Infrastructure & Risk: Identification, Management & Transfer of Risk by HM Treasury

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28/02/14

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1 Introduction

Large infrastructure projects have a reputation for being risky and costly. This reputation is well founded, Flyvbjerg et al. (2003) estimate that 90% of infrastructure projects result in cost overruns, with costs on average 28% higher than anticipated. The UK is not immune to this trend, in fact when compared to other European countries the UK performs particularly poorly. A review of infrastructure cost by HM Treasury and Infrastructure UK (2010) found that both construction and maintenance costs for high speed rail links (for example) were considerably higher than similar projects in Europe. Clearly then, there is potential to improve infrastructure selection and delivery.

This report examines the risk identification, quantification and management processes put forward by HM Treasury (2011) in their guidelines for appraisal and evaluation (known as the Green Book). The aim of this report is to give a broad overview of existing processes and identify how these processes and their implementation contribute to the UK's poor record of infrastructure delivery.

2 Project Appraisal: Risk Identification and Quantification

This stage of the project lifecycle consists of identifying potential options for achieving the project objectives and consists of:

- Estimation of Costs
- Estimation of Benefits
- Valuation of cost and benefits with no market value (e.g. social and environmental impacts)
- Adjustments of the above values to account for distributional effects and relative price changes
- Estimation of a suitable discount rate

This analysis is undertaken for each of the potential options (HM Treasury, 2011).

2.1 Risk Identification

Any estimation will involve uncertainty and will hence have a range of potential values. The Green Book (HM Treasury, 2011) includes a list broad categories of risk that can be applied to each cost or benefit identified in the estimation process. HM Treasury's project risk management document, the Orange Book (HM Treasury, 2008a) provides further guidance on specific risk identification tools.

2.2 Risk Quantification

2.2.1 Expected Value

HM Treasury (2011) guidelines require that a risk adjusted expected value be used for costs and benefits. This is calculated by multiplying the probability of the risk occurring times the (monetised) magnitude of the impact. The Green Book also provides guidelines for calculation of benefits/costs without market value. The risk register for High Speed 2 can be found in appendix B

2.2.2 Sensitivity Analysis

For highly uncertain variables project appraisals are to be subjected to sensitivity analysis to determine at which point a project becomes sub-optimal.

2.2.3 Scenario Planning

In addition, Treasury advocates the use of scenario planning, as per the below:

> "Scenarios should be chosen to draw attention to the major technical, economic and political uncertainties upon which the success of a proposal depends. Considering scenarios needs to be proportionate. […] The expected NPV can be calculated for each scenario. It may also be helpful to undertake some sensitivity analysis within a scenario."

2.2.4 Monte Carlo Analysis

For more complex projects, HM Treasury (2011) sets out guidance for developing a full risk model using Monte Carlo analysis. This approach has been adopted for High Speed 2 and the output of this analysis has been included in appendix B.

2.3 Optimism Bias

The Green Book (HM Treasury, 2011) deals explicitly with optimism bias, namely the tendency for benefits to be over-estimated and costs to be underestimated. HM Treasury (2011) specifies that an allowance for optimism bias be added to the project. This allowance should be empirically derived, from similar projects in the UK or elsewhere – with adjustments made for the specific project. The document notes that adjustment for optimism bias is designed to complement rather than replace calculations of project specific risk values.

2.4 Criticism of the Project Appraisal Process

2.4.1 Procedural

A number of criticisms have been levelled at the appraisal process for an infrastructure project. These can be categorised broadly as follows:

Political buy-in at an early stage: All infrastructure projects have a political dimension. Theoretically the need for action and desired outcomes should be determined by Parliament, while the means to achieve these outcomes should be determined by Civil Service, the private sector or some combination of the two. In reality, we often see politicians staking considerable political capital on specific solutions at an early stage– High Speed 2 is a notable current example. In such circumstances there is a risk that political views will skew the project appraisal process to reject or accept certain projects. The appraisal process should be structured in such a way to minimise such influence.

Over-development of the proposal: While attempting to define a project as well as possible and quantify risks is laudable, this can lead to stifling of innovation later in the project. This is particularly important where the private sector is likely to be involved.

Private sector involved too late: For many projects the extent of private involvement is apparent at an early stage. For complex projects or projects likely to require a high level of private sector involvement, early contractor involvement can shorten construction time, reduce price and introduce innovation (HM Treasury & Infrastructure UK, 2010). Beckers et al. (2013) note that; "In public private partnerships, private risk takers and their management techniques are introduced too late in the process to influence risk management and allocation". However, competition laws and the need for transparency are major barriers to introducing early contractor involvement.

2.4.2 Risk Classification and Ownership

As the risk register for High Speed 2 shows, the output of the appraisal process includes a list of potential project specific risks. However, HM Treasury (2011) guidelines make no provision for early risk management measures or ownership of these risks. Becker et al. (2013) suggest that risks should be allocated early and risk management techniques applied before a procurement decision is made. With this in mind, this report proposes that risk registers resulting from the application process should include the following:

- A named risk owner for each identified risk from the public procuring body, HM Treasury or a person nominated on their behalf. This is regardless of whether this risk will be transferred to the private sector on procurement
- Classification of risks, in addition to likelihood and impact, by the extent to which these can be mitigated or further investigated prior to procurement
- Risk management procedures in place to actively investigate or mitigate risks prior to procurement

2.4.3 Over-reliance on Quantitative Measures

While Treasury guidelines explicitly state that scenario planning should be undertaken, the manner in which scenario planning is used appears to be limited. The lifetime of infrastructure projects is typically longer than half a century; calculating NPVs for different scenarios is meaningless over such long time horizons. Rather, scenario planning should be used to investigate changes to the key drivers of demand and cost of an infrastructure project that may occur over its lifetime and identify where flexibility should be built in.

2.4.4 Optimism Bias

Optimism bias was introduced in response to the fact that infrastructure projects always appeared to go over budget. This is the antithesis of good risk management for a number of reasons:

- It fails to address the underlying cause. Flyvbjerg (2003) suggests that over estimation of benefits and underestimation of costs is a result of deliberate misrepresentation. Allowance for optimism bias reduces the accountability of those making the forecasts.
- It discriminates against projects with honest and accurate risk-adjusted base costs. Projects are generally selected based on cost/benefit trade off. As two similar but mutually exclusive projects will have a similar optimism bias uplift, the project with the lower risk adjusted base case cost

will be selected. This is not necessarily the best or cheapest option, it may simply be the one with the most dishonest or least developed base case.

- Optimism bias reduces incentives to control cost and risk. The Infrastructure Risk Group (2013) states "Optimism bias may be increasing the cost of infrastructure projects as this "uplift" becomes part of the project budget and spent, even if there is no need to do so". As optimism bias budget is not allocated to a particular contingency, there is little direction on what this money should be spent on.

3 Addressing Risks

3.1 Risk Management Structure

The Green Book (HM Treasury, 2011) provides the following guidance on actions to be taken for successful organisational risk management:

- Establishing a risk framework, within which risks are identified and managed;
- Senior management support, ownership and leadership of risk management policies;
- Clear communication of risk management policies to all staff; and
- Fully embedding risk management policies into business processes and ensuring it applies consistently

3.2 Risk Management Strategies

The Orange Book (HM Treasury, 2008a) gives five key aspects to addressing risk

Tolerate:	This action is appropriate for risks that either cannot be managed or where the cost of taking any action is disproportionate to the benefit gained. Tolerating risk does not preclude contingency planning to mitigate impacts should the event arise.
Treat:	This action is undertaken to constrain risks to an acceptable level. Risk is treated through the following mechanisms: Preventative controls, corrective controls, directive controls and detective controls.
Transfer:	This may refer to conventional risk transfer (i.e. insurance) or risk transfer though the project procurement method (see section 4 below for further details). The key aspect to this risk transfer mechanism is that risk is transferred to party most able to bear the risk. The Orange Book also notes that the relationship with the third party must be carefully managed to ensure successful transfer of risk.
Terminate:	Where risk is deemed unacceptable and cannot be reduced, all or part of the project should be terminated. It is noted that this option may be severely limited in government compared to the private sector.
Take the Opportunity:	This measure is to be taken in conjunction with those described above and involves to exploiting positive impacts and examining the project for upside potential as well as downside risks.

In addition to the above the Green Book (HM Treasury, 2011) provides more specific guidance on risk management tools, these can be found in appendix A.

3.3 Criticism of Risk Management Strategies

This section is a critical assessment of the government's approach to tolerating and treating risk. Risk transfer via the procurement process is dealt with in more detail in section 4.

3.3.1 Bridging the Procurement Divide

Beckers et al. (2013) highlight the fact that "project owners fail to see that risks generated in one stage of the project can have a significant knock-on impact throughout its later stages". Given that large infrastructure projects will typically involve a number of stakeholders at different stages, an overall risk management perspective is required.

Related to this is the fact that timetable pressures can result tendering or construction contracts being awarded before the output requirements or design specifications of the end user are sufficiently developed (HM Treasury & Infrastructure UK, 2010). This raises the risk that;

- The finished asset does meet the end users requirements; or
- Variations and rework must be done to meet these requirements, resulting in claims and additional cost.

3.3.2 Misaligned Incentives

Given the diversity of stakeholders in infrastructure projects, an important aspect of risk management involves ensuring the interests of these parties are aligned, if possible, or managing the relationships between parties to ensure delivery.

The Infrastructure Risk Group (2013) identify the following behaviours that result from misaligned incentives:

- Project sponsors will tend to adopt assumptions which favour a project, which might be gaming (also known as 'strategic misrepresentation'), or might be genuine optimism (see optimism bias above)
- Financial managers will tend to exert pressure to reduce risk contingencies irrespective of actual risk levels to address more short-term financial needs.
- Project managers will tend to overstate risk so as to secure and maintain large contingencies, for example to avoid the ignominy and career impacts of overspending.
- Contractors may price unrealistically in order to win work and then use commercial means to maintain their profits.
- Project managers may resist any activity that leads to reduced contingencies. This may include mitigation activity that could lead to reduced risk levels needing less contingency.

3.3.3 Co-dependent Risk & Contingencies

As noted above, project budgets tend to be spend, regardless of whether the full budget is required or not. It is therefore important that the total budget is a reasonable estimate of the true cost of the project and that contingencies are assigned to specific risks. The Infrastructure Cost Review (HM Treasury & Infrastructure UK, 2010) suggests that the public sector favours "the management of large infrastructure projects and programmes within a quoted budget, rather than aiming at lowest cost for the required performance. If the budget includes contingencies, the higher total becomes the available budget".

Related to this is the issue of co-dependent risk. Large infrastructure projects often require numerous contracts across time and space. The Infrastructure Risk Group (2013) notes that the public sector does not manage risk in co-dependent projects effectively and there is potential for risk contingencies to be included in both. More broadly, Beckers et al. (2013) state that enterprises (in our case the UK government) tend to focus on the management of individual contracts. The portfolio effects of multiple contracts are overlooked.

4 Procurement & Risk Transfer

4.1 Types of Procurement

All infrastructure projects involve the private sector in some way. This can range from a contract to undertake construction (Conventional Procurement) to full privatization (e.g. Channel Tunnel). The government, therefore needs to select the optimal level of private sector involvement. For simplicity, these have been be categorised based on ownership and operation of the asset in the table below:

	Construction	*Operation*	*Ownership*
1	Private	Public	Public
2	Private	Private	Public
3	Private	Private	Private[1]

1. Private party owns the asset for a specified length of time before transferring the asset to the public.

Construction by a public works department, although common in the past, is no longer used for large infrastructure projects in the UK and has not been included in the above. Option 1 is known as Conventional Procurement, Options 2&3 are known as Public Private Partnerships (PPPs). Within each of these categories there are a number of subcategories depending on the form of the contract. The most appropriate will depend on the project. The Private Finance Initiative (PFI) is the form of PPP most commonly used in the UK (HM Treasury, 2012). For our purposes it is sufficient to consider the two broad categories: Conventional and PPP.

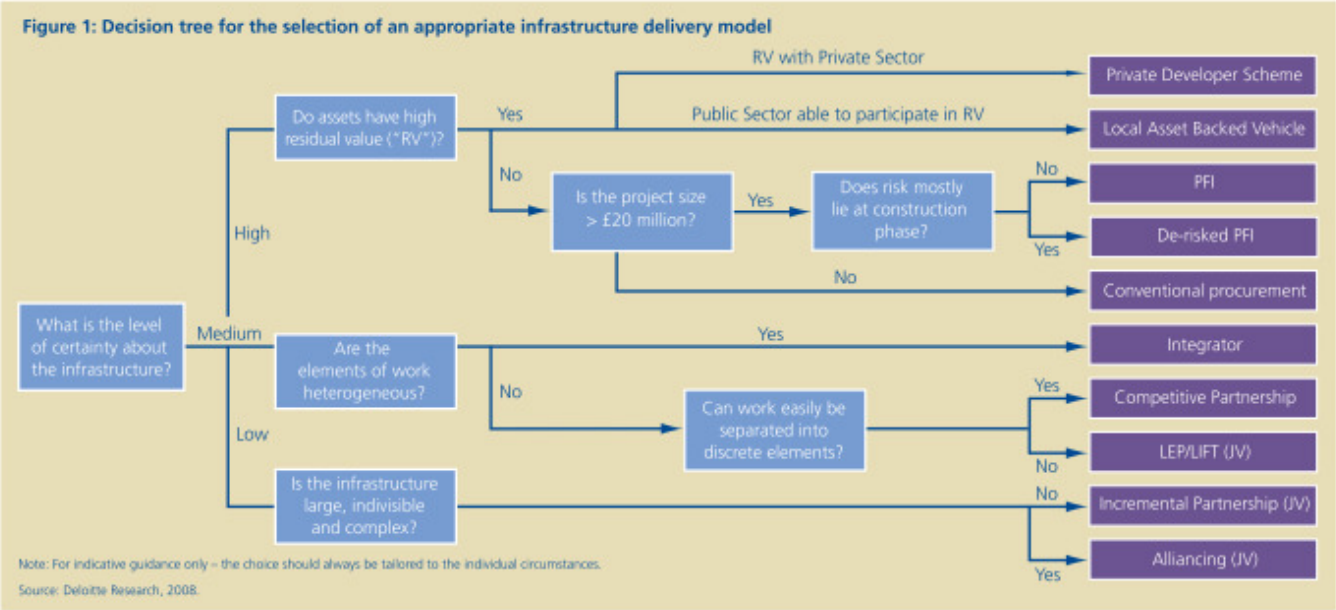
4.2 When to involve the Private Sector

The Green Book and HM Treasury (2008b) outline the following circumstances in which private sector involvement (in the form of a PPP) should be considered, namely where:

- Major capital investment is required
- Risk allocation between the public and private sectors can be made and enforced

- Innovation can be used to reduce costs or improve outcomes
- Additional revenue flows can be generated by sales to third parties
- The private sector is better able to exploit economies of scale
- Savings in whole life costs can be achieved through effective design
- The project is foreseen to operate into the long term

HM Treasury (2008b) also provides guidance on which type of private sector involvement is most appropriate. This is summarized in the graphic below:



Prior (2008)

Where private sector involvement is considered, HM Treasury undertakes a cost/benefit appraisal of the project assuming both conventional and PPP procurement (Burger and Hawkesworth, 2011) in order to reach a transparent decision regarding the use of a PPP over conventional procurement.

4.3 Which Risks to Transfer

Corner (2006) states that "the main benefit of transferring risk from the public sector is that it should generate the incentives for the private sector to supply cost effective and higher quality services over time". This is only true for risks that the private sector is best able to bear. If the public sector transfers risk incorrectly, the private contractor will (or should) charge a premium to carry that risk.

While the government is categorically better at bearing certain risks (such as inflation risk), the type of risks that should be transferred will generally depend on the project in question.

4.4 Criticism of the Procurement Process

4.4.1 Inappropriate use of PPPs

Historically PPPs have been used to avoid debt financing. As a sole driver behind the use of PPPs, this view has been thoroughly debunked (Quiggin, 2002; Flyvbjerg, 2003) and steps have been taken by the

National Audit Office (2009) to correct this. Further, Quiggin (1996) notes that, due to higher costs of capital in the private sector, the efficiencies achieved through PPPs need to be considerable and cost comparisons between conventional procurement should take this into account. HM Treasury's process for comparison does reflect this but their review still finds that there exists a perception that private contractors are making windfall gains at the public expense (HM Treasury, 2012).

From a broad economic perspective, a number of conditions have to be met for a PPP to deliver value. In addition to those listed in section 4.2 above, Burger & Hawkesworth (2011) note the following are essential to the success of a PPP:

- **Competition for and in the Market:** If a PPP contractor fails to deliver the required services, enters bankruptcy or is otherwise unable or unwilling to complete the contract, the government must have options beyond renegotiation of the contract or bailing out the contractor. This means that the market for the services delivered must be contested or new entrants can easily enter this market.
- **Well defined and agreed output measures:** The priority of government is the quality of service delivered, while that of the private contractor is the reduction of whole life costs. Unlike conventional contracts, PPPs encourage contractors to incur higher construction costs if this results in lower whole life cost. However, the private sector may also seek to reduce costs through lower quality service. It is therefore imperative that output measures are clearly defined and agreed at the outset. Once the asset has been built, it may be difficult or impossible to redefine output requirements.

4.4.2 Failing to Assign Risk Appropriately

As noted above, failure to assign risk correctly will result in the public paying a premium. This premium can be in the form of higher prices, contractual disputes or lower quality service. HM Treasury's review on PPPs (HM Treasury, 2012) notes that risk allocation has historically been done poorly. Risk allocation is a project specific exercise and can be difficult in practice. For example, demand risk (i.e. the demand for the service provided by an infrastructure operation contractor) can be affected by:

- **Price of the service:** This may be set by the contractor or by government
- **Quality of the service:** Specified by government but delivered by the contractor. Consumers' quality expectations may change over the lifetime of the contract.
- **Existence of substitutes/competition:** This may depend on the regulatory environment and contractual arrangements between the contractor and the public.
- **The number of buyers**: Quiggan (2004) argues that if there are multiple buyers, the service provider should bear demand risk, if there is a single buyer that buyer should bear demand risk
- **Network effects:** Infrastructure is, by definition, part of a network and reliant on that network for demand to exist. If that network is incomplete or overloaded, demand will suffer. Individual infrastructure operators are typically only responsible for a small portion of the wider network.
- **Promotion:** The ability of the service provider to advertise or otherwise promote the service.

Given the above, different aspects of demand risk may be best borne by public or the private sector, depending on circumstances. As a general rule and starting point, this report suggests that risk should be borne by the party most able to *undertake actions* to minimise the chance of a risk being realised at a given stage in the project. This requires that a detailed risk assessment be carried out prior to procurement contracts being awarded and that this assessment includes risk minimisation strategies.

4.4.3 Inflexible Contracts

A review by HM Treasury (2010) on infrastructure cost found that leaving the private sector to determine the best way to meet predefined outputs is results in more cost-effective solutions. This requires considerable flexibility. The review also notes that there is a tendency to over-specify solutions and apply unnecessary solutions. It is the view of this author that such inflexibility is locked-in at the assessment stage of the project.

The review on infrastructure cost (HM Treasury, 2010) also found that the evaluation process for selecting contractors stifles innovation as the criteria for selection fail to properly distinguish between the lowest-cost outcome and the lowest priced bid. In addition, HM Treasury's review of Public Private Partnerships (HM Treasury, 2012) notes that "contracts are generally too inflexible during the operation phase. Making alterations to reflect the public's service requirements is difficult"

5 Recommendations for Improvement

Risk management in infrastructure projects is complicated and project specific. In many instances the guidance set out by Treasury can be difficult to apply in practice and in such cases there can be no substitute for a skilled risk management team. However, taking the above criticisms into account, this report recommends that the following steps be taken to improve the assessment and procurement of infrastructure projects:

- Initial focus on defining need and output by government. HM Treasury should be initially concerned with determining measurable outputs and benefits only and, by association, the price the public sector is willing to pay for such benefits.
- Private sector involvement at an early stage to determine methods of delivering outputs defined above. This would be run in parallel with Treasury's own development of the project scheme.
- Early application of risk management prior to procurement and risk ownership for all risks at government level.
- Avoidance of optimism bias and clearly defined contingencies associated with specific risks, where possible. This must be combined with a change in project cost reporting; project costs should be reported as a range (such as P10 and P90). This will help avoid the political stigma associated with projects going over budget, which has resulted in inflated budgets that are unlikely to be exceeded.

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Appendix A: HM Treasury Tools for Risk Management

Active Risk Management:	This involves: ▪ Identifying risks in advance and putting mechanisms in place to reduce their likelihood of occurring ▪ Monitoring risks ▪ Having controls in place to mitigate the adverse consequences of risks, if they materialise ▪ Decision-making processes supported by risk analysis and evaluation
Early Consultation:	Experience has shown that more risks are identified as project is developed. Consulting early can bring these risks to light before significant resources have been devoted to a project
Avoidance of irreversible decisions:	Where lead options involve irreversibility, a full assessment of costs should include the possibility of delay. Alternative ways of achieving the same objectives should be investigated
Pilot Studies:	Pilot studies should be used where there is insufficient information regarding a risk's probability of occurrence or impact. Pilot studies can also be used to determine the best steps to mitigate risks
Design Flexibility:	Where demand and prices are uncertain, flexibility in design is recommended. Breaking the project into stages, with reviews at each stage, can also increase flexibility
Precautionary Principle	This is a tool for managing perceived risk. Extreme but unlikely events may require special consideration and expert advice
Making less use of leading-edge technology	Provided similar outputs are achieved, it is advisable to use simpler methods over highly technical solutions
Develop different options:	Following the risk analysis, the appraiser may want to develop alternative options that are either less inherently risky or deal with risks more effectively

HM Treasury (2011)

Appendix B: High Speed 2 Risk Appraisal Documents

High Speed 2 Phase 1 – Project Level Risks
(HS2 Ltd, 2012)

Risk Category	Cause	Consequence	Likelihood	Probability %			Minimum (£)	Most Likely (£)	Maximum (£)	Estimated Value (Pert)
Procurement	Inappropriate procurement structure selected / tender rates not achieved	Contractors include significant price premium in commercial tenders. Liabilities for consequential losses lie with client	2	Medium	35%	65%	£150,000,000	£300,000,000	£600,000,000	£162,500,000
Market Context	Construction industry resources (e.g. tunnelling contractors, concurrency of major projects (Crossrail, other railway projects)	Increased tender prices. Delay whilst await for available resource	2	Low	5%	35%	£350,000,000	£700,000,000	£1,400,000,000	£151,666,667
Statutory Consultees (Technical)	Rail company disruption greater than planned	Increased Cost to project	2	Medium	35%	65%	£100,000,000	£250,000,000	£500,000,000	£135,000,000
Statutory Consultees (Technical)	Rail company objection to scheme details (e.g. parallel running, junction configuration)	Programme delay whilst rework. Cost of redesign and associated works	3	Medium	35%	65%	£100,000,000	£200,000,000	£400,000,000	£108,333,333
Utilities	Unknown buried services	Increased cost of protection or diversion	3	Medium	35%	65%	£100,000,000	£200,000,000	£300,000,000	£100,000,000
Geotechnical	Uncertain ground conditions	Cost of ground improvements higher than expected. Cost of alternative design	3	Medium	35%	65%	£100,000,000	£200,000,000	£300,000,000	£100,000,000
Statutory Consultees (Technical)	Statutory technical approval bodies require additional assurances	Approvals take longer than expected Cost of mitigations (e.g. additional station)	3	Medium	35%	65%	£50,000,000	£100,000,000	£200,000,000	£54,166,667
Environmental	Extent and activity of contaminated land different from expected	Cost of treatment and disposal	3	Medium	35%	65%	£75,000,000	£100,000,000	£150,000,000	£52,083,333
Constructability	Contractor questions constructability of design	Associated costs higher than expected. Programme delay associated with alternative methods	2	Low	5%	35%	£120,000,000	£240,000,000	£360,000,000	£48,000,000
Non-Statutory Stakeholders	3rd party objections to construction methodology	Delay owing to restricted working hours. Cost of more expensive methods	2	Low	5%	35%	£120,000,000	£240,000,000	£360,000,000	£48,000,000
Environmental	Unexpected discovery of archaeological artefacts	Cost of expert investigation. Programme delay whist investigate	2	Low	5%	35%	£120,000,000	£240,000,000	£360,000,000	£48,000,000
Project Scope	Interfaces with proposed developments (e.g. BAA , LUL, Crossrail, HS1, other railways). Terminal points unclear	Cost of scope changes to integrate with interfacing schemes	2	Low	5%	35%	£100,000,000	£200,000,000	£400,000,000	£43,333,333
Railway Technology	Emerging technical equipment unavailable in time (e.g. ERTMS)	Cost of modifying scheme to match available technology Programme delay whilst rework design	2	Low	5%	35%	£100,000,000	£200,000,000	£300,000,000	£40,000,000
Railway Technology	Obsolescence of technical equipment (e.g. GSM switched off)	Cost of providing replacement/alternative equipment. Applies to pre-construction phase	2	Low	5%	35%	£100,000,000	£200,000,000	£300,000,000	£40,000,000
Optioneering	Unreliable optioneering process (e.g. options mistakenly parked) owing to for example insufficient EIA (significant environmental issue overlooked)	Cost of rework and associated delays Adverse effect on HS2 reputation	2	Medium	35%	65%	£5,000,000	£75,000,000	£150,000,000	£37,916,667
Input data	Incorrect input data leads to incorrect scope definition	Cost of redesign and associated works	3	Medium	35%	65%	-£50,000,000	£75,000,000	£200,000,000	£37,500,000
Land	Additional commercial property at risk due to proximity to rail corridor	Acquisition of additional properties (and subsequent resale potential?)	2	Medium	35%	65%	(£40,000,000)	£50,000,000	£156,000,000	£26,333,333
Land	Uncertain land acquisition costs	Land costs higher than expected. Legal process delays land take	3	Medium	35%	65%	(£30,000,000)	£50,000,000	£120,000,000	£24,166,667
Traction Power	Additional cost incurred connecting to National Grid / additional cabling required	Additional power supply scope / cost / redesign	2	Medium	35%	65%	20000000	£40,000,000	£100,000,000	£23,333,333
Waste	Waste regulation changes	Related costs of treatment/disposal higher than expected	2	Low	5%	35%	£50,000,000	£100,000,000	£150,000,000	£20,000,000
Design Standards	Changes in standards (e.g. TSIs) during design lifecycle	Cost of designing to alternative standards	2	Low	5%	35%	£30,000,000	£50,000,000	£75,000,000	£10,166,667
HS&E Standards	H&S standards change	Cost of mitigation (e.g. clearances, safety fencing) increases	2	Low	5%	35%	£30,000,000	£50,000,000	£75,000,000	£10,166,667
Environmental	Adverse effect of noise and vibration	Floating slab track required in tunnels and restricted choice of viaduct solutions	3	Medium	35%	65%	£10,000,000	£20,000,000	£30,000,000	£10,000,000
Project Scope	Enabling works delayed or cancelled (e.g. LUL)	Cost of enabling works borne by HS2	2	Low	5%	35%	£20,000,000	£40,000,000	£60,000,000	£8,000,000
Design Standards	Major incident on HSL	Alteration of standards introducing rework at increased cost Higher cost of risk financing (e.g. insurance cover)	4	Minimal	0%	5%	£50,000,000	£150,000,000	£250,000,000	£3,750,000
Constructability	Efficiencies in construction of elevated structures	Elevated scope cost reduced	2	Medium	35%	65%	(£150,000,000)	(£75,000,000)	£0	(£37,500,000)
Procurement	Continental construction rates achieved	Tender prices reduced	2	Low	5%	35%	(£1,500,000,000)	(£100,000,000)	(£50,000,000)	(£65,000,000)

Total	£1,239,916,667

Top 10 Site Specific Risk: Phase 1 – London to West Midlands
(HS2 Ltd, 2012)

Risk	Route Section	Value (£k)
Tunnels - ground conditions / obstructions affect methodology / alignment	Tunnelled Sections	245,783
Additional interface requirements	Euston	69,583
Uncertainty associated with elevated section length	Coleshill to Belfry Golf Course	62,500
Vertical clearances at Heartlands spine road	Water Orton Corridor	50,667
Possible additional requirements to enable capacity approaching Old Oak Common	Old Oak Common area	50,000
Proximity to Central Line at Hanger Lane - additional bridge/highway works, impacts on Central Line	Hanger Lane area	50,000
Additional interface requirements	Delta Junction area	48,000
Construction more complicated - e.g. increased box size	Old Oak Common	44,584
Uncertain highway infrastructure requirements (HS2 works only)	NEC to Coleshill	39,000
Uncertainty associated with length of elevated section	Spur Lines (Delta Junction)	36,667

High Speed 2 Monte Carlo Benefit/Cost Output
(HS2 Ltd, 2013)