High Speed Rail: HS2 – A Project Business Case in Crisis [1]

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HS2 is the UK's future high speed railway network. The project's initial objective was to provide an additional 134 mile high speed rail link from London to the centre of Birmingham. After a series of delays, the UK Government's current plan is to have this link, HS2 Phase 1, in operation by 2029. The plans for HS2 have also been extended to build additional high speed rail links North of Birmingham. The first of these links is covered by the HS2 Phase 2a plan to extend the line to Crewe through the West of England. Phase 2a will enable connections to be made via existing traditional (lower speed) railway lines with terminal points in Liverpool and Macclesfield. It is also planned for completion in 2029.

Further extensions to the HS2 network are covered by the Phase 2b plan due to complete in 2035. Phase 2b will provide high speed connections to Manchester and Leeds and three further links to existing railways, providing reach to Sheffield, the North East of England (through to Newcastle) and through the North West of England and Scotland (to Edinburgh and Glasgow). Figure 1 is a simplified version of the overall network figure that can be viewed on the HS2 website [1] and shows why it is often described as resembling a Y figure.

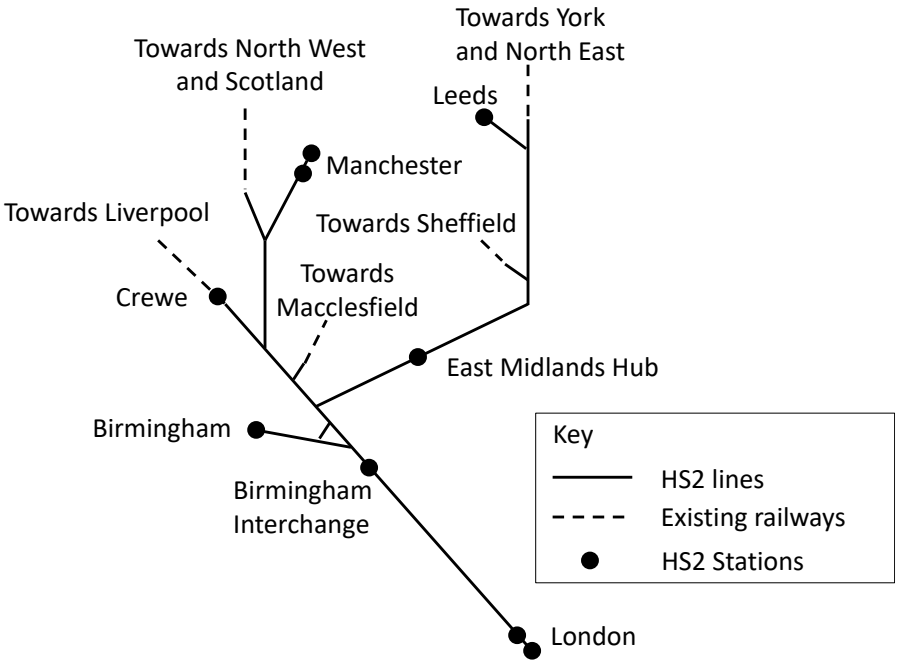

Figure 1: The HS2 network and its connections with existing (traditional) railways

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The project has always been controversial. One reason for this has been its escalating cost. HS2 has become exceptionally expensive with a project delivery cost likely to exceed £100bn at 2020 rates. Opponents of the project have also questioned the basis for calculating the economic benefits of reduced journey times. Despite this, the Government's calculation of the Benefit Cost Ratio (BCR) has remained favourable. This paper challenges the assumptions that lie behind this calculation. In doing so, it illustrates the sensitivity that a BCR calculation has to a combination of challenges to both a project's cost and its benefits.

The Department for Transport Business Case

On 11th February 2020 the Prime Minister, Boris Johnson announced that the government was committed to building both Phase 1 and Phase 2. The Project Notice to Proceed (NtP) to industry followed two months later on 15th April. The Government's project business case for Phase 1, signed by Andrew Stephenson MP, Minister of State at the Department for Transport (DfT), was issued in the same month [2]. Table 1 below shows the BCR calculation from that document. The figures are based on present values at 2015 rates and exclude sunk costs, of approximately £6bn. The benefits estimates are based on the first 60 years of planned service.

PV, 2015 prices, £bn	Phase 1 only	Phase 1 and 2a	Phase 1, 2a and 2b
(1) Net Transport benefits (incl. wider economic impacts)	32.8	38.0	94.7
(2) Total costs	43.3	51.2	108.9
(3) Revenues	15.7	18.4	45.4
(4) Net costs to government = (2) - (3)	27.6	32.8	63.5
Benefit Cost Ratio (incl. wider economic impacts = (1) / (4)	1.2	1.2	1.5
Value-for-Money Category	Low	Low	Low to Medium

Table 1: Government HS2 BCR Calculation, April 2020

A BCR value that exceeds 1.0 indicates a project for which the benefits are forecast to exceed the costs of project delivery and subsequent ownership. Table 1 shows that the government has forecast a favourable BCR for all phases, including for phase 1 only. However, building the full Y shaped network is forecast to increase the BCR to 1.5. Although this latter value would appear to be reassuring, it can be noted that the equivalent calculation made by the DfT business was 2.3 [3]. The drop from 2.3 to 1.5 over the intervening three years is attributable to escalation in the cost forecast and a three-year delay to the service commencement date, illustrating the sensitivity of BCR calculations to their input estimates.

The DfT business case was released at the height of the Covid-19 pandemic. The document acknowledges the pandemic to be an issue but comments that it would be unlikely to affect

progress with construction. It does not consider the question as to what effect the pandemic experience will have on the long-term demand for business-related travel.

Oakervee - The Government's Independent Review

The UK Government's decisions in February and April were preceded by an independent review commissioned by the DfT in 2019. The review panel was chaired by Doug Oakervee and its final report is titled the Oakervee Review [4]. Its key conclusion is a strong recommendation that the project should not be cancelled. As a former Chair of HS2, Oakervee was a controversial choice for the chair of review panel. It was, after all, difficult to argue that he would be seen to be taking an independent position. Evidence from later sections of this paper supports the contention that he failed to do so.

Based on the higher end of the updated HS2 "Chairman's stocktake" cost estimate, the Oakervee Review forecasts the HS2 project BCR to be 1.3, but only on condition that the full Phase 1 / Phase 2 y-shaped network is built. If the project was restricted to Phase 1 only the BCR would be approximately 1.0. Table 2 uses data from the Oakervee Review and summarises how it assessed the BCR for the full Phase 1/2 network.

	Benefits-Cost Ratio Components capturing the impacts 60 years after opening	PV £ billion, 2015 prices
1	Total Cost (capital, operational and whole life costs)	114.5
2	Revenue (net of abstraction from other rail services)	45.4
3	Net Cost to the transport budget = (1) – (2)	69.1
4	Net Transport benefits	74.2
5	Wider economic benefits	18.4
6	Total Benefits = (4) + (5)	92.6
7	Net Present Value (NPV) = (6) – (3)	23.5
8	Benefits to Cost Ratio (BCR) = (6) / (3)	1.3

Table 2: Oakervee Review HS2 Full Phase 1/2 Economic Business Case Summary

A comparison of Tables 1 and 2 suggests that the DfT's BCR calculation is based on optimistic estimating choices. Its total benefits estimate is approximately £2bn higher than the Oakervee Review and the cost forecast corresponds with a build cost at the lower end of the Chairman's stocktake. The DfT thus chose to disregard some of the estimates adopted by the independent review panel that it had appointed.

The Berkeley Report – Towards a more Realistic BCR Calculation

The Oakervee Review's BCR calculation was itself controversial. Its own panel's Deputy Chair, Lord Tony Berkeley, cited a range of issues and refused to support the final report. Instead, he chose to publish his own report [5] in January 2020. In this report, he disclosed a number of experiences which, in his view, indicate that the undeclared purpose of the Oakervee Review was to confirm that the project should proceed whilst adjusting the business case to cover issues that were already known to exist. For example, he complains that the panel was reliant mostly on data sourced by HS2, that it was given insufficient opportunity to challenge the basis of the HS2 cost estimates, and that it had declined to make use of an independent bottom up estimate that structured using on recognised best railways practice. This bottom up estimate (excluding the cost of rolling stock) was £103bn at 2015 prices, more than 25% higher than the HS2's Chairman's stocktake.

As a member of the Oakervee panel, Lord Berkeley was also able to estimate the economic effects of differing train frequency assumptions. The government business case assumes a frequency of 18 trains per hour (tph). However, the Oakervee Review noted that no other high speed train service in the world operates at this frequency and recommended a maximum of 14 tph as being an appropriate working assumption. The network shown in Figure 1 illustrates one the issues that may have been of concern to Oakervee panel members. A train frequency 18 tph would imply that trains directed down the single line towards London will be spaced at intervals of just over 3 minutes. Given that they will be travelling at speeds of 330 kph routinely, the coordination of trains will have to be controlled to accuracies of measured in seconds. Yet these trains will be arriving from 8 different branches, five of which commence on an existing railway system on which the rate of delays exceeding one minute is greater than 30% [6]. It would seem likely that the objectives of maximising both connectivity and service frequency will prove to be mutually exclusive and that one or both will be compromised. There is also a risk that the need to prioritise the timeliness of HS2 trains will impact negatively on the reliability of other rail services that use the existing lines.

HS2's calculation of benefits is dependent both its connectivity and its train operating frequency assumptions. If one or both are reduced, the project's benefits are also reduced. One of the issues identified by Berkeley is that, despite the Oakervee Review's own findings, its BCR calculation retained the 18tph assumption.

Table 3 summarises the BCR calculations in the Oakervee and Berkeley Reports. The differences are attributable to two factors: the cost of project delivery and a reduction of the train operating frequency to 14 tph.

	HS2 Phase 1 and Phase 1, capturing impacts up to 60 years following commencement of full service	PV £ billion, 2015 prices	
		Oakervee	Berkeley
1	Total Cost (capital, operational and whole life costs)	114.5	119.9
2	Revenue (net of abstraction from other rail services)	45.4	30.6
3	Net Cost to the transport budget = (1) – (2)	69.1	89.2
4	Net Transport benefits	74.2	58.6
5	Wider economic benefits	18.4	13.8
6	Total Benefits = (4) + (5)	92.6	72.4
7	Net Present Value (NPV) = (6) – (3)	23.5	-17.1
8	Benefits to Cost Ratio (BCR) = (6) / (3)	1.34	0.81

Table 3: Berkely and Oakervee – Comparison of BCR calculations for HS2

Table 3 provides an example of how changes to both the costs and benefits of a project can combine to transform a BCR calculation. In this case, the project is transformed from one that seems likely to be of economic benefit to one in which the cost exceeds the benefits. The UK Treasury guidance describes projects with a BCR less than 1.0 as being of poor value for money. If one was to judge such projects in purely economic terms, they could be equally described as being worse than useless.

The Berkeley Report was published in January 2020. Thus, when making its decision to proceed with the project on 11th February 2020, the UK government knew that the business calculation was contentious and that there were reasons to believe that the Oakervee BCR calculation might be optimistically biased.

Further Challenges to the BCR Calculation

The phenomenon of optimism bias affects projects across a wide range. Major public projects are not immune. A strong body of evidence for this can be found in the book *Mega Projects and Risk* by Flyvbjerg, Bruzelius and Rothengatter [7], who show that project costs and benefits both tend to be optimistically biased. In practice it is issues with the cost element that most often cause controversy. In comparison, issues with benefits tend to be identified later, receive less attention but be of greater importance [8]. Thus, if, a project's estimates are optimistic, its estimates for benefits may be even more optimistic than its cost estimates. Despite this, the DfT and Oakervee BCR calculations appear to have made either minimal or no adjustments to the HS2 estimates for benefits, whilst the Berkeley benefits adjustment is confined to the impact of reducing the train frequency to 14 tph. Given HS2's proven record for optimistically biased cost estimates, it is reasonable to consider whether its other estimates for benefits might not also optimistically biased. The following sections describe the potential impact on the BCR for the following three additional challenges:

1. HS2's profitability in service.
2. Delays to the service caused by prolongation of the project implementation phase.
3. Future demand for business travel in the wake of the Covid-19 pandemic.

This list is not exhaustive. For example, HS2's approach to estimating the economic benefits of shorter journey times has been questioned. Similarly, disbenefits, such as ecological damage, noise and the permanent severance of land have been given no economic value. However, the list illustrates ways in which the DfT may have failed address issues that could have a significant impact on the economic business case. Failure to take account of unhelpful but contentious issues is a common cause of optimism bias.

HS2's Profitability in Service

HS2's forecast profitability can be estimated by comparing its forecasts for revenue and operating costs. Since the latter includes the manpower costs for running the trains and stations and the costs of maintaining the infrastructure, these forecasts run side by side over time. The effects of present value adjustments are thus similar, making the comparison valid, at least approximately. The Berkeley report quotes the present values for revenue and operating costs as being £43.6b and £27.6b respectively (or £30.6b and £19.7b respectively assuming 14 trains per hour). These figures, derived from those prepared by HS2, would indicate that the railway will run at a profit level of more than 50% above costs. This profit can be compared to the losses made by the UK's traditional railways, which require government subsidies.

Why is it that the UK's fastest and most expensive rail system can be expected to make a profit when its traditional railways do not? Why is it forecast to make a profit at a rate higher than any other high speed rail in a capitalist country? And why is it forecast to make such a profit even though, unlike many other high speed rail services, it will compete with a traditional railway service running along approximately parallel routes? The most obvious answer is that it will not and that its forecast is based on optimistic estimates. If this is the case, its estimates for operating costs are likely to be too low and its revenue forecast likely to be too high. If the Berkeley BCR calculation is adjusted to equalise revenue and operating costs, the BCR is reduced from 0.81 to 0.72 as detailed in Table 4. This would represent the position in which the HS2 breaks even; a financial performance that is still superior to that the current system of traditional railways.

	HS2 Phase 1 and Phase 1, capturing impacts up to 60 years following commencement of full service	PV £ billion, 2015 prices	
		Berkeley	Adjusted
1	Total Cost (capital, operational and whole life costs)	119.9	125.3
2	Revenue (net of abstraction from other rail services)	30.6	25.2
3	Net Cost to the transport budget = (1) – (2)	89.2	100.1
4	Net Transport benefits	58.6	58.6
5	Wider economic benefits	13.8	13.8
6	Total Benefits = (4) + (5)	72.4	72.4
7	Net Present Value (NPV) = (6) – (3)	-17.1	-27.6
8	Benefits to Cost Ratio (BCR) = (6) / (3)	0.81	0.72

Table 4: Berkeley BCR adjusted to with equalised revenue and operating costs

Implementation Phase Prolongation Risk

The Oakervee and Berkeley Reports both comment that HS2 has identified significant sources of schedule risk. However, they do not disclose the results of its schedule risk analysis. A prolongation of the planned implementation phase would mean that the London to Birmingham service will start later than 2029 and that that the full Y-shaped network will not be in operation by 2035. This would impact on the BCR calculation by delaying the points in time at which benefits start to materialise. Given that HS2 has already proved itself to be prone to unrealistically optimistic cost estimates it would be unsurprising if its schedule estimates prove to be similarly unrealistic. One thing to bear in mind is that some sources of cost increase if a project takes longer to deliver. Thus, when working in an environment that fosters optimistic cost estimates, it becomes convenient to assume that the project will delivered over a shortest plausible period of time.

There is also little evidence that the HS2 has adjusted its schedule in response to the lessons being learned on the London Crossrail project. Crossrail (or the Elizabeth Line) is a new East-West underground/railway line running across London and was planned to open in December 2018. The public was led to believe that this would be the opening date until as late as five months before the event. The London Mayor, Sadiq Khan, appeared to be as surprised as anyone by the delay. Since then there have been further announcements of delay. The current position is that the complete service is unlikely to commence prior to the middle of 2023. On the face of it, the final five months of work on the project will have taken almost five years! It may be instructive to look at the reasons for late delay and future schedule risk as identified by the National Audit Office [9]. These include software development and system integration. For example, the trains' operating system has to be developed and tested to work with three different signalling systems.

System integration risk is a feature of many complex engineering projects. Part of the problem is that systems integration is not well understood by either project sponsors or project managers and that this leads to unrealistically optimistic schedules. Another part of the problem is that new systems and designs can produce new integration issues that even the best engineers are unable to anticipate in advance. To the inexperienced observer the obstacles are baffling: all the system's components are available, each of which work in itself, and yet the system itself will not work without significant changes. Even when those changes are made, new problems may emerge. System integration causes delays to engineering projects just as they seem to be nearing completion.

HS2 is unlikely to be immune from systems integration risk, particularly as it will be integrated with a number of existing railways. Thus, whilst, like Crossrail, HS2 might make relatively good progress with earlier activities such as boring tunnels and laying track, it is the later activities that bring the overall system together that could prove to be more difficult. Despite its recent difficulties, Crossrail still has a better record for estimation and planning than HS2. Even if HS2's schedule forecasting performance proves to be no worse than Crossrail's, delays to the commencement of its services will be measured in years.

Future demand for business travel in the wake of the Covid-19 pandemic

It is not clear how the HS2 revenue forecasts have been produced. Even as a member of the Review panel, Lord Berkeley has reported having seen no information related to matters such as the pricing strategy. However, there are some stated assumptions that provide useful clues. For example, it has been assumed that there will be 2.5% growth in the demand for long distance train journeys each year until the late 2030s. Thereafter, it has been assumed that this growth will be in line with the growth in the UK's population. It has also been assumed that all of the growth in passenger demand for trains routed from Birmingham to London will be channelled into HS2. These assumptions are all important factors that lie behind the HS2 estimates for revenue and transport benefits.

By recent pre-pandemic standards the 2.5% annual demand growth for long distance rail journeys is relatively prudent. The equivalent figure in recent years up to 2019 has been above 3%. However it has also been noted that previously high rates in the growth in demand for shorter train journeys have tailed off in recent years. One question is thus whether or not this trend will start to affect longer journeys. However, perhaps the bigger question is whether extrapolating demand in this way from historical trends might be wholly misleading. In practice, much of the increased demand to be filled by HS2 is expected to materialise from people travelling to business meetings. Indeed, connecting businesses through the centres of the major urban areas of England is its core purpose and is intended to help rebalance the country's economy by levelling up other cities with London. Given the manner in which business have chosen to operate historically, this might seem to be a good strategy. But this risks the mistake of projecting our understanding of the future by looking at past behaviours. In particular, the business case for HS2 assumes that business people will continue to travel in increasing numbers to conduct face to face meetings. The advent of increasingly sophisticated virtual meeting systems and the drive for ever increasing internet bandwidth could result in this assumption becoming false.

The recent Covid-19 pandemic has given the business world an opportunity to test virtual meeting systems on a transformative scale. While the experience has not been consistently positive, it has been discovered that virtual meetings have a number of advantages, the saving of travel costs being but one. Moreover, business people have had to learn how to use the virtual meetings technology, thus acquiring skills that will make its continued exploitation more likely. Virtual meeting technology will also improve into the future. In these circumstances, it would be difficult to believe that HS2's passenger demand forecasts are realistic. Yet its business case is based on forecasts for demand up to the year 2095. Disregarding the competing opportunities arising from a virtual business environment is an example of the perils of projecting project estimates so far into the future.

The recent Covid-19 experience also resulted in large number of organisations requiring their employees to work from home. Again, this has also produced mixed results. However, it has become difficult to believe that all organisations will return to the practice of expecting such a high proportion of their employees to commute. If this becomes a permanent change to the pattern

of working lives, the trend for traditional commuter rail services to become increasingly packed is likely to be reversed. This would cause the demand assumptions used to plan HS2 and estimate its benefits to be fundamentally flawed. Despite this, there has been no indication from the British government that it will reconsider the project in this light.

A More Realistic BCR Estimate for HS2

To summarise, this paper identifies five issues with the BCR calculations used by the British Government to justify pressing ahead with HS2:

1. The project delivery costs are likely to be higher (as identified in the Berkeley Report)
2. The benefits calculations should be based on a train frequency of no more than 14 tph (as is also identified in the Berkeley report)
3. The ratio of revenue to operating costs should be challenged.
4. Significant schedule delays are likely to occur that could cause cost escalation and decrease the value of benefits.
5. The passenger demand assumptions should be reassessed in the wake of the Covid-19 pandemic.

The effects of issues 1 and 2 are reflected in Berkeley's BCR calculation detailed in Table 3. The additional effect of issue 3 is reflected in Table 4 which gives a BFC of 0.72. The further effects of issues 4 and 5 are more difficult to predict because of the high levels of uncertainty involved. However, my own modelling suggests that a BCR value of around 0.4 is a realistic representation of the middle of the range involved.

The HS2 Payback Period

A project's payback period is the time taken for its cumulative benefits to exceed its cumulative costs. This is the time by which the cumulative Net Present Value is zero. Comparing the Oakervee and Berkeley Reports highlights the political importance attached to BCR calculations. In comparison the project payback period is an aspect of the project that receives little or no attention. It is not included in the government business case and the reports don't mention it or even suggest that it has any importance.

In an attempt to calculate the payback period, I created a simple model to simulate the effects of business cases figures presented in the reports. The results of this are shown in Figure 2. Without the base data, the accuracy of this analysis is, of course, limited. In the case of the Oakervee business case, my estimate is that the cumulative value of the benefits just matches the cumulative value of the costs in 2056. This point is marked by where the cumulative NPV curve crosses the x-axis and can be used to calculate that the payback period starting from the main decision point in 2020 is 36 years. Including sunk costs would prolong this by approximately 3 years. If this analysis were to be performed with the HS2 base data, the calculated payback periods might be

longer or shorter. However, it is unlikely that they would be sufficiently different to change the types of issue that are prompted by the results.

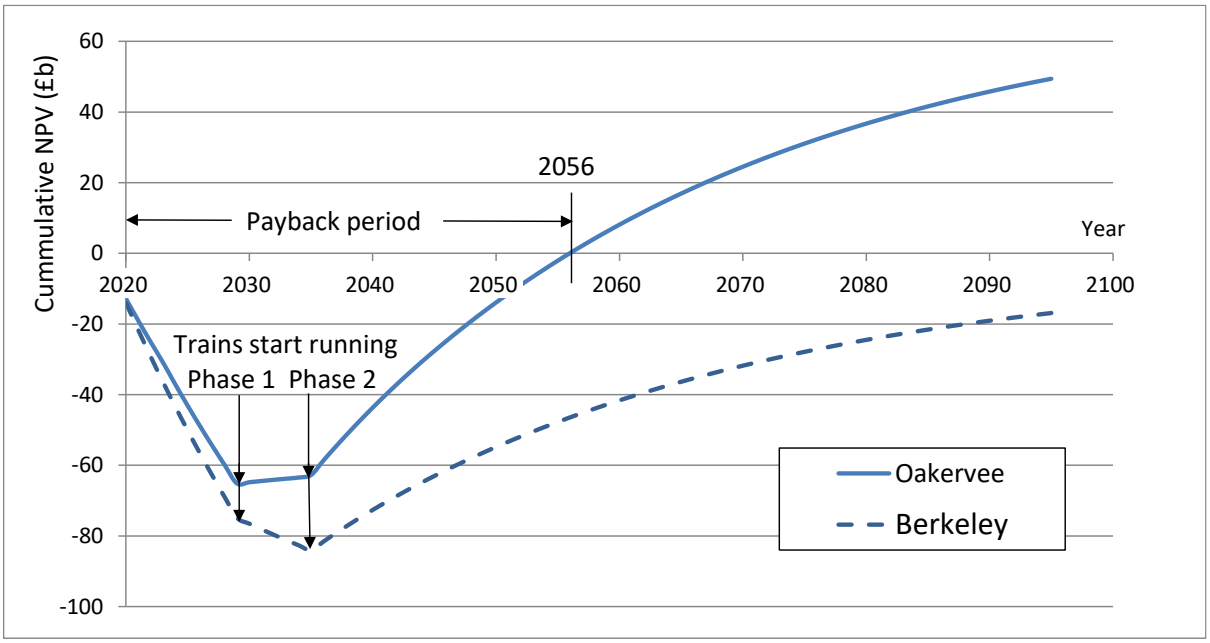

Figure 2: Cumulative NPVs and the Payback Period

If the Oakervee business case proves to be optimistically biased, the payback period would be longer. The payback period's sensitivity to input estimates can be illustrated by modelling the estimates in the Berkeley BCR calculation. In this case there is no payback period; the project never gets back into credit during the 85-year period over which it is modelled. Taxpayers would have to wait until 2095 just to recover to a position in which there has been an economic loss equivalent to £17bn. In the meantime, the cumulative values of economic loss will have been much higher peaking, at over £80bn.

HS2 and the Political Aims of Economic Rebalancing

Even if the HS2 project fails to deliver economic value, it might be argued that the project could be deemed a success if it delivers intangible benefits that are perceived to more than compensate for any economic shortfall. Since not all benefits can be measured in terms of money, political choices should not simply be driven by a BCR forecast.

HS2 has been identified by the government as being an important part of its strategy for rebalancing the economy. In essence, this rebalancing is intended to enable the North of England to catch up with the rate at which wealth is being generated in the South. Rebalancing the economy is a valid political aim, even if it fails to produce a net economic benefit to the country. Narrowing the so called North-South divide is arguably the most important intangible benefit that HS2 is intended to deliver. It is thus important to consider whether or not the new service will achieve this aim.

The key feature of the project is that it will enable faster travel between cities. For example, the average journey time between the centre of Manchester and London should be reduced by one hour from 2hrs 8 mins to 1hr 8mins. However, these faster journey times will only help the cause of economic rebalancing if, on average, the resultant business growth is stimulated in Northern cities to a greater extent than in London. The design of the line and its effects on timetabling make this doubtful. As shown by the branching network in Figure 1, trains to and from London will be divided between routes to different destinations. As a consequence, Londoners will be able to travel directly to and return from any station in the new network. This will not be true of any other station. Any business requiring complete HS2 connectivity will have to be based in London.

After London, Birmingham will benefit from the next greatest number of services and connections. Compared to London, Birmingham will also benefit from being closer to the cities with which it will be connected. It would therefore seem probable that the centres of Birmingham and London will prove to be the most attractive sites from which businesses can exploit HS2-related benefits. In contrast, the benefits to Northern cities are more limited. For example, people travelling from Manchester will be able to travel directly only to London, Birmingham or the Birmingham Interchange. Some towns and cities will only be able access high speed rail travel to and from London. Liverpool is an example. With the sole exception of the new link between Manchester Piccadilly and Manchester Airport, it can also be noted that HS2 will not improve journey times within the North of England or between Northern cities and Scotland. Nor will HS2 provide much needed increases in railways capacity and efficiency within the North. Indeed, if future UK rail investment becomes concentrated on HS2, the project railways improvement projects in the North of the country may be held back. Overall it is difficult to see how this approach will contribute to narrowing the North-South divide.

The need for economic rebalancing should also be understood in a wider context. Besides the issue of the North-South divide, there is an emerging issue of division within regions. Evidence from this can be seen in voting patterns that suggest a growing feeling within some communities of having been "left behind". Many in these communities have voted Leave in the EU referendum of 2016 or have abandoned their traditional preference for the Labour Party in favour of the Brexit or Conservative parties. Although these communities are often to be found in the North of England it is noticeable that they tend not to be in in the large urban areas that will benefit most from HS2. It seems likely that this is because city centres such as Birmingham, Manchester and Leeds have done well by comparison with the regions that surround them. If this is the case, the effect of HS2 may be to exacerbate what has been a growing problem. The winners will be in a small number of locations that that are already thriving, whilst the losers will tend in be those places that already feel left behind.

Discussion and a Recommendation

Flyvbjerg, Bruzelius and Rothengatter have identified how optimism bias has affected government-backed infrastructure projects across a number of Western countries. Their book

identifies a number of causal behaviours amongst politicians and senior government decision makers, including lying. There is no evidence in this paper that anyone in the UK has lied in order to support the HS2 project. However, there is evidence to suggest that significant issues about the business case have been ignored. In some cases this is despite the issues have been drawn to the attention to the DfT by experienced and respected professionals. The selective use of estimates is a classic cause of optimism bias.

When considering the effects of project risk it is important to strike a balance between optimism and pessimism in order to be realistic. The evidence in this paper suggests that in setting out its business case for HS2, the UK Government has failed to follow this principle and that some of the people involved must know this to be the case. If so, the DfT's HS2 economic business case should be understood as being one-sided and unrealistic. It is a political document.

The Covid-19 pandemic will have longstanding effects on business practice. It would seem likely that passenger demand for business-related train transport will be negatively impacted in the long term; a period of "very long Covid". This would fundamentally undermine forecasts based on the extrapolation of future demand from previous trends. However, the pandemic did not start until after Boris Johnson announced that the project would proceed to completion. The context of HS2 has thus changed in a way that could not have been envisaged at the time, creating a political opportunity for UK Government to re-assess the HS2 business case. This paper concludes with the recommendation that the Government should take this opportunity and establish a truly independent panel to support the review.

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