchange. The flow from Old Oak Common (OOC) to Birmingham and beyond is 144,000 per day. These are each way (about 72,000 in each direction). Of these, 95,000 journey between OOC and Euston. Most of these travel to or from the wider London area and a small number, 11,000 travel on to SE regional destinations, perhaps via other London stations. OOC relives Euston by allowing 31,000 London passengers to access HS2 by other, slower routes. Without OOC, all HS2 traffic must pass via Euston. The SW passengers are highly uncertain on HS2 estimates.

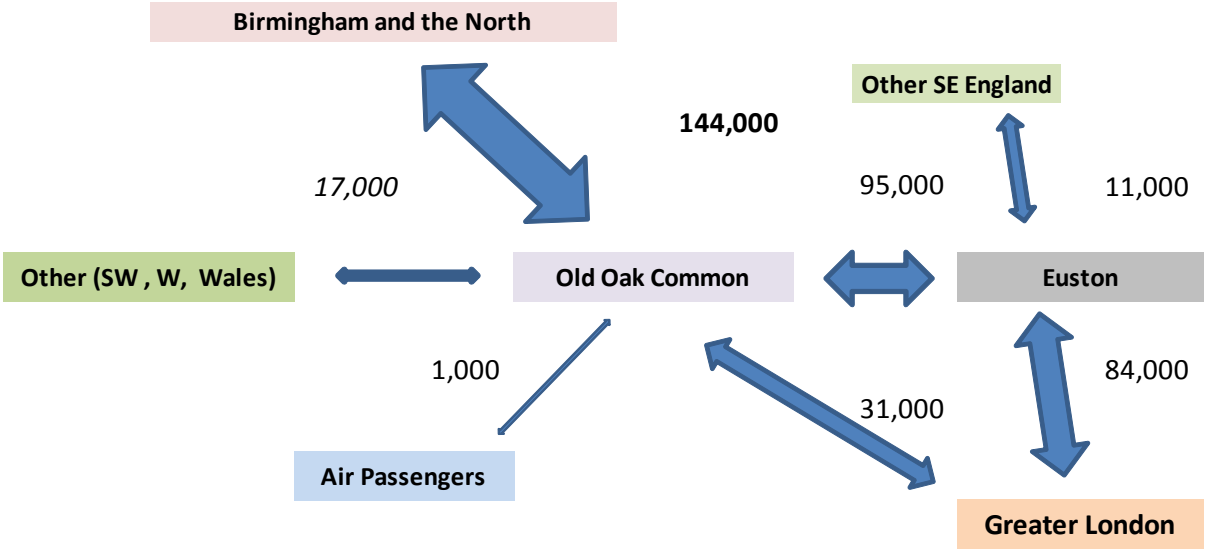
The whole point of the HS2 route corridor was Heathrow. On HS2 figures 1,000 passengers access HS2 from Heathrow, 500 people or half a train each way daily. These forecasts rely on capturing Scottish air passengers. 1,000 passengers is about 6 flights per day or 2 return Glasgow flights plus one return Manchester flight.

The freed slots will be used for more profitable long-haul jets, probably larger models with higher CO2 emissions on takeoff and landing. The impact on UK carbon emissions for air will be zero.

There is a time and cost penalty for going via OOC. There are complex, costly tunnels from Euston to OOC and from OOC to beyond Amersham. The passage from OOC to Euston is slow speed. Tunnels beyond limit speed and use extra energy. The route is then too far south and needs to curve north to realign with the Warrington- alignment, Manchester being inconveniently built in a Pennine dead end. Birmingham can only be access via a low-speed spur.

[11] http://www.dft.gov.uk/pgr/rail/pi/highspeedrail/lordmawhinneyreport

Exhibit 1.11: Old Oak passenger flows to Heathrow and Greater London



Source: HS2 report

Sensitivity analysis

One aspect of discounting is that it enables uncertainties in future predictions to be compensated for. However, it is debatable whether 3.5% is adequate compensation for such long-term predictions. Most transport planning operates a few years ahead and even then is notoriously unreliable. The recent National Audit Office report into the provision of additional commuter capacity into London and other rail improvements notes rather caustically that the Department of Transport has very little idea about whether its forecasting methods are actually reliable.[12]

There are only two sensitivity analyses in HS2 documents. One of these relates to the effect of premium fares on demand and the other one is a very limited assessment of the impact of falling demand.

We have done further analysis using the BCR framework, see Section 3.

[12] http://www.nao.org.uk/publications/1011/rail_capacity.aspx

Section 2: How to Hide Awkward Realities Behind Obscure Numbers

Unfortunately the benefit cost ratio BCR is fundamental to the assessment process. To make it easier, a vain hope perhaps, a spreadsheet which allows simple imports to be made is available to allow anyone to construct scenarios and painlessly construct their own BCR. It is free to the public but Government Departments and Companies limited by Guarantee are required to contribute to Wendover HS2.

It is generally assumed that a BCR of at least 2 is required that is, the benefits of the project must be at least twice the costs. The BCR allows different projects to be ranked.

The BCR calculation

The BCR is a fraction with intangible benefits based time savings and other economic calculations on the top and costs, offset by cash fares, on the bottom. The figures, expanded on HS2 Ltd's presentation but using its figure unmodified in any way, is shown in Exhibit 2.01. (next page)

The top elements are all theoretical based on economic theory and partial surveys of travellers. The bottom elements are more "real" since although there will be large errors, these at least relate to cash people might pay, the numbers of users and the actual construction costs. These elements are the ones that can be retrospectively measured. In HS1's case, the user and fares estimates were major error sources, at least 200% overestimates.

The BCR is a tool used to rank projects. Projects with higher BCR values should be preferred. In politics, however, flashy projects with low BCR may higher utility than small, cheap and boring incremental improvements with very high BCR's

Business traveller Benefits

These are shown in Exhibit 2.02

Exhibit 2.02: Business traveller benefits

Road	£1,326	7.6%	
Air	-£61	-0.3%	
Classic	£16,293	92.8%	
HS2	£0	0.0%	
Total Business Benefits			**£17,559**

The £17.5bn of benefits are inflated by the Value of Time growth of 2% per year to 2085. This is discussed in Section 1. This inflates the present value by 143% relative to constant 2002 prices. This method favours very long project forecast to get a positive BCR when upfront costs are high.

Exhibit 2.01: Expanded Benefit Cost Ratio Table

Road	£1,326	7.6%	
Air	-£61	-0.3%	
Classic	£16,293	92.8%	
HS2	£0	0.0%	
Total Business Benefits			**£17,559**
Road	£694	6.2%	
Air	-£20	-0.2%	
Classic	£10,432	93.9%	
HS2	£0	0.0%	
Total Commuter and Leisure Benefits			**£11,105**
East Midlands	£114	5.7%	
East of England	£134	6.7%	
London	£928	46.2%	
North East	£22	1.0%	
North West	£222	11.1%	
Scotland	-£220	-10.9%	
South East	£118	5.9%	
South West	-£30	-1.5%	
Wales	£5	0.3%	
West Midlands	£653	32.5%	
Yorkshire and The Humber	£60	3.0%	
Agglomeration benefits			£2,006
Imperfect competition			£1,610
Total Wider Impacts			**£3,616**
Other road benefits	£44		
Carbon emissions (not scaled)	£0		
			£44
Total Benefits			**£32,280**
Commuter	£705	4.7%	
Business	£6,715	44.8%	
Leisure	£7,583	50.5%	
Fares			£15,003
Construction	-£13,722		
Rolling stock	-£2,354		-£16,076
Infra-structure renewal	-£1,112		
Rolling stock renewal	-£662		-£1,774
Total capital cost			-£17,850
Total Construction			-£17,850
Finance cost			£0
Maintainance cost	-£4,209		
Operating cost	-£3,390		
Train operator profits	£0		
Track operator profis	£0		
Total operating costs			-£7,599
Indirect taxes			-£1,465
Total Costs			**-£11,911**
Benefit Cost Ratio			**2.71**

Source: HS2 Ltd

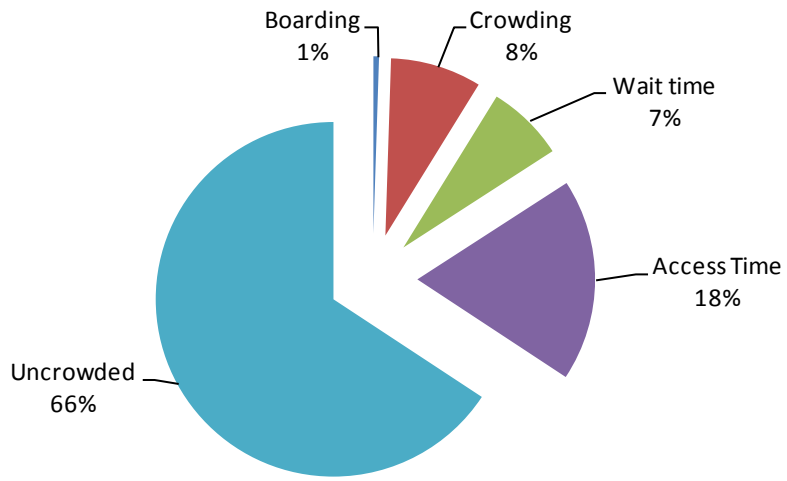
Most benefits, 93%, accrue to rail passengers. There is a small disbenefit to air and minor road gains. Looking at the demand figures, it seems that business road journeys fall by 8% to the West Midlands form London and 16% between London and the NW, in total 1,191 fewer individual car journeys per day in 2033; this is about 0.8% of the current M1 daily flow.[13]

The time savings to HS2 passengers are not included in this. Guidance is that fare paying scheme passengers should have any time gains valued at low rates to avoid double counting. The Present Value calculated, but not used, is £3.68 billion.

The benefits to rail passengers not using HS2, we assume, are clearly vitally important. They are worth at £74 billion[14] after GDP inflation in 2009 money before applying the STPR rate.

Exhibit 2.03 shows the breakdown.

Exhibit 2.03: source of business rail benefits



Source: HS2 figures

Some 74%%, come from crowding benefits: crowding and uncrowding.

Crowding is worked out, we understand, by increasing the fares on crowded routes till enough passengers are priced off to give 100% occupancy (including the "crush limit"). The theoretical increased fare yield is the cost of crowding. Of course, unregulated real fares are higher in the peak times to reflect this and given more profit.

Uncrowded benefits are still a puzzle. They seem to be the value of the freed-up rail capacity. They are clearly the key to the HS2 economic case. This accords with HS2 creating WCML underutilisation.

The other elements again are 100% benefits to the economy: having to wait less, being able to get on faster. It seems a restricted basis for a major project.

Leisure traveller benefits

Interestingly, HS2 Ltd calculated that the time savings in HS2 for this class of passenger were negative: -£1.82 billion. The non HS2 benefits are an impressive, £11bn, Exhibit 2.04.

[13] Decrease is 3,970 but not divided by passenger category; we assume 30% are business, 70% leisure.
[14] Based on PLD only, the PS and PM contributions are minimal.

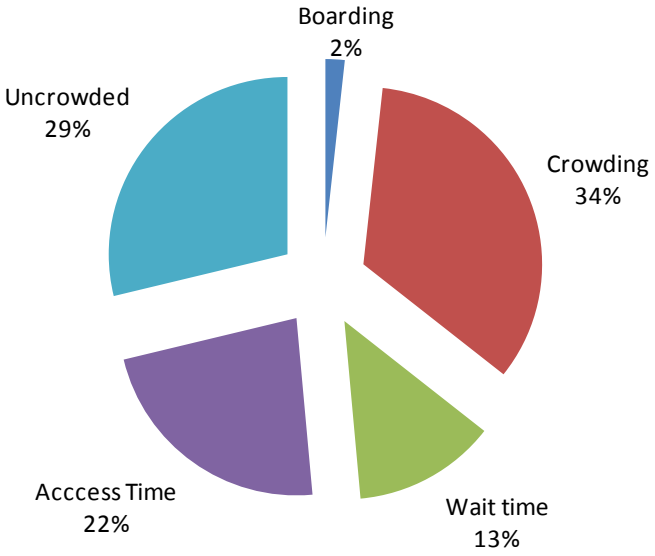
Exhibit 2.04: Leisure Traveller benefits

Road	£694	6.2%	
Air	-£20	-0.2%	
Classic	£10,432	93.9%	
HS2	£0	0.0%	
Total Commuter and Leisure Benefits			**£11,105**

Source: HS2

Again there are small road benefits (c 2000 vehicles per day less on the M1) but the value of time on leisure passengers is marginal. Air is again negative. The PLD value of the rail benefits is £44 billion, non-discounted and inflated 2009 prices, Exhibit 2.05.

Exhibit 2.05: source of leisure rail benefits



Source: HS2 figures

Relief of physical crowding is 34%. The value of freed up capacity of is 29%. Probably as leisure travellers travel more off-peak on less crowded trains anyway. This may inflate the relative importance of access and boarding time.

Wider Economic Benefits

Even though the Bank of England cannot predict the economy precisely next year, HS2 Ltd is more prescient so can predict regional economics in 2085 with ease and assurance. However, HS2 Ltd does supply its BCR calculation with and without these figures implying perhaps less hubris than one might expect.

These regional impacts are crucial since they form the basis for assertions, like " Yorkshire will gain 50,000 jobs", made by an accountancy firm for the GreenGauge lobby group. So for the £35 billion, what do we get?

Exhibit 2.06 shows the HS2 ltd. figures. These are supposedly localised regional agglomeration benefits worth £85m per year based on higher economic activity due to less crowded trains. The benefit of linking major urban centres (i.e. London-Birmingham) is estimated at £8 million per year in an authoritative study from Imperial College; this figure does not appear in HS2 Ltd spreadsheets so may not be used. Agglomeration means that businesses are better linked so communicate more so do more business. This also ignores what are fundamental but poorly understood changes in

economies due to the internet. There is, for example, evidence that job structures have changed with polarisation between low and high paid work and the middle management tiers squeezed as they are most prone to IT automation. Transport planning cannot cope with this.

Exhibit 2.06: Wider Economic benefits

East Midlands	£114	5.7%	
East of England	£134	6.7%	
London	£928	46.2%	
North East	£22	1.0%	
North West	£222	11.1%	
Scotland	-£220	-10.9%	
South East	£118	5.9%	
South West	-£30	-1.5%	
Wales	£5	0.3%	
West Midlands	£653	32.5%	
Yorkshire and The Humber	£60	3.0%	
Agglomeration benefits			£2,006

Source: based on HS2 figures

Exhibit 2.07 shows Exhibit 2.06 graphically. Scotland loses £220m in NPV terms and the South West looses marginally. Of the net benefits, four regions (green in Exhibit 2.07) gain 96% but 78% goes to just two: London and the West Midlands. Manchester has fewer benefits than SE England. This reflects London's hub role in the UK economy. This is another HS2 myth: that it spreads wealth from London, in fact, it overwhelmingly benefits London and especially the richest western parts of the capital like Kensington and Chelsea.

There are two benefits included: agglomeration (WB1) and jobs (GP1). There are no more productive jobs (GP3).

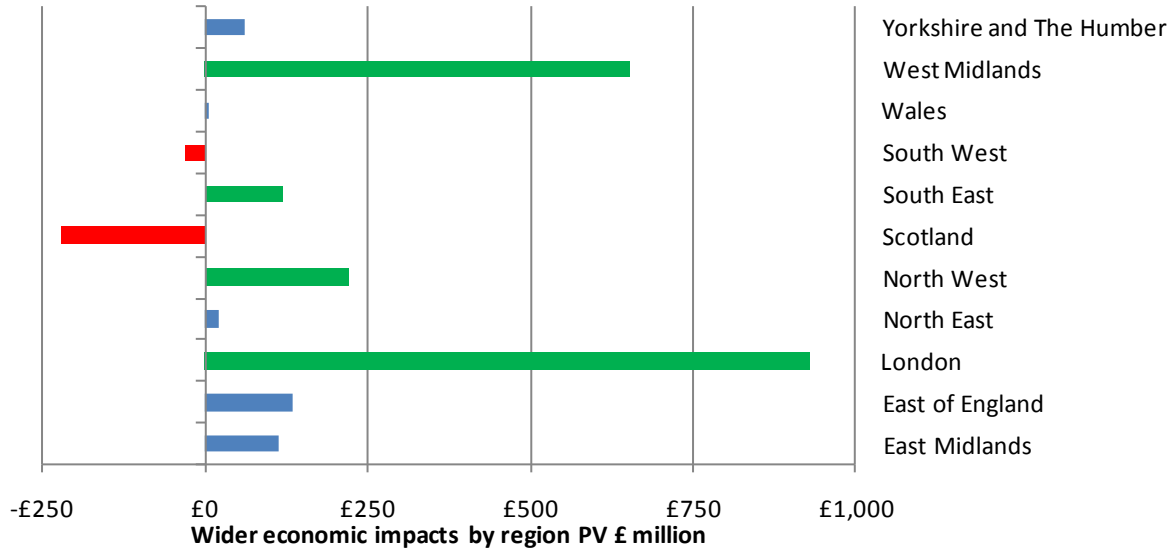
WB1	Agglomeration
GP1	Increase in labour force
GP3	More productive jobs

The agglomeration figure is £85m per year. The more productive jobs estimate is £3m per year. HS2 assumes it takes eight years for the full benefits to arrive; that is, by 2033. Both are then inflated with the VoT growth of 2% per year.

Note: these benefits assume "classic compatible" services to Yorkshire, the NE and Edinburgh. These do not now seem likely so the picture is even more skewed to London.

The HS2 Ltd spreadsheets note that 54% jobs are in London. Yorkshire, rather than gaining 50,000 as the accountants guessed would **lose** 3,521, according to HS2 Ltd. However, we do not see that these numbers can be at all plausible.

Exhibit 2.07: Economic winners and losers



Source: based on HS2 Wider economic impact data

Imperfect Competition

This is worth a PV of £1.6 billion so a useful contribution to the project benefits. However, this rests on some economic theory and a single hypothesised number: a 10% price rise.

The theory is that HS2 increases wealth so local businesses can sell more to local customers, who thereby benefit from increased supply. Higher production would mean higher costs but HS2 enables costs to be kept low. Competition would normally increase to use up the extra profit but is "imperfect. Hence, local business profits rise. This value is set at 10% of business benefits excluding rail crowding. This is then inflated by c 1.7% a year till 2085 – so the profits keep rolling in. These have a PV of £16bn so the Imperfect Competition PV is £1.6 billion. The logic is therefore that empty West Coast trains equals higher profits for Birmingham and London businesses.

Carbon and road accidents

The last category is carbon emissions and reduced accidents due to less road travel. As the latter is negligible, so are the benefits. This section will focus on carbon. HS2 Ltd. has been rather vague about carbon. The green case for HS2 is also one of the presumed attractions. This study looks at the actual HS2 CO_2 numbers generated in what is supposed to be a comprehensive model.

Carbon and the environment

HS2 is generally perceived to be "green" because rail is seen as green, largely as it has sunk Victorian construction costs, and there is a blithe assumption that there will be big modal shifts from car and air to HS2. Using HS2 Ltd's figures, it is clear that, HS2 increases the overall amount of transport consumed: an anti-green effect. The impact, excluding construction costs, is a net 11 million tonnes increase. HS2 Ltd makes the assumption that HS2 has the same carbon operating cost as conventional rail[15] which is set at 60 grammes /passenger kilometre (g/pkm).[16]

[15] http://www.uic.org/IMG/pdf/carbon_footprint_of_high_speed_rail_infrastructure_pre-study.pdf shows that the carbon sources used to power high-speed has a major effect on the carbon impact. We assume, in line with reality, that the UK will be more like Germany (mainly fossil sources) than France, mostly nuclear.

[16] There are many figures in this area, Network Rail comes to different conclusions but is also advocating a cause. The arguments are confusing as they are based on CO_2 per passenger kilometre so it s a function of the carbon profile of the train's power source, the train's energy use and the number of passengers. All these vary independently.

This means that a 400m HS2 train will emit about 8.4 tonnes of CO2 in travelling at 70% load from London to Birmingham.[17] A high-speed London-Edinburgh route (c 650km) would take 27 tonnes, about 3 Boeing 737s or c 500 people. The difference with air travel is less than supposed on this basis especially as modern 737's can seat around 200 passengers and are becoming more fuel efficient.

We also know from the HS2 Ltd Traction Study (Imperial College) that HS2 requires 23% more energy to save 3.5 minutes and that time saving is critical to HS2 Ltds business case; this increase could be much higher as tunnels also increase energy use by up to 96% and Routes 3 and 2.5 both use extensive tunnelling. It seems prudent therefore to adjust the 60g/pkm CO_2 value (based on slow conventional rail) to 74g/pkm to reflect this. This is still within the range of European high speed carbon use.

The carbon sources for the electricity are key to minimising direct environmental climate impact. For example, Germany is more fossil fuel reliant than France. Hence, the carbon use pkm on French trains is lower but this relates to energy source, not train energy efficiency.

HS2 also ignore the construction and maintenance cost. HS2 think that construction may use c 1.2m tonnes CO_2 but the construction process is not estimated and nor is maintenance. In Germany, these aspects add 20% to the carbon running costs.

Finally, HS2 Ltd offsets the carbon emissions from their trains with air and road savings due to modal shift. Overall, this assumes that any air flights cancelled are not replaced – but they this is not likely. Hence, at the overall level, HS2 can have no impact on UK air transport emissions but it could improve airline profitability by swapping UK domestic for more profitable long-haul flights.

Air carbon offset

HS2 Ltd's demand forecast relies on a major shift to "classical compatible" HS2 services from the Scottish air market on very marginal time savings. HS2 Ltd justifies this at length but the effect probably stems from over-sensitive modelling parameters. We assume no more than six flights switched to HS2 from air; HS2 Ltd assume c 80-90 flights saved. This removes the major HS2 CO_2 mitigation. Even if we are wrong, it will still be correct in terms of overall UK air emissions: zero.

Air travel is claimed to have a carbon impact of 175.3 g / pkm.vs 60 g/pkm on HS2. Budget airlines tend to be fuel efficient with high load factors however, plus they are aggressive and flexible competitors. The air figure may therefore be too high and a figure around 120g/pkm fits better with use on Scotland-London routes. A study by Cranfield University puts most aircraft in the 120-140 g/pkm range[18]. It is difficult to compare as p/km depends on route, plane type, distance and especially the load factors.

A study[19] using 2006 as a base year, Exhibit 2.08, since when domestic flights have dropped in frequency, shows that the four major Heathrow domestic routes accounted for about 160,000 tonnes of carbon yet HS2 claims to save 260,000 per year; that is HS2 save more than was emitted in the peak year.

As only 1,000 air passengers would use HS2 to access Heathrow per day (c 6 flights) HS2 Ltd must be counting on capturing significant share from other airlines and airports. An estimate for all UK domestic flights in the peak 2006 year is 952,000 tonnes with BA and EasyJet having a 42% combined share. HS2 on HS2 Ltd figures, would get a 27% market share.

[17] The passenger load is irrelevant other than in pkm calculations as the vast majority of the mass is train.
[18] Slide 3: http://www.tsu.ox.ac.uk/events/nectar/miyoshi_pres.pdf although we wonder on this overall figure as it includes some airlines with no current UK domestic routes like Air Berlin.
[19] https://dspace.lib.cranfield.ac.uk/bitstream/1826/3825/1/Carbon_emissions_of_selected_airlines_and_aircraft_types_in_three_geographic_markets-2009.pdf

Exhibit 2.08: estimated domestic air CO2 emissions 2006 from Heathrow

Air Route	2006 carbon use	
Heathrow-Edinburgh	58,000	
Heathrow-Glasgow	55,000	
Heathrow-Manchester	31,000	
Heathrow-Newcastle	18,000	162,000
Other London-Scotland		108,000
Total		270,000

Road carbon benefits – all very local

Road gains are small, 260 ,000 tonnes over 60 years or 0.003% of yearly peak transport emissions. Oddly, these savings mostly occur within regions, this is in the planet South (PS) and Planet Midland (PM) models not in the long-distance routing PLD model. This is saying that HS2 reduces local road congestion within London and Birmingham. One would expect Birmingham traffic to rise due to road access to the HS2 Birmingham interchange.

Carbon budget

Exhibit 2.09 summarises our revised carbon "budget".

Exhibit 2.09: HS2 estimates of carbon emissions with WHS2 adjustments

	Carbon emissions tonnes					% 2006
	PLD	PS	PM	Total	Per year	transport CO2
HS2 if as conventional rail	-26,427,078	783	188	-26,426,107		
HS2 speed penalty minimum +23%	-6,078,228	NA	NA	-6,078,228		
Infrastructure cost @20% running cost	-6,501,061	NA	NA	-6,501,061		
Total HS2 carbon emissions	**-39,006,368**	**NA**	**NA**	**-39,006,368**	**-650,106**	**-0.49%**
Road cardon savings	**55,769**	**159,301**	**45,542**	**260,612**	**4,344**	**0.003%**
Air savings assuming Heathrow from 2026	*15,593,973*	*NA*	*NA*	*15,593,973*		
Adjustment to 2036	*-1,587,815*	*NA*	*NA*	*-1,587,815*		
Realistic domestic air carbon savings	1,260,000	NA	NA	1,260,000	25,200	**0.02%**
Net carbon emissions	**-37,690,599**	**160,085**	**45,730**	**-37,484,784**	**-624,746**	**-0.47%**

Source: HS2 figures with adjustments by Wendover HS2 noting energy costs cited in Traction Study and figures from European HS lines.

HS2 increases UK CO_2 by between 26 and 32m tonnes over the forecast period. Adding construction takes this to possibly 39m tonnes. This, per year, adds c 0.5% to the UK peak transport emissions.[20] It will become very significant as car emissions fall due to switching to new car power sources over HS2's construction and operating period.

We have recorded HS2 Ltd's optimistic view on air gains (15.5 m tonnes) but note that as there is no Heathrow link, the air gains cannot start anyway till Stage 2 which is sometime in the 2030's plus tens of billions more in costs.

The social economic cost of CO_2 is set at £21 per tonne (2006 price) and rises throughout the period; it is not capped in 2036. The value of CO_2 is a highly debatable issue and is currently low due to EU political factors. The overall carbon cost of HS2 at 2009 prices is £668 million. This is only £11m per

[20] 134 million tonnes in 2006

year (undiscounted, real 2009 money) so not drastic overall. The Stern report took the view that carbon costs, as they have profound long term consequences, should have very low discount rate of about 1%. This is not done in HS2 Ltd's analysis but indicates that these costs should be more significant in the BCR calculation. If carbon prices rise significantly future years, the carbon cost of HS2 in cash terms will rise drastically.

In summary, HS2 increases UK transport carbon emission by 0.5%, c 625 tonnes per year. There is a negligible offset of 0.003% from savings in car use. Any air offset is highly uncertain and unlikely overall but could be 0.02%.

Other HS2 environmental costs and benefits

Four highway benefits are specifically identified and costed: congestion, accidents, noise and air quality. These are shown in Exhibit 2.10. These figures could never be verified within the mass of UK road transport data.

Exhibit 2.10: other road benefits

Road benefit	Total	Per year
Congestion	£347,457,633	£5,790,961
Accident	£33,120,093	£552,002
Local Air Quality	£4,707,013	£78,450
Noise	£2,616,706	£43,612
Total	**£387,901,445**	**£6,465,024**

Source: HS2

Factors not accounted for

Noise: HS2 trains will run at 95 decibels or more at high frequency. There will therefore be a big localised noise dis-benefit to communities along the route and the noise footprint could be substantial and widespread. Note that HS2 has made it clear that detailed route noise surveys have not been carried out as designs are too uncertain (despite the low optimism bias).

HS2 assume that there will be no restrictions on running between 05.00 and 24.00 but local communities may seek to restrict evening, night and early morning use and local speeds - as with local restrictions on many airports.

Environmental impacts other than construction carbon. There will be considerable damage to preserved landscapes some of which have AONB, which is the same in panning and national importance as National Park, status. Important aquifers may be damaged. These costs must be added in but HS2 Ltd has ignored them to be borne by affected communities.

Disruption: the East Birmingham and Euston areas will face years of turmoil. A wide area on either side on any selected route will be severely disrupted for some years during construction. The experience of Kent during HS1 construction has been noted by affected HS2 communities.

Damage to business and property along the route. Affected communities along the route gain no benefit but will experience the loss of income and amenity once completed. These costs are not accounted for.

Summary of benefits

This has been a long discussion of complex and abstract issues. In summary

- HS2's main economic benefit, worth £20 billion in present value, is that passengers will not be as crowed on conventional trains after 2026 .

- These values are inflated by assumptions about long-term GDP growth and assumed to have a 100% GDP benefit. This increases their present value relative to costs.
- Wider benefits are gained by West London, the eastern parts of Birmingham and marginally by Manchester and South East England (96%). Overall, London gets nearly half the inflated benefits; Scotland loses £220m.
- A general "benefit" of prices increasing by 10% is included.
- HS2 increase transport emissions by at least 0.5%. HS2 claims a large share of the HS2 claiming to capture most of the domestic air flights despite handling only six plane loads of Heathrow passengers per day.

These slippery benefits are next divided by the cost elements to get the BCR.

Construction costs

These are the first items in the bottom half of the BCR calculation. Construction consists of:

- Track and station construction;
- Rolling stock;
- Renewals of track and stations; and
- Renewal of rolling stock.

These are calculated in 2009 prices. They are increased by the relevant optimism bias before indirect tax of 20.9% is added. As discussed in Section 1, for Treasury purposes, the annual figures are inflated to give the actual cash requirement. In this section, we are concerned with the BCR so do not inflate the costs. We view HS2 Ltd's choice of optimism bias as optimistic to favour its business case rather than prudent. The sums discounted at prudent optimism bias rates are in Exhibit 2.11.

Exhibit 2.11: 2009 construction costs after adjusted optimism bias

		Base estimate £ million	Opt. Bias	Number (Units)	Public (ex tax)	Private (inc tax)
Track		£11,795	60%	NA	£18,872	£22,816
Rolling stock	HS2	25	40%	16	£560	£677
	Compatible	37.5	60%	45	£2,700	£3,264
Total					£22,132	£26,758

Source: HS2 estimates modified by WHS2

We have used the revised bias figures as an alternative scenario in the BCR calculation.

Demand and Fares

HS2 Ltd talks a lot about demand but it is an implicit not explicit parameter in the BCR calculation. We break out the HS2 Ltd figures in this section. Demand drives fares, the only cash gain in the entire project. HS2 Ltd's fare treatment is so opaque we can come to only general conclusions.

Demand

To properly analyse HS2 Ltd's proposals, one needs to understand the basis of the demand forecast. The overall elasticity approach was discussed earlier. This section looks at the outcome and finds that HS2 may have over claimed passengers on HS2. This maters as HS2's benefits, including the massive c £20bn of claimed and inflated crowding and uncrowding benefits, depend on HS2 gaining passengers from conventional rail.

The core exogenous demand assumption is of 105,490 WCML passengers in 2033. HS2 then generates 61,698 extra daily passengers making 167,188. HS2 captures 86% of these leaving 21,164 on the conventional rail system. This is because HS2 has no fare difference, is faster and is assumed

to be more reliable. The first assumption is likely to be false, the second true but marginal and the third is an unknown.

The extra 61,698 passengers equal to a 3.9% increase in rail demand excluding London. HS2 Ltd. expects that rail will have a 19% share of long-distance travel - which is vastly more than it currently enjoys: about 7%. Of these 61,698, c 11,000 come from air and 11,000 from road, Exhibit 2.12.

Exhibit 2.12: HS2 Ltd estimates of modal shift and endogenous rail growth due to HS2

	Air	Car	Classic	HS2
Reference Case	97,041	6,848,324	1,582,903	0
Do Something	86,220	6,836,891	1,644,596	0
DS Change In Demand				
Absolute Difference	-10,820	-11,433	61,693	0
DS Total/RC	89%	100%	104%	-
Mode Share				
Reference Case	3%	80%	19%	0%
Do Something	2%	80%	19%	0%

Source: HS2 Ltd. Reference case is the implied transport pattern without any HS2 investment. Do something is build HS2. The impact of HS2 itself is small on overall rail use.

On closer examination, these figures are odd. Exhibit 2.13 shows the change in rail use by region. We interpret this as travel from a region (top line) to other regions. Journeys which might use "classic compatible" trains for part of the journey but not use the stage one alignment are highlighted in red. Journeys that would not use HS2 at all, like East Midlands to London where there are two direct main lines are also in red. HS2 Ltd predicts a net increase of 1,486 passengers travelling within their regions due to HS2 – which is nonsense – but they are still claimed (orange highlight, boxed).

Exhibit 2.13: changes in rail travel patterns due to HS2 annotated by WHS2

New HS2 demand	Scot.	NE	NW	Y & H	Wales	W Mid	E Mid	SW	SE	London	EA
Scotland	-73	-1	410	-5	89	321	91	397	897	3,648	214
North East	26	31	-30	-65	-4	-19	-23	-13	-33	-164	-26
North West	462	-7	522	-187	51	280	36	620	2,136	8,102	477
Yorkshire and Humberside	39	-22	-194	-416	-5	980	-3	43	134	602	35
Wales	104	-2	72	-2	-9	71	3	8	53	637	11
West Midlands	346	-4	308	1,255	83	1,370	210	490	1,747	6,163	490
East Midlands	127	-10	87	2	6	196	16	39	221	543	62
South West	533	-4	708	40	13	416	46	45	9	127	1
South East	998	-10	2,161	137	58	1,688	177	7	0	0	0
London	3,548	-30	7,793	750	523	5,989	360	176	0	0	0
East Anglia	233	-9	531	34	12	527	64	1	0	0	0
Total Change	6,343	-68	12,368	1,543	817	11,819	977	1,813	5,164	19,658	1,264
HS2 related	5,991	0	11,203	0	89	9,221	0	1,507	4,780	17,913	967

Key

Intraregional no HS2	1,486	2.4%	Limited HS2 use	3,768	6.1%	London Comuter
Cannot use HS2	9,447	15.3%	HS2 to/from Scotland (80%)	7,196	11.7%	
Compaible service, no gains	2,127	3.4%	HS2 to/from NW (80%)	15,895	25.8%	
Partial (50%) HS2 use	13,395	21.7%	HS2 to/from WM (80%)	12,152	19.7%	

Source: HS2 Ltd with aspects highlights by WHS2

The only routes which definitely use the high-speed line link are those direct to London. To be very prudent, only these should be included. They are yellow (Scotland), North West (Green) and West Midlands (blue). Scotland presents a dilemma as we do not, despite FoI requests, have the data on specific passenger origins since HS2 did not possess this in any coherent format. As there are two major Scottish centres and only one is served by HS2 compatible trains, we have adjusted the figures so we only use 40% of the Scottish total. This reflects Glasgow's share of the air travel market.

We have nonetheless added in other services. On routes, such as to the SE where other services exist but HS2 offers good access, we have taken 50% of the HS2 Ltd increased demand estimate. On routes where a HS2 route path is possible, if more expensive and longer, we use 25%. We ignore services where classic compatible trains replace conventional trains but offer no advantages, for example, the North West to Glasgow. HS2 Ltd, however, includes these in its demand numbers.

We then estimate the shift from conventional to HS2 routes. The current network has 25% business use. We assume 80% of business users move, the other have destinations better served by conventional rail or lower budgets. Due to the expected premium, we have 50% of leisure users transferring. Leisure passengers are more susceptible to conventional rail discounting and HS2 does not offer a large time advantage and has less flexibility as to destination and connections. We note that HS2 has net time disbenefits to leisure passengers, a calculated figure not used by HS2 Ltd.

Air presents another dilemma. HS2 assumes, Exhibit 2.12 that 10,820 are attracted from air. As discussed earlier in the carbon and Heathrow demand sections, this seemed implausible. We have accordingly assumed that HS2 cuts two Glasgow and one Manchester return flights to Heathrow. Even if this is too pessimistic, it is prudent.

Exhibit 2.14 gives a modified HS2 modal switch and daily use rate. Our assumptions have no evidence base as such but they follow common sense and are transparent. They also avoid HS2 Ltd's tactic of claiming any increase in rail use even if it is on lines not served at all by the HS2 line.

Exhibit 2.14: Revised, prudent HS2 modal switch assumptions

Region to and from London	Mode shift from				
	Air	Road	New	Classic	Total
Scotland	640	42	1,423	3,029	5,134
North West	320	1,011	14,559	28,978	44,868
West Midlands	-	2,959	11,162	30,164	44,285
Total	**960**	**4,012**	**27,144**	**62,170**	**94,287**
% of Total	1.0%	4.3%	28.8%	65.9%	

Source: WHS2

Looked at in this way, it becomes clearer that the main beneficiary in movement terms is Manchester and the North West. Scotland has very marginally increased demand if over ambitious air targets are not included. This argues (excluding costs) for a direct Stage one Manchester connection and Birmingham spur which means avoiding irrelevant west London diversions. Adding Leeds in Stage will improve real benefits. This again rules out the Heathrow /OOC irrelevance.

This, of course, assumes that the over-confident underlying demand projection is correct. If the underlying demand growth is half that which HS2 Ltd projects, as many experts believe, the number in Exhibit 2.14 must be scaled accordingly. This would mean c 45,000 passengers a day on HS2 and three quarter empty trains. Carbon emissions and running costs would be virtually the same, however. The overall change is shown in Exhibit 2.15

Exhibit 2.15: Adjusted HS2 demand based on an asumtion of 50% less UK rail demand

	HS2 Ltd	WHS2 revised	Change
Business	43,500	34,260	-21.24%
Leisure	101,500	60,026	-40.86%
	145,000	94,287	-34.97%

Source: WHS2

Fares

The forecast models are not capable of developing sophisticated fare pricing schemes for taking into account premium fares. Some work was done in the Atkins demand model on integrated value of time calculations to enable some sensitivity on fares to be undertaken. No one seems to know what these mean, we have obtained minutes of meetings, and they are not standard in the industry.

A primary assumption behind the high speed two proposals is that there is **no difference** in fare between the conventional classic rail and HS2. This assumption underlies the demand forecasts. Rail fares are at 2002 levels adjusted for GDP and increased in real terms by 1% per year till 2033. This RPI+1% is a feature of regulated fares and mostly applies to London commuter fares. This might increase the fare line in the BCR by c 36% but it is difficult to establish this from the spreadsheets. Unregulated rail fares have risensharply, especially peak and fully flexible business fares.

Exhibit 2.16 shows the fares stated to be used by HS2 Ltd in its model. We do not know why the Glasgow fare is lower than Manchester. This makes the model over-emphasise Scottish demand.

Exhibit 2.16: HS2 fare assumptions

Table 8.4 - Business Fares (Average Pounds, one-way)

	0	10	20	30
Premium	0.00	3.84	7.68	11.52
London – Birmingham	38.39	42.23	46.07	49.91
London – Glasgow	44.92	48.76	52.60	56.44
London – Liverpool	51.55	55.39	59.23	63.07
London – Manchester	54.76	58.60	62.44	66.28

Table 8.5 - Leisure Fares (Average Pounds, one-way)

	0	10	20	30
	0	10	20	30
Premium	0.00	2.24	4.48	6.71
London – Birmingham	22.38	24.62	26.86	29.09
London – Glasgow	35.49	37.73	39.97	42.20
London – Liverpool	30.85	33.09	35.33	37.56
London – Manchester	31.82	34.06	36.30	38.53

Source: Model Demand Report Page 68 Table 8.4

To provide a reality check, the fares in Exhibit 2.17 were available in July 2010 via the internet. One could conclude that HS2 is maybe optimistic in leisure fares and pessimistic in business fares.

The actual fare numbers used by HS2 Ltd are calculated by PLD-PS-PM interlinked models with further manipulation in the spreadsheets. As we cannot replicate what HS2 Ltd. did to get these fares, not having adequate data, we have not been able to them more detail.

The HS2 Ltd fare numbers are in Exhibit 2.18. HS2 adds in separate passenger numbers for Planet South and Planet Midland. These are relatively small additions but PS and PM are purely regional models. We assume that these are passengers that PS and PM identify as long-distance and

therefore feed into PLD via wormholes and batch files respectively. If they are local, they should not be in the HS2 Ltd demand numbers.

Table 2.17: Peak and off-peak fares to Birmingham from Euston in 2010

	HS2	2010	
	Anytime	Peak 07.23	Offpeak 10.24
Business			
Advance 1st anytime single			£ 23.00
1st Class		£ 105.50	£ 60.00
1st anytime single	£ 38.39	£ 120.00	£ 120.00
Leisure			
Anytime single	£ 22.38	£ 70.00	£ 70.00
Advance anytime single			£ 6.00
Super offpeak single			£ 16.90

Source: Trainline.com

To get the PV fare figure of £15 billion, some manipulations had to be done, Exhibit 2.18. The conventional rail PLD fares are based on 2002 giving a PV of £8.7bn. Additional 2002 demand PV figures were then brought in from PLANET South and PLANET Midlands. This gives £9.77 bn PV in 2002. To bring these to a BCR 2009 PV this was multiplied by 1.27. The growth in GDP is accounted for by then multiplying by 1.21. Together, these give a multiple of 1.53. This gives the stated 2009 PV of £15 billion used in the BCR. Fares already have the tax element included.

Exhibit 2.18: derivation of 2009 PV fares

NPV classic rail NPV to 2002	£ 8,745.55		
PLANET South additon 2002	£ 789.94		
PLANET Midlands additon 2002	£ 230.55		
Total		£	9,766.04
Adjust by			
Convert 2002 to 2009	*1.272279263*		
Convert 2002 prices to 2009	*1.20750238*		
Total Adj (multiple of adjsutments)			1.536280237
Total fare NPV		£	15,003.4

Source: PLD in Econ_TemplateCombined_v13k_DAY1c_5079_PLD_AllACTBPinTime_FinalReported.xls cells /DCF row 89- , PV in Cell B152; PS in **Econ_TemplateCombined_v13e_DAY1c_5079_PS_ACTBPinTime.xls/DCF row 89, PV Cell B152;. PM in Econ_TemplateCombined_v13e_DAY1c_5079_PM_ACTBPinTime.xls/DCF row 89,** PV Cell B15;. PLD Econ_TemplateCombined_v13k_DAY1c_5079_PLD_AllACTBPinTime_FinalReported.xls/TEE-Main-2009 cells L9 and L10.

The peak fare level is £1.1 billion per year by 2033, Exhibit 2.19, in 2009 prices without any discount factor. As we cannot dissect this, further, when we adjust demand, we to scale this figure directly[21].

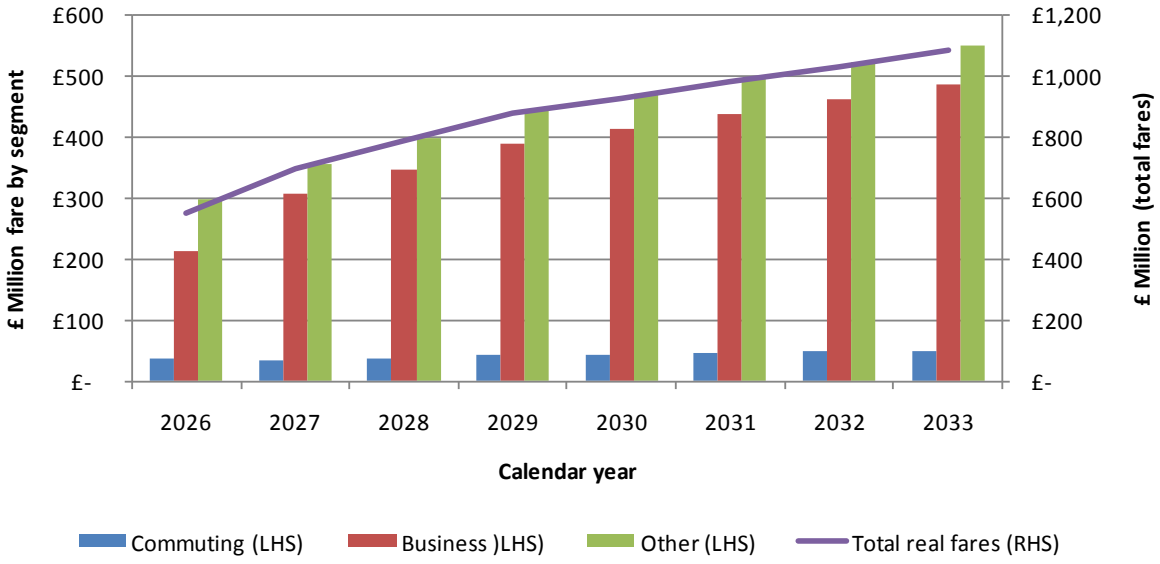
Other Costs

These costs are:

- Operations,
- Maintenance,
- Rolling stock company (not included but do s not mean that there will not be one),
- Operating company profits (not in HS2 Ltd BCR),
- Government profits.

[21] HS2 has stated this information it is held by its consultants. It would cost too much to retrieve this.

Exhibit 2.19: Fares to 2033 (volume growth plus RPI+1%) at 2009 prices



Source WHS2 based on HS2 Ltd data

Operations

HS2 has calculated that it will cost £186.7 million a year to run HS2 (2009 ex tax prices) or £241 m in private sector terms. We have not altered this figure. However, there is an assumption that each train has few staff. It is possible that this figure may be too low. In addition, we note that whilst HS2 Ltd increases intangible benefits by 2% per year, it does not do this for its staff salaries.

Maintenance

This is estimated to cost £231.8 million per year in 2009 ex tax prices or £280 million in private sector terms. This does not include renewal costs which are already in construction figures.

Operator profits

HS2 has some debate about how the line will be owned and run. If it is leased to a private operator, as it likely, the operator will have to make a profit. This is assumed to be 5% of revenues or £54 million per year. HS2 Ltd do not include these profits in its BCR. On a stock exchange utility basis, the owners might have a company worth maybe £250 million (P/E of 5x). If the Chairman and CEO each owned 10%, this would give each of them a capital gain of £25 million.

Track operator profits

If the track is also leased, as E&Y assumed in their report and as seems likely for HS1, the track operator will also make a profit. It is assumed that the operating company will pay £150 million per year in track access fees. The profits at 5% will be £7.5 million annually. This will also need a Chainman, CEO etc. These costs are not included in HS2 Ltd's BCR.

Rolling stock Company

There may be one but it is assumed that the 61 sets of rolling stock envisaged are part of the operating lease package. We have not costed this as it was not in E&Y.

Government profits

Whatever is left from fares and profits after costs is taken by the Treasury. This might be £880 million per year from 2033 (after operator profits). However cynically, government, despite demanding fees from train operating companies guarantees profits and still spends c £4-5 billion per

year on railway support. The East Coast route, surely a clear business winner, electrified, defined market, links major cities, has had many leasing troubles as it cannot make money.

Financing

A high risk project like HS2 funded by the private sector would need to show a high rate of return, much more than the 3.5% STPR used by the Treasury and in any case undermined by 2% VoT increases and 1% real fare rises. HS2 Ltd is very clear that it will need substantial subsidy. This means that taxpayers have to pay more tax or forego other investments, for example, in roads (taking most transport), regional development, schools, university R&D healthcare, defence or international aid. HS2 would be used by a minority and vastly benefits the west Midland and west side of London. Yet, all taxpayers pay.

The cash for HS2 will have to be borrowed. Even on elimination of the structural deficits, there will be in most years a government debt funding need. The cost in cash terms could be £35 billion.

In doing a cash flow model, the outcome depends on assumptions. Hence, the detailed findings are preliminary but the overall conclusions seem robust. To assess funding, we assumed the following.

- All intangible benefits are real cash and go to offset the debt burden. In fact, only the taxable element of any increase in GDP will do this (the indirect tax rate is 20.9%) and in practice, will spending £35 bn to get emptier trains generate much more GDP? However, the project is totally bankrupt unless one takes this assumption. We have, however, made it possible to tweak this number using our BCR model.
- There is no inflation but VoT benefits rise by 2% per year. This makes the intangible benefits very valuable as the project progresses. Fares rise in real terms by 1% per year till 2033.
- The wider economic benefits are real and have a 100% offset on costs. These rise by 1.5% (variable) per year so are increasingly valuable.
- The interest rate is cumulative. Current bond rates are around 3.5% but we assume that 5% is a more realistic long-term interest rate for a 75 year project.
- The operating and maintenance costs are as in HS2 Ltd.
- Profits are made by train operators.

On an inflation-free basis as above, the costs repay by 2046. The debt peaks in 2027 at £31 billion (2009 prices). We have not calculated real inflation adjusted debt using real optimism bias but a rise in debt to £40-50 billion is possible.

Of course, the treasury will not ever see the intangible benefits, other than as some increased VAT receipts and increased direct tax revenues. These cannot be measured in relation to HS2.

If one ignores intangible benefits, the government receipts per year, estimated at £880m per year, are less than the interest on the £31 billion of debt: £1.6 billion per year in 2027 (interest of 5%). Hence, the debt spirals out of control. It can only be recouped by increasing taxes. Of course, inflation over long time periods destroys debt.

The present value of the interest is up to £15 billion which represents £75 billion in non-discounted 2009 money. On the worst-case scenario, the debt is almost repaid by 2085

Perhaps the bigger question is what else we can buy for £35 billion cash plus £75 billion in interest?

Section 3: Sensitivity analysis

A spreadsheet is available so that alternative scenarios can be explored. The analysis looks first at the two BCR cases presented by HS2 Ltd looking at where the benefits and costs lie. The difference between the two is in the wider economic impacts. A series of scenarios are developed. All are based on HS2 figures or our interpretation of them. Exhibit 3.01 summaries our inputs to the scenarios. They are divided into percentage changes and on/off switches where an input can be either on (1) or off (0). The BCR values of each are in the bottom red boxes.

Exhibit 3.01 Scenarios on BCR calculations

	Base	No WEB	Curtailed	Financed	Real demand	Treasury Rules
Business	100%	100%	100.0%	100.0%	78.8%	75.8%
Leisure	100%	100%	100.0%	100.0%	59.3%	59.3%
Passenger forecast	100%	100%	100%	100%	65.2%	65.2%
% of intangibles accepted as cash	100%	100%	100%	100%	25%	100%
Wider Economic Benefits	1	0	0	0	0	0
VoT rise after 2033	1	1	0	0	0	1
CO2 costs	0	0	1	1	1	1
Realistic Optimism Bias	0	0	1	1	1	1
Operator Profits	0	0	1	1	1	1
Finance costs	0	0	0	1	1	1
Interest	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
BCR	2.71	2.41	1.37	0.68	0.04	0.28

Main values

Demand: this can be varied as a percentage of the original demand prediction with business and leisure and commuting as separate functions. The business function links to some of the economic benefits. The line "Passenger Forecast" gives the overall change in demand relative to the HS2 baseline. Demand changes affect fares.

The % **Intangible Benefits as Cash** allows variation in the intangible, non-cash benefits although it is policy to treat these as 100% cash GDP. This allows some assessment of sensitivity.

Wider Economic Benefits (WEB) can be switched on or off. This is 10% of the business benefits less crowding so scales accordingly.

Value of Time (VoT) rise after 2033. Standard practice increases VoT in perpetuity to capture the rise in GDP in wages. These can be held constant after 2033 in line with passenger numbers. If not, these benefits eventually exceed the current GDP..

CO_2: HS2 regards this figure as too uncertain – or embarrassing. It is a negative benefit as HS2 predicts it will be a net carbon emitter. It is marginal due to the low carbon price.

Realistic Optimism Bias: HS2 may have been too optimistic on its optimism bias. This switches in more prudent values.

Operator Profits: the HS2 train operating and track companies make a 5% profit on turnover according to Ernst & Young in their accounting report on HS2. HS2 forgot to include these.

Finance and interest, HS2 needs a £25-£35 billion subsidy to fund the construction. As we have a cash flow model, we can project finance costs using a choice of interest rate. We use the fare yield after costs and profits plus the infallible benefits to pay down the debt. In practice, only any surplus fare revenues can be used to do this.

Other demand values

Two other workbooks have been assembled to look at demand.

2033 HS2 Demand is concerned with correct allocation of new passengers to HS2 and wit the modal switch from conventional rail to HS2. It has a further function to allow the underlying conventional rail demand to be adjusted.

Rail demand is a simple model that takes any projected GDP growth rate, adds any rail demand elasticity (the percentage rate of rail use growth for every 1% of GDP growth) and calculates a revised 2033 demand. This can be switched into the 2033 HS2 Demand sheet and thence into the BCR. The sheet also report the BCR value back so can be used for sensitivity analysis on the GDP. It is not used in the following examples as it adds a further layer of complexity

HS2 Ltd Base cases

The two BCR scenarios presented by HS2 ltd are in exhibit 3.02. These are with and without wider economic benefits. As Section 2 showed, 79% of these benefits accrue to the west Midlands and West London. The base case BCR is 2.71.

Exhibit 3.02: HS2 ltd BCR calculations

	HS2 Ltd	
	Full	ex WEB
Non-cash intangible "benefits" treated as 100% cash under		
Business	£17.56	£17.56
Leisure and commuting	£11.10	£11.10
Economic (WEB)	£3.62	£0.00
Other (Road, Carbon)	£0.04	£0.04
Total Benefits	**£32.32**	**£28.71**
Cash items in 2009 private sector money		
Fares	£15.00	£15.00
Construction and trains	-£17.85	-£17.85
Finance	£0.00	£0.00
Operating Costs	-£7.60	-£7.60
Lost Indirect Taxes	-£1.47	-£1.47
Total Costs	**-£11.91**	**-£11.91**
Ratio	**2.71**	**2.41**

	Base	No WEB
Business	**100%**	**100%**
Leisure	**100%**	**100%**
Passenger forecast	**100%**	**100%**
% of intangibles accepted as cash	**100%**	**100%**
Wider Economic Benefits	**1**	**0**
VoT rise after 2033	**1**	**1**
CO2 costs	**0**	**0**
Realistic Optimism Bias	**0**	**0**
Operator Profits	**0**	**0**
Finance costs	**0**	**0**
Interest	**5.0%**	**5.0%**
BCR	**2.71**	**2.41**

The top section shows the summary Present Values of each section as discussed in Section 2 based on the methodology described in Section 1. The bottom, coloured section shows variables which will be adjusted in the following scenarios.

Wenover HS2 Scenarios

We have prepared four scenarios to illustrate the sensitivity of the BCR model.. These are shown in Exhibit 3.03. Each scenario is the discussed in turn.

Exhibit 3.03: Wendover HS2 Scenarios

	Wendover HS2 Scenarios			
	No WEB or VoT post 2033, real Op Bias	Profits and Finance	Realistic Values	Treasury Rules
Non-cash intangible "benefits"				
Business	£12.49	£12.49	£1.19	£8.26
Leisure and commuting	£8.55	£8.55	£0.62	£3.20
Economic (WEB)	£0.00	£0.00	£0.00	£0.00
Other (Road, Carbon)	-£0.13	-£0.13	-£0.14	-£0.14
Total Benefits	**£20.91**	**£20.91**	**£1.66**	**£11.32**
Cash items in 2009 private sector money				
Fares	£15.00	£15.00	£10.26	£10.26
Construction and trains	-£20.39	-£20.39	-£20.39	-£20.39
Finance	£0.00	-£15.43	-£26.28	-£22.15
Operating Costs	-£8.46	-£8.46	-£8.20	-£8.20
Lost Indirect Taxes	-£1.47	-£1.47	-£0.60	-£0.60
Total Costs	**-£15.31**	**-£30.74**	**-£45.21**	**-£41.09**
Ratio	**1.37**	**0.68**	**0.04**	**0.28**

	Curtailed	Financed	Real demand	Treasury Rules
Business	**100.0%**	**100.0%**	**78.8%**	**75.8%**
Leisure	**100.0%**	**100.0%**	**59.3%**	**59.3%**
Passenger forecast	**100%**	**100%**	**65.2%**	**65.2%**
% of intangibles accepted as cash	**100%**	**100%**	**25%**	**100%**
Wider Economic Benefits	**0**	**0**	**0**	**0**
VoT rise after 2033	**0**	**0**	**0**	**1**
CO2 costs	**1**	**1**	**1**	**1**
Realistic Optimism Bias	**1**	**1**	**1**	**1**
Operator Profits	**1**	**1**	**1**	**1**
Finance costs	**0**	**1**	**1**	**1**
Interest	**5.0%**	**5.0%**	**5.0%**	**5.0%**

Curtailed

This scenario, asks how important is the assumption, used in the 1980's in transport planning, that the Value of Time rises at 2% a year. By doing this, the longer the project horizon, the better the BCR; HS2 Ltd uses 60 years. Further, the VoT adjustment means that the STPR used for discounting is 57% lower. This favours non-cash benefits over costs in the BCR. These non-cash benefits are 74% (business) and 62% (leisure) related to crowding. Hence, if another means to alleviate crowding can be found, these benefits are delivered at lower cost. We have also adjusted for optimism bias. This

increases the construction costs from £17.8bn to £20.4bn in Present Value terms. In addition, we add in the HS2 operator and track management profits; these are not large overall once discounted.

The impact is massive. If the VoT growth is zero after 2033, as happens for demand and fares, the BCR drops from 2.41 to 1.37. Since these non-cash benefits are not seen at the Treasury, except maybe in marginal increases in tax revenues, the taxpayer is left funding the debt. Do we want to pay hard cash to buy hypothetical benefits?

Financed

HS2 has to be paid for in cash. This is an inconvenient truth that HS2 agonised over and then asked for a large subsidy whilst being vague about the true levels it might need. Exhibit 3.03 shows what happens if finance is added to the Curtailed scenario. The spreadsheet allows other variations.

The Finance Charge in Present Value terms is £15 billion. The debt peaks at £32 billion but is still repaid by 2049 as the non-cash benefits are still substantial and still count 100% as real GDP payback. The cash costs now outweigh the non-cash benefits.

Real Values

This takes the Finance scenarios and put in our realistic demand forecast. We use 25% of the indirect benefits noting that the indirect tax element of the economy is actually 20.9%. The BCR at this point is now close to zero: 0.04. This is as close as we can come to a realistic cash-based BCR value for the project. We are aware that this scenario breaks two transport planning guidelines, namely that all non-cash benefits are treated as 100% real cash and that VoT is increased towards infinity.

Treasury Rules

This scenario duplicates the Real Demand version but has VoT added back in as this seems to be a standard element. The Intangible Benefits are also recognised in full. Even so, the BCR is still only 0.28. This illustrates again the high sensitivity to demand of the HS2 Ltd case. HS2 needs to have demand 137% greater than the 145,000 passengers per day to be a viable project. As experts have already queried the high demand forecasts, this looks unlikely.

Conclusions

This HS2 Ltd proposal is arbitrary and driven by lobbyists, consultants and contractors. HS2 Ltd has hidden the hollow reality of its business case behind spurious certainties and obscure numbers. The BCR scenarios show that the model is exquisitely sensitive to small variations in growth assumptions. As others have noted, there are easier ways to increase UK rail capacity at lower cost and faster.

It might be that the UK eventually needs a new efficient rail scheme that connects the major northern cities and London directly, by doing this, real demand might be there paid in real cash. Further, all regions should be treated equally. A project that the entire UK pays for but that benefits two regions disproportionately, one of them being the richest parts of London, is hardly equitable.

Our conclusion is that a proper evaluation of High Speed rail in the UK needs to be done and its strengths and weakness impartially set out. The body doing this must to be one that voters can trust. Only then the public judge such a scheme fairly.