



## **Crossrail Project Representative**

Crossrail Joint Sponsor Team

## **Crossrail Cost Scenario Review**

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## Executive Summary

As the Crossrail infrastructure programme (tunnels, track and stations) entered its final year of construction and delivery in 2018, CRL (Crossrail Ltd.) began to update its cost projections and the likely potential total completion cost, otherwise known as the potential outturn. In support of this process the JS (Joint Sponsors - Transport for London and the Department for Transport) asked CRL to prepare cost scenarios, in order to provide a quantum of the actual cost of completion against potential delivery scenarios, and any resulting variation from the approved IP2 funding limit of £12,512m. The cost scenarios were aimed at understanding:

- a) The sensitivity of the cost forecast to achieve the Stage 3 completion date of 9 December 2018.
- b) The impact of a potential software or control system delay resulting in a prolonged delay to opening.

Following submission of the cost scenarios by CRL, the JS Board requested an independent review of the work completed, primarily to provide assurance on the reasonableness of the approach taken by CRL in compiling the scenarios, and to provide confidence or otherwise in the likely potential outturn cost upper limit known as the 'book-end'.

This report details and presents the scope, methodology, analysis and findings associated with the completion of the independent cost scenario review. The review utilises cost and programme data from CRL and hence the numbers and data presented are based on CRL's figures. No cost or schedule data was independently prepared, verified or developed during this review.

The main findings of the review are:

- a) The methodology followed by CRL to develop the cost scenarios, given the constraints and objectives at the time of preparation, was understandable and reasonable.
- b) Based on the premise that Stage 3 opening on 9 December 2018 is achieved<sup>1</sup>, the expectant potential outturn at the time of this report is circa £300m above IP2.
- c) The upper limit book-end as determined by the cost scenario review, including the completion tail scenarios, is in the region of £400m above IP2.
- d) Material cost reductions are unlikely to be achievable, as the opportunity to re-phase work or de-scope, and still deliver a functioning railway system has passed.

The project is strongly focussed on achieving Stage 3 opening on 9 December 2018 and all projects are experiencing a concertina affect as work is compressed against a hard completion deadline. Consequently, there is negligible float for future problems, delays and defects correction and the likelihood of construction completion work extending into trial running, trial operations and passenger operations is high.

Based on the findings of this cost scenario review the recommendation to Joint Sponsors is to be prepared for additional spend in the region of £300m, with an upper limit of circa £400m above IP2, to deliver the CRL scope.

Overall this represents a 3% variation of CRL AFCDC (Anticipated Final Crossrail Direct Cost) compared to the agreed funding allowance (IP2), which when compared to similar magnitude major projects reflects a strong delivery performance in terms of actual cost vs. budget performance.

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<sup>1</sup> The cost scenarios and resulting potential outturn and upper limit book-end, are based on the programme achieving Stage 3 opening on 9 December 2018, with the exception of the "B" scenarios which allow for a software or system fault preventing opening.

# 1. Introduction

## 1.1 Background

During February 2018 CRL began to update its AFCDC (Anticipated Final Crossrail Direct Cost) projections to reflect the impact of the revised hand over schedule (MOHS 2018) and progress to date, versus the Stage 3 completion milestone of December 2018. As part of that work and at the request of JST (Joint Sponsor Team), CRL undertook to prepare two sets of cost scenarios to quantify the costs associated with the following completion circumstances:

- The sensitivity of the cost forecast to achieve the Stage 3 completion date of 9th December 2018, including acceleration and prolongation costs.
- The impact of a potential software delay resulting in delay to opening and prolonged maintenance of the physical asset.

The primary objectives were to provide a quantum of the actual cost of completion against potential delivery scenarios and any resulting variation from the approved IP2 funding limit. Plus, an upper “book end” estimate of the cost to complete such that the JS (Joint Sponsors) could understand the potential magnitude of additional funding that may be required.

## 1.2 Scope of Cost Scenario Review

The revised forecasts were submitted to the Sponsors and JST at the end of February 2018 who then commissioned Jacobs to undertake an independent review of the updated cost projections. The review was conducted in three phases as described below.

### Phase 1 – Initial Review

The purpose of phase 1 was to provide:

- Independent assurance to JS that the approach taken by CRL in updating its cost projections, in order to reflect MOHS 2018, is appropriate and well founded.
- An evidence based assessment of any concerns, risks, opportunities or issues that remain, and help the JS understand the resulting magnitude and importance in terms of programme success.

Importantly phase 1 was conducted by an independent Jacobs team who were not part of the incumbent Project Representative team (P-Rep), nor part of any other CRL activity at the time.

### Phase 2 –Further Review

On completion of phase 1, further work was considered beneficial and JST commissioned phase 2 with a view to:

- Demonstrating the reasonableness of judgements made by the CRL executive team in compiling the scenarios by conducting a focussed review of critical contracts.
- Providing JS with greater confidence in the range of outcomes by seeking to qualify the potential outturn range versus the CRL cost scenarios, and consider the wider implications for the overall programme position based on data led trends.

Given the tacit knowledge and access to data held within the P-Rep team, all parties agreed that phase 2 was to be completed openly with the P-Rep team supporting and providing data, context and perspective.

### Phase 3 – Completion Tail Review

Following the presentation of the phase 2 findings at JS Board on 19 April 2018, it was agreed that CRL should develop and prepare a new scenario(s) describing a construction completion tail, and that for expediency this should be done in consultation with the Jacobs independent cost scenario review team.

The objectives of phase 3 were to:

- Develop a cost scenario(s) that take a more pessimistic view on construction completion and describe a tail of work which may extend into trial running, trial operations and passenger operations.
- Stress test the upper limit book-end numbers and provide JS with further reassurance and confidence surrounding the upper limit book-end value.

This report presents the scope, methodology, analysis and findings from the work undertaken in all three phases.

### **1.3 Exclusions & Limitations**

The following exclusions and limitations of the cost scenario work should be noted.

- All the data originates from CRL and has not been independently re-produced or verified.
- The cost scenarios are based on the premise that all essential construction work is completed in time for Stage 3 opening on 9 December 2018.
- The work excludes any additional funding required for rolling stock, Network Rail and/or other scope outside that considered within the CRL cost scenario work.

## 2. Phase 1 – Independent CRL Cost Scenario Review

### 2.1 Scope

#### 2.1.1 Scenario Description

In early March 2018 CRL presented to JST its document entitled AFDCD Scenarios whereby it proposed two scenarios and developed costs for three options within those scenarios, in order to establish and describe an estimated upper and lower limit of funding requirements (known as the 'book-ends'). During this meeting CRL stated that it felt the book-ends of the cost projections lay between Scenario A, Range 2 and Scenario B, Range 3 month delay, equating to a £200m to £300m increase in cost above IP2 at P50.

Appendix A includes the full Summary of Assumptions and issues considered by CRL in calculating the cost projections, and the table below provides a high level summary of the scenarios and ranges considered.

Scenario A			Scenario B		
Stage 3: Paddington to Abbey Wood opens 9 December 2018; Stage 4: Paddington to Abbey Wood & Shenfield opens 19 May 2019 and Stage 5: Reading & Heathrow to Abbey Wood opens 8 December 2019.  Stage 2 continues under Plan B because of continuing delays to BT train software development  No adjustment to current Scope of Work.			Stage 2 continues under Plan B.  No adjustment to current Scope of Work.  Stages 3, 4 and 5 open late as described in the time periods below. With a delay to Stage 3 having equivalent delay to Stages 4 and 5.  Assumes elements handed over to IM's with limited CRL Service.		
Range 1	Range 2	Range 3	3 Month delay	6 Month delay	12 Month delay
Work proceeds as per current MOHS and P10 AFDCD used as basis for costing. Outturn per contract based on updated management view.	Work delayed vs current MOHS but recovered (acceleration, resources and work around), with Scenario A1 used as basis for costing.	Work delayed further vs current MOHS requiring substantial recovery (acceleration, resources, prolongation and work around), with Scenario A2 used as basis for costing.	Physical works completed on schedule, but delay in systems testing and commissioning, or incurring a 3 month delay to Stage 3 opening. Scenario A2 used as basis for costing.	Physical works completed on schedule, but delay in systems testing and commissioning, or incurring a 6 month delay to Stage 3 opening. Scenario B1 (3m) used as basis for costing.	Physical works completed but major commissioning event occurs resulting in a 12 month delay, with extended care and commissioning. Scenario B2 (6m) used as basis for costing.

**Table 1: High level summary of the scenarios and ranges**

CRL develop costs for the above scenarios and ranges for each live contract with work remaining to be completed, generating revised outturn costs which could be compared to IP2 (Intervention Point 2), which is the approved investment amount upper limit.

CRL’s AFDCD Scenarios Summary of Assumptions was supported with a number of spread sheets and corresponding calculations which included (see appendix B for the documents received from CRL and utilised):

- High Level Elemental Summary of Costs
- Project by Project calculation of Projected Costs for Scenario A Ranges and Scenario B ranges
- Exclusions, Opportunities, Incentives
- Contract Breakdown sheet to determine time related costs to completion
- Schedule/Performance/Productivity Calculations
- Indirect Costs, Risk Allowances

**2.1.2 CRL Cost Scenarios - Values**

Table 2 below summarise the AFDCD Scenario Costs as presented by CRL. The figures in the CRL AFDCD row are the total potential outturn cost per scenario for the scope of work included within the IP2 funding allowance of £12,512m. The bottom row of the table shows the cost increase from IP2 for each scenario outturn and hence the additional funding required should that scenario materialise.

Item	Scenario A (£m)			Scenario B (£m)		
	Range 1	Range 2	Range 3	3m delay	6m delay	12m delay
CRL AFDCD	12,651	12,743	12,794	12,797	12,826	12,856
IP2	12,512	12,512	12,512	12,512	12,512	12,512
Increase vs. IP2	140	231	283	285	314	344

Table 2: AFDCD Scenario Costs

Figure 1 below presents the cost increase (delta) to IP2 and the potential total outturn cost for each scenario. The delta is shown as an increase from the IP2 funding limit of £12,512m. All data is in GBP millions.

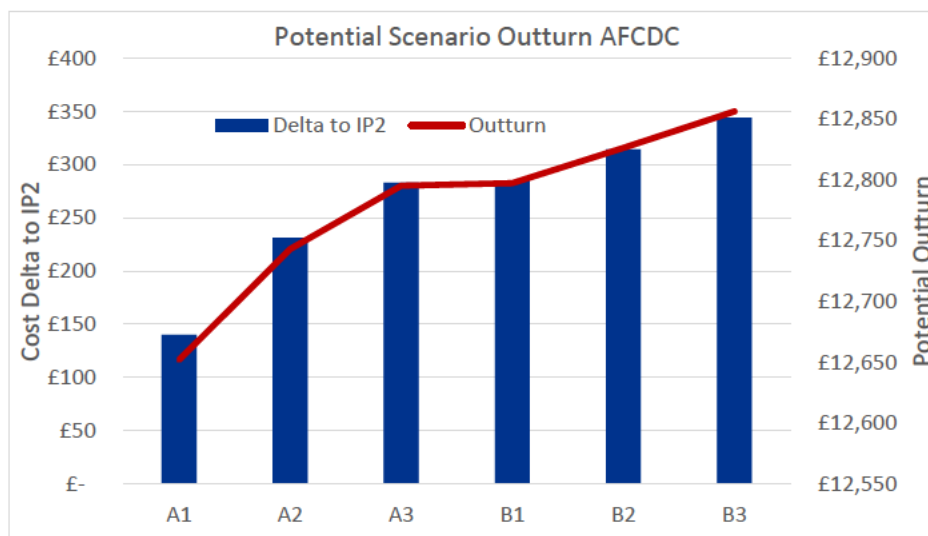


Figure 1: AFDCD Scenario Costs

**2.2 Assumptions, Allowances and Boundaries**

CRL’s cost scenarios are based upon cost data within the CRL Board Report Period 10 2017-2018 and the MOHS 2018 Level 0 dated 14 February 2018. The MOHS 2018 Level 0 was subsequently amended and re-issued during



the review period, and CRL advised in a meeting on 13 March 2018 that these amendments would likely influence the cost scenarios, the impact of which would be formalised within its Period 13 Board Report.

## **2.3 Methodology**

The CRL AFDCD calculations utilise data collected from multiple sources and individuals, which was then collated analysed and processed to form a potential outturn cost. As part of the review an analysis of the source data was undertaken to provide visibility to JST and therefore provide confidence or otherwise in the reported numbers. Following an initial review of CRL's approach in building up the AFDCD scenarios, a three step approach was undertaken comprising:

- Data gathering on the scenarios and corresponding contracts including the scope, cost, schedule and risk.
- Reviewing all the scenarios to identify uncertainties, issues and inconsistencies.
- Interviewing key personnel involved to understand the logic, approach and thinking employed.

In support of the review work a number of meetings were held between CRL and Jacobs during March 2018 as detailed in Appendix C.

The output of the review comprised a scenario flow diagrams and data uncertainty assessment, coupled with an overview of the main threats regarding cost to go.

## **2.4 Identification of Uncertainties, Issues and Inconsistencies**

When reviewing the cost scenarios uncertainties, issues and inconsistencies were identified and collated under the following headings, with corresponding comments and observations noted.

### **2.4.1 Contractual Arrangements**

Many of the Contracts are moving away from pure NEC Option C to include with Supplemental Agreements that in some instances have also made provision for major subcontractor cost 'pass through' which changes the commercial liability and requires closer CRL administration. The approach also risks eroding commercial incentives to complete within agreed limits unless provision is made elsewhere. The incentives remaining are anchored on achieving schedule milestones, to drive progress against plan and performance against defined cost.

### **2.4.2 CRL Risks at Period 10**

At Period 10 the P50 risk allowance was £303m (excluding Land & Property and NR Finance), which when added to the corresponding cost to go of £551m identified the remaining risk spend as 60% of the committed spend to go, which given the proximity of completion at Period 10 appeared high. CRL explained this was a function of catching up with unresolved trends (expected expenditure not yet authorised but likely committed) and risks. It was noted that there were £8.3m opportunities (credit) in the risk register, but it was unclear where they originated from or who was monitoring and driving them to a positive outcome. Overall it proved difficult to further quantify the changes in the risk profile without the base data and a detailed evaluation, and the unresolved trends approach confused risks with issues (i.e. materialised risks).

There is likely to be an overlap between risk draw down and contingency utilisation as the project nears completion and is approaching its IP2 approval ceiling. At this Stage of the project the risk profile would normally be clear and the remaining risk budget assigned to identified risks and/or released.

### **2.4.3 CRL Cost Reports**

CRL's ADR New Style Cost Sheet Period 10 details the spend breakdown per contract and in effect is the master cost summary sheet underpinning current thoughts within CRL in relation to contract costs. It provides insight into Project Manager and Contractor views, and details of changes from the original budget and contract sum, e.g. the statistical comparison EAC (Estimate at Completion) high for C610 is £803m vs EAC low £776m. It also

identifies an assessment of Pain/Gain share but it is unclear how this may or may not impact the potential Outturn Cost, however CRL have advised this is not a material consideration for the AFCDC scenario calculations.

The CRL P10 2018 Board Report shows a delta between the CRL and Contractor's view of forecast Defined Cost of £285m but what is not clear is if or how this information has been used in the formulation of the AFCDC Scenario document.

#### 2.4.4 Time Related Contract Costs

A key element of the AFCDC Scenario A calculations are costs associated with acceleration, based on increased resources for Range 2 and Range 3. To evaluate this CRL have reviewed the costs to complete for each contract and assessed the fixed and time based elements.

Where subcontractor costs have been considered as a high proportion of the cost to go, they have been assessed on a subjective basis assuming 30% time related costs. However, this assessment is considered to be low and a sensitivity analysis has been undertaken to assess the quantum of this element as summarised in table 3.

% Subcontractor time related cost	Impact upon Scenario A2 (£m)	Impact upon Scenario A3 (£m)
50%	+25	+28
70%	+51	+56

*Table 3: Impact of increasing Subcontractor time related percentage to Scenario A2 and A3*

In the event the time related cost proportion is increased the overall potential outturn cost increase to IP2 (scenario delta to IP2) is further increased by an additional 10% to 20%. Therefore, the time related costs are a material factor in the cost scenario analysis and provide an indication of the level of accuracy which could be applied to the potential outturn costs.

#### 2.4.5 CRL Programme

The CRL cost scenarios were based upon a version of the MOHS 2018 programme at Period 10 2018. It was confirmed by CRL on 7 March 2018 that the MOHS 2018 was under review and that a new version with changes was expected in early April. CRL confirmed during a meeting on 13 March 2018 that these amendments would likely influence its cost predictions, which would be formalised within the CRL Period 13 Board Report. Overall the MOHS18 schedule provided a good starting point for the cost scenario review and is a critical piece of the potential cost to complete jigsaw.

Regarding the critical path for Stage 3 opening in December 2018 it was noted that C610 was not shown on the critical path as shown in the high level programme summary in the Board Report, nor did it have any connections to or from it, yet it is the system wide delivery that has to perform to enable the Stage 3 milestone date to be achieved. Furthermore, the links between the critical path activities were unclear from a cost impact perspective and would require further review to understand.

As the programme approaches Stage 3 completion there are a significant number of contract completions programmed for end Q3 2018 aligning with major CRL milestones, and then a 3-month gap allowed for final commissioning, trial running and trial operations. The schedule therefore describes significant effort being deployed in the coming months against a hard finish date.

#### 2.4.6 Care & Custody Costs




Within the AFCDC Scenario B calculations costs have been assigned for the maintenance, upkeep and safe operation of the infrastructure in the event of a prolonged train control and/or system operating delay post

completion and average around £8m/month over 6 months. These allowances are based upon tendered contractor pricing plus CRL adjustment and allowances for expected snagging and completion works, but do not consider any contribution from TfL in terms of staffing costs or OPEX costs.

## 2.5 Scenario Outturn Cost Uncertainty Analysis

### 2.5.1 Data Evaluation

A qualitative assessment of all the data inputs and calculations in terms of the data utilised against the following three categories and colour coding was undertaken and documented. The cost scenario process maps developed describe how the cost scenarios were constructed and calculated.

-  Recognised – CRL P10 Board Report, Project Risk Register, etc.
-  Supported – Combination of recognised source data and experience led best practice to generate cost data.
-  Subjective – Experience led assessment and data generation only.

The assessment also considered both uncertainty distribution and magnitude for each scenario outturn cost scenario increase, using heat maps to show the distribution and pie charts to indicate the magnitude and relative proportion. The CRL cost scenario process maps are contained in Appendix D along with an example heat map and pie charts for scenarios A1 and A2.

It is important to note that the only “Recognised” data point as per the above definition was the P10 AFDCD value (i.e. the starting point).

Work was also undertaken to understand the distribution and magnitude of data/calculation inconsistency or source uncertainty, to help inform the overall understanding of the cost scenario build up and reliability, as well as checking of calculations, data source checks, inconsistencies and/or uncertainties.

An important point to note is that the ‘Additional Risk’ allowance used in Scenario A1 is subjective as per the above definition, and is back calculated and carried through into all further scenario calculations. Through conversations with CRL during the phase 1 review it became clear that the ‘Additional Risk’ number was used to bridge the gaps between the supported additions and the potential outturn cost. The potential outturn cost used in Scenario A1 was based on the CRL commercial team view on the cost to complete, and this comprised approximately 50% of the scenario cost increase from the P10 starting figure.

## 2.6 Phase 1 Findings

### 2.6.1 Context

On 22 March 2018 Jacobs presented its findings at the Sponsor Board Meeting; a copy of this presentation is included in Appendix F. As stated at this Sponsor Board Meeting CRL had limited time to prepare the cost scenario analysis and consequently used available data and tacit programme knowledge to compile the potential outturn costs. The approach taken was a top down analysis by competent and experienced people from within the CRL leadership team, with a desire to isolate the work from the project delivery teams. The work included an evaluation of costs to date, current spend rates, commercial exposure, forecasted costs to go, risks and unresolved trends. The following sections outline the main phase 1 findings and provide context for the subsequent phase 2 work undertaken.

### 2.6.2 Approach Followed

Overall the methodology followed by CRL to develop the cost scenarios, given the constraints and objectives, is understandable and reasonable. The process was logical and an expected approach to answer the question posed by JST. The methodology favoured tacit understanding over forensic analysis, using the current and forecast cost position at the time of completion (i.e. Period 10 2017/18) to determine potential outcomes.

However, whilst the scenarios are understandable but not necessarily all encompassing, there is considerable subjectivity and experience led input and assessment. Furthermore, the acceleration and recovery costs are based on the prolongation costs and not a bottom up quantification of actual resources needed to accelerate, and they assume acceleration is achievable.

### 2.6.3 Outer Limits – ‘Book-Ends’

Based on the work undertaken in phase 1 the following emerging findings were noted and shared with the JS board on 22 March 2018.

- Scenario A2 is the most realistic at the time the phase 1 work was completed. Scenario A1 had appeared to have materialised.
- The scenarios assume rigid boundaries, whereas reality is likely to have variability in project completion and transition operations.
- The costs and schedule are based on an optimised demobilisation at the end of Q3 2018 and the current MOHS18 is under review.
- Dynamic testing complexity is understood but not clear how this is reflected throughout the programme costs and the programme is currently losing time at the back end to thoroughly test. This is a concern.
- Changes in commercial models from pure Option C to modified arrangements through supplementary agreements may erode commercial incentives for completion and expose CRL to subcontractor claims.
- There are differences in the CRL vs. Contractor views on the defined cost position, and one-month delay equates to █████ in time related (only) costs.
- The current scenarios provide an overview of potential cost increase ranges, but are not definitively the “book ends”.

## 2.7 Phase 1 Recommendations

Upon completion of phase 1 the following recommendations were made to the JS Board during the meeting on 22 March 2018. The recommendations and extent to which further review and analysis should be undertaken were framed within the forecast accuracy desired in consideration of the budget impact for future investment plans. This was described as a +/- £100m accuracy or a +/- £10m accuracy order of magnitude as detailed below:

To support a +/- £100m accuracy the following should be undertaken:

- Review the updated MOHS18 schedule and re-assess the cost impact through the existing scenarios.
- Undertake a focussed review of contracts C610 Systemwide, C435 Farringdon Station and C412 Bond Street Station, with a view to substantiate and quantify:
  - Prolongation cost and risk
  - Recovery cost and capability to achieve
  - Risks and unresolved trends
  - Subcontractor positions and overall validity of Contractor view.
  - Modified contract risks and potential cost impact.

To support a +/- £10m accuracy the following should be undertaken:

- Complete as for +/- £100m.
- Extend focussed review to the top 10 contracts.
- Build a more complex model and run multiple scenarios to generate a potential outturn probability distribution

Following the JS Board meeting JST agreed a scope of work with the Jacobs independent cost review team, which best reflected the degree of accuracy required, based on the information and time available, whilst maintaining a focus on the desired output. Overall this involved balancing the depth of analysis and effort needed, within the context of a live and fluid programme, such that the output was reasonable and useful to Joint Sponsors. This resulted in phase 2 of the cost scenario review being defined, agreed and executed as detailed in section 3 of this report.

### 3. Phase 2 – Focussed Review of Critical Contracts

#### 3.1 Scope

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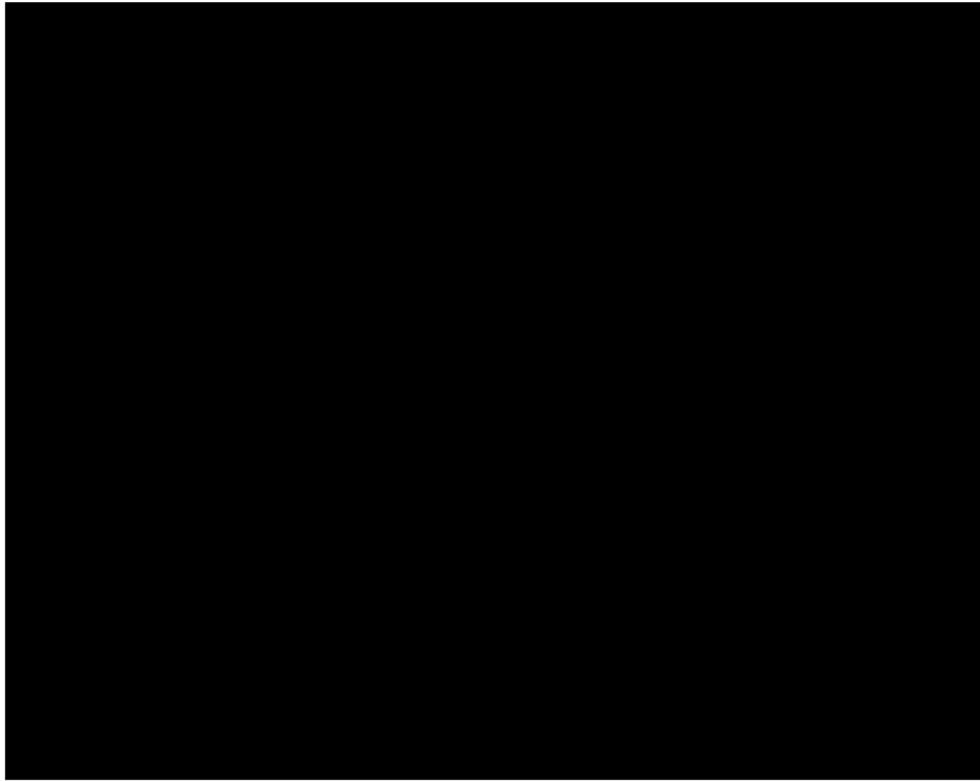
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### 3.2 Methodology

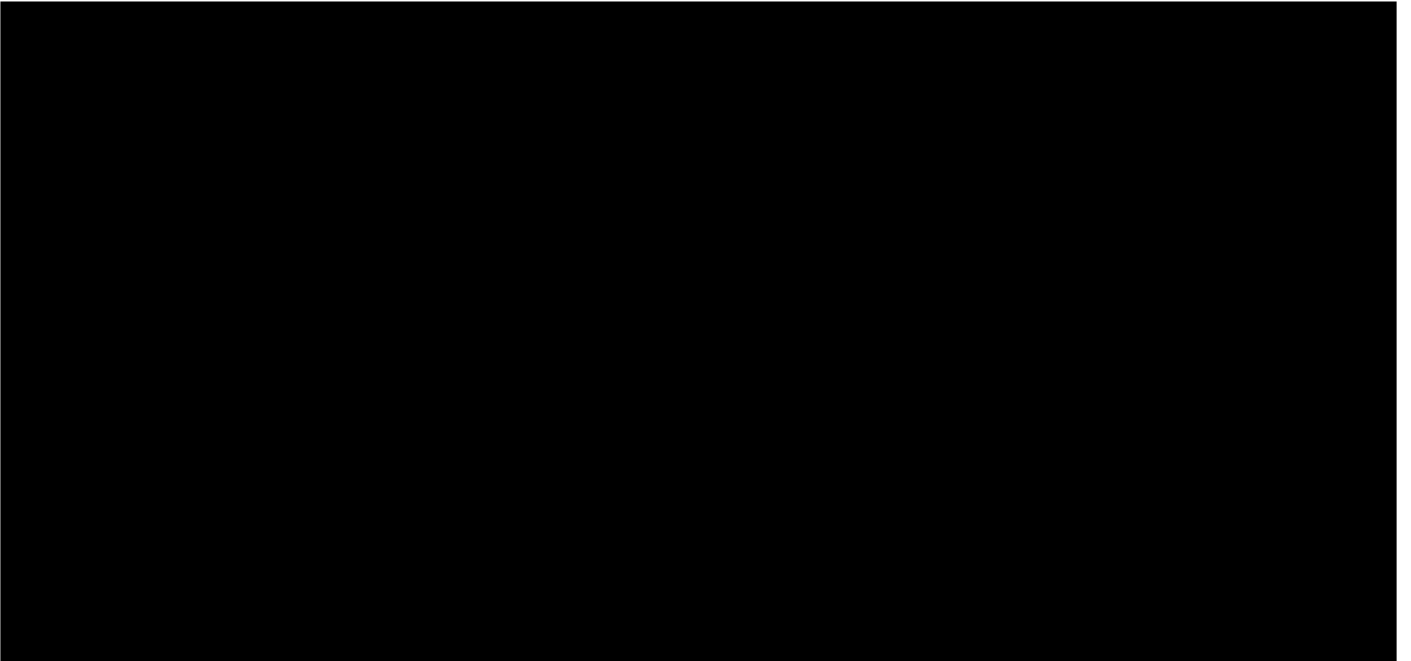
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### 3.3 Identification of Uncertainties, Issues and Inconsistencies

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### 3.5 Cost Performance Analysis & Predictions

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### 3.6 Contract Observations & Commentary

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### 3.7 Supplementary Agreements

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### 3.8 Phase 2 Findings

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**3.9 Phase 2 Recommendations**

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## 4. Phase 3 – Completion Tail Scenario

### 4.1 Scope

Following the presentation of the phase 2 findings, JS requested that CRL should develop and prepare a new scenario(s) describing a construction completion tail with a view to substantiate and quantify:

- Cost of construction work with the potential to complete after the current (at time of completion) MOHS dates and Stage 3 opening on 9 December 2018.
- Changes to the AFCDC scenarios from preliminary MOHS to current MOHS and any new issues arising.
- Risk items remaining and/or allowed for within the revised AFCDC forecasts and actuals.

The aim of the phase 3 cost scenario work was to:

- Develop cost scenario(s) that described a more pessimistic view on construction completion, allowing for a completion tail extending into trial running, trial operations and passenger operations.
- Stress test the upper limit book-end numbers and alongside the data from phase 1 and 2 provide JS with further reassurance and confidence surrounding the upper limit book-end value.

It was agreed with JS Board that given the timescales and the need to support funding conversations, that CRL would engage Jacobs in the scenario thinking and approach, to in effect provide a peer review whilst the work was being completed, rather than on completion.

### 4.2 Methodology

CRL developed and prepared two new scenarios titled Range Tail 1 and Range Tail 2, hereinafter called Tail 1 and Tail 2 (T1 and T2). The scenarios were developed on the following premises:

- Based on similar assumptions to Scenario A2 but updated to reflect known issues.
- Potential carry over of non-critical work.
- Updates for changes from draft MOHS to final (current at time of completion) MOHS.
- New issues that have arisen and/or been resolved.
- Comparison with P13 defined cost review and inclusion of identified additional risks.

CRL engaged with Jacobs in the early Stages of scenario development to allow both parties to share the thinking and approach surrounding the items to include, and subsequently towards the end the work to share and discuss the emerging tail scenario costs and explain the analysis completed.

It is important to note that as with phase 1 and 2, all the data is generated by CRL and no independently developed cost or schedule data was used.

### 4.3 Completion Tail Cost Scenario Assessment

The preparation of the tail scenarios Tail 1 and Tail 2 is consistent with the earlier scenarios (A1 to A3), whereby items are added to a starting point and revised potential outturn generated per contract, with the total potential outturn a summation of the all the line items plus an allowance for indirects. Table 7 below describes the elements included in the tail scenarios and assigns an uncertainty descriptor as per phase 1 (see Section 2.5).

Cost Element	Description	Uncertainty
Starting Point	Scenario A2 was used as the starting point, to which the tail cost elements were added.	Subjective (as per phase 1)
The Tail	This reflected the estimated additional costs per contract for work that may complete after the current MOHS dates or Stage 3 opening. The lower tail reflected an expected outcome, and the upper tail a more pessimistic outcome driven by either higher costs or longer durations. The work included programme wide and contractor specific items such	Supported

	as tunnel ventilation, permanent power, documentation through to Whitechapel heritage brickwork and Woolwich external cladding.	
MOHS Update	This primarily reflected prolongation costs and additional complexity within some final aspects of the construction work including [REDACTED]. The additional costs per extended period were assessed, resulting in a low and high range being generated.	Supported
Inclusions & Changes	This allowed the CRL executive team to make adjustments for items already included and/or allowed for elsewhere and for risks materialised or remaining to be accounted for.	Subjective
Additional Risks	This allowed the CRL executive team to make further adjustments for costs (addition or removal) based on Tail 2 assumptions.	Subjective

*Table 7: CRL Tail 1 and 2 Cost Elements and Uncertainty*

Using these cost elements CRL calculated the tail scenarios as follows:

Tail 1 = Scenario A2 + Tail Lower + MOHS Update Lower + Inclusions & Changes

Tail 2 = Tail 1 + Tail Upper + MOHS Update Upper + Additional Risks

#### 4.4 Phase 3 Findings

Overall the completion tail scenarios contain a similar level of supported and subjective data as per the original cost scenarios (A1 to A3). The approach taken by CRL is logical and consistent with the prior cost scenario work completed, and consequently the level of uncertainty within the overall assessment is similar.

The evaluation has enabled a more detailed assessment of the upper limit by CRL, where the cost impact of delays to station and infrastructure completion, versus the current programme, were quantified and assessed. Furthermore, the more pessimistic considerations adopted in Tail 2 provide further review and quantification of an upper limit potential outturn cost.

Importantly the tail cost scenarios take into consideration several permutations and combinations of activity completion and delay, and are therefore more balanced in their assessment of what may or may not occur. However, they support the phase 2 emerging finding that the upper book-end for funding availability should be in region of £400m above IP2.

#### 4.5 Phase 3 Recommendations

It was recommended and agreed with JS Board on 18 May 2018 that no further scenarios should be prepared and that the scenarios should be used to help monitor cost movement and forecast potential outturn for the coming 3 to 6 months as the project approaches completion.

## 5. Conclusions

### 5.1 Cost Scenarios

Overall whilst the process followed by CRL to generate the cost scenarios was reasonable, understandable and logical, the certainty regarding the data used and outputs generated remains mixed, with approximately a 50% split between supported and subjective data (see the Scenario A 3 example in Figure 6), as per the definitions in Section 2.5. Therefore, the scenario potential outturn costs rely considerably on the tacit knowledge of the CRL leadership team, and their detailed knowledge of the programme and contracts, and hence they should be utilised with a commensurate appreciation of their relative accuracy.

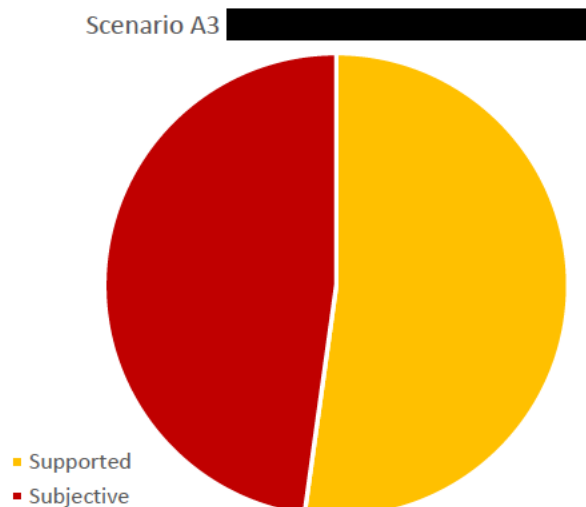


Figure 6: Scenario A3 Potential Outturn Increase Quantum of Relative Uncertainty

It is also important to note that the scenarios do not cover extreme cases, such as a tunnel fire, terrorist event, main contractor liquidation, etc. and they are all premised on the basis that the essential infrastructure construction work is completed in time for Stage 3 opening on 9 December.

### 5.2 Expectant Potential Outturn & Upper ‘Book-End’ Correlation

Combining the data, observations and findings from phase 1, 2 and 3 enables a view to be formed on the current potential AFCDC outturn and the upper limit (book-end) at the time of this report. Combining the output of phase 2 and 3 generates a view that the expectant potential outturn at this point in the programme is circa £300m above IP2 with a corresponding total potential outturn in the region of £12,800m.

Regarding the upper limit book-end, Table 8 below presents a summary of the inputs, their potential impact on the upper limit and the quantum of the corresponding AFCDC increase above IP2. Importantly the assessment combines different qualitative and quantitative data sources and therefore the correlation is valuable in providing a balanced perspective on a realistic potential upper book end value.



Input	Description	Impact on Upper Limit	Increase to IP2
Scenario Uncertainty	Subjective elements constitute circa 50% and assumes all construction work completed by stage 3 opening.	Indicates an overall scenario outturn accuracy of +/- 10%. B3 outturn increases by +£35.5m	£391m
Time cost element	Time related costs within the scenarios greater than 30% of costs as assumed.	Additional +£51m (@70% time costs added to scenario A2 and hence B3.	£406m
P13 AFDCD Review	Variation between scenario A3 and reported forecast outturn.	CRL view = + £72m Contractor view = + £188m Mid Point = + £130m	£413m
P10 to P13 cost performance	Analysis of changes to AFDCD and spend rate indicates a 0.76 multiplier of cost to go for every £1 spent.	This equates to +£187m added to the corresponding AFDCD.	£397m
P10 to P13 schedule performance	Analysis of % complete and cost to date.	This generates an outturn of £12,916m.	£404m
Scenario Tail 2 Additional Risk	Additional risk in scenario tail 2 has a negative number to off-set risk assumed accounted for and/or not applicable.	Setting the additional risk to 0 (zero) has the effect of adding +£29m to scenario tail 2.	£398m

**Table 8: CRL Cost Scenarios Uncertainty Summary**

The correlation of data sources supports an upper-book end cost scenario potential outturn of £400m above IP2, based on Stage 3 opening on 9 December 2018.

Based on the findings of this cost scenario review the recommendation to Joint Sponsors is to be prepared for additional spend in the region of £300m, with an upper limit of circa £400m above IP2, to deliver the CRL scope.

## 6. Appendices

### 6.1 Appendix A - Summary of Assumptions

The assumptions made by CRL in preparing the scenarios are summarised in the following table. The data is from the CRL cost scenario reports and is presented here for completion and relevancy.

#### **General Notes (From CRL Cost Scenario Report, February 2018):**

1. All figures are OOM based on current cost information. URT's are all assumed as cost.
2. This is not a P50, P80 or P95 position. It is an estimate of forecast outturn based on assumptions.
3. Amounts for prolongation taken using current project cost to go forecasts as basis.
4. Indirect allowances based on forecasts in last Business plan.
5. Assumes no change to accommodation strategy.
6. Inflation is not considered to be material.
7. It is assumed that TFL's revenue from OSD's is unaffected and there will be no additional cost from developers.
8. TFL income effect taken from TFL financial update paper.
9. Any cost implications associated with the train contract has not been included.
10. The main function of cost impact is the amount of time it will take to complete works.
11. There is no allowance for any fundamental failure of systems or trains which causes an indeterminate delay or prevents a functioning railway.
12. Assumes that CRL Stage 3 can open outside timetable changes.

	Scenario A			Scenario B		
	Stages 3, 4 and 5 open as currently planned. Stage 2 follows Plan B using Cl. 360's and Cl. 345's with RLU's. No adjustments to current scope.			Stages 3, 4 and 5 open late. Stage 2 follows Plan B using Cl. 360's and Cl. 345's with RLU's. A delay to Stage 3 has equivalent delay to Stages 4 and 5. No adjustments to current scope. Assumes elements handed over to IM's with limited CRL service.		
Issues Considered	Range 1 Assumptions	Range 2 Assumptions	Range 3 Assumptions	3 Month Delay	6 Month Delay	12 Month Delay
<b>General overview of Range</b>	MOHS goes to current plan.  Current AFCDC as basis for costing.	MOHS suffered further delays which can be overcome through additional resource and work around to open Stage 3 as planned.  Current AFCDC adjusted by Range 1 as basis for costing.	MOHS has significant further delay that requires substantial work arounds and prolongation to open stage 3 as planned.  Current AFCDC adjusted by Range 2 as the basis for costing.	Assumes that all steps are taken to achieve Stage 3 on time and the delay occurs during systems or dynamic or software testing or lack of viable train. Assumes delay occurs after start of Zones 3 and 4 DT on 11 June 2018.  Use Scenario A Range 2 as basis for costing.	Assume that limited steps are taken to achieve Stage 3 on time but then plan for delay.  Uses 3 month delay as basis.	Assumes that there is a serious event that means wholesale reprogramming.
<b>Exclusions from current AFCDC</b>	Each excluded item considered on merit on a best case basis.	Each excluded item considered on merit on a realistic basis.	Each excluded item considered on merit on a pessimistic basis.	As Range A3	As Range A3	As Range A3
<b>Schedule and performance issues</b>	MOHS 18 as planned. Effect on projects considered on an individual basis.	Assumes a further delay across all projects considered on an individual basis.	Various further delays across individual projects leading to disruption across all projects.	As Range A2 plus 3 months delay at project specific levels.	As Range B1 plus 3 months delay at "care and custody" levels for most stations plus others on merit.	As Range B1 plus 6 months delay costs at "care and custody" levels.
<b>Cost efficiency review</b>	A cautious view on cost efficiency recovery.	A mid range view on cost efficiency recovery.	Fuller potential cost efficiency recovery.	As Range A3	As Range A3	As Range A3
<b>Contractual and commercial risks</b>	Updated management view on potential outturn and additional risks.	Additional contract specific risk allowances included.	A judgement against Contractors defined cost forecast included.	As Range A3	As Range A3	As Range A3

## 6.2 Appendix B – Documents Received

Date Received	Received from	Date of Document	Document Title
7/3/18	CRL	N/A	High level AFDCD for Director Review
7/3/18	CRL	31/1/18	AFDCD Scenarios Summary of Assumptions
7/3/18	CRL	P10 2017/18	Crossrail Board Report P10 2017-18 Board Issue
7/3/18	CRL	P10 2017/18	PR220 Contract Run Rate Proposed for P10
7/3/18	CRL	N/A	P10 CRM Programme Unallocated Risk
8/3/18	CRL	25/1/18	Indirect Cost email
8/3/18	CRL	Extract from P10 2017/18 report	AFC Delivery Contracts
8/3/18	P Rep (Jacobs)	1/2/18	Project Status Report 107 Period 10 FY 2017/18
15/3/18	CRL		URT Detail Sheet LUL
15/3/18	CRL		URT Detail Sheet Civils
15/3/18	CRL	Rev 0	Wk2 P10 Aged URTs Rev0 by Contract
15/3/18	CRL	14/2/18	MOHS Refresh2018 Level 0
15/3/18	CRL		URT Status Variances Wk 2 P10 Status
15/3/18	CRL		ADR Sheet P10 2017-2018 Final Summary
15/3/18	CRL		ADR Sheet P10 2017-2018 Final Detail
April 2018	P-Rep		CRL Period 13 Board Report
April 2018	P-Rep		Crossrail Anchor Milestones 2018 – 2019 Period 13

### 6.3 Appendix C – Schedule of Meetings for Phase 1 Data Collection

Date	Meeting	Attendees	Location
7 March 2018	AFDCDC Review – Initial Meeting	CRL, JST, Jacobs	25 Canada Square, Canary Wharf, London, E14 5LQ
8 March 2018	CRL and Jacobs	██████████ ██████████ ██████████	25 Canada Square, Canary Wharf, London, E14 5LQ
8 March 2018	CRL and Jacobs	██████████ ██████████ ██████████	25 Canada Square, Canary Wharf, London, E14 5LQ
13 March	CRL and Jacobs	██████████ ██████████ ██████████ ██████████ ██████████	25 Canada Square, Canary Wharf, London, E14 5LQ
19 March	Site Visit Bond Street	██████████ ██████████ ██████████ ██████████ ██████████	CRL Site Office, 75 Davies Road, London

6.4 Appendix D – Qualitative Reviews

## Data Process Maps – Scenario A

### Scenario A1



### Scenario A2



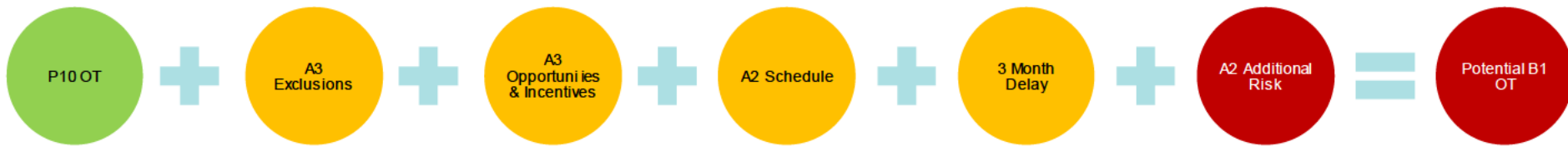
A1OT – Subtotal = Additional Risks

### Scenario A3



## Data Process Maps – Scenario B

### Scenario B1



### Scenario B2



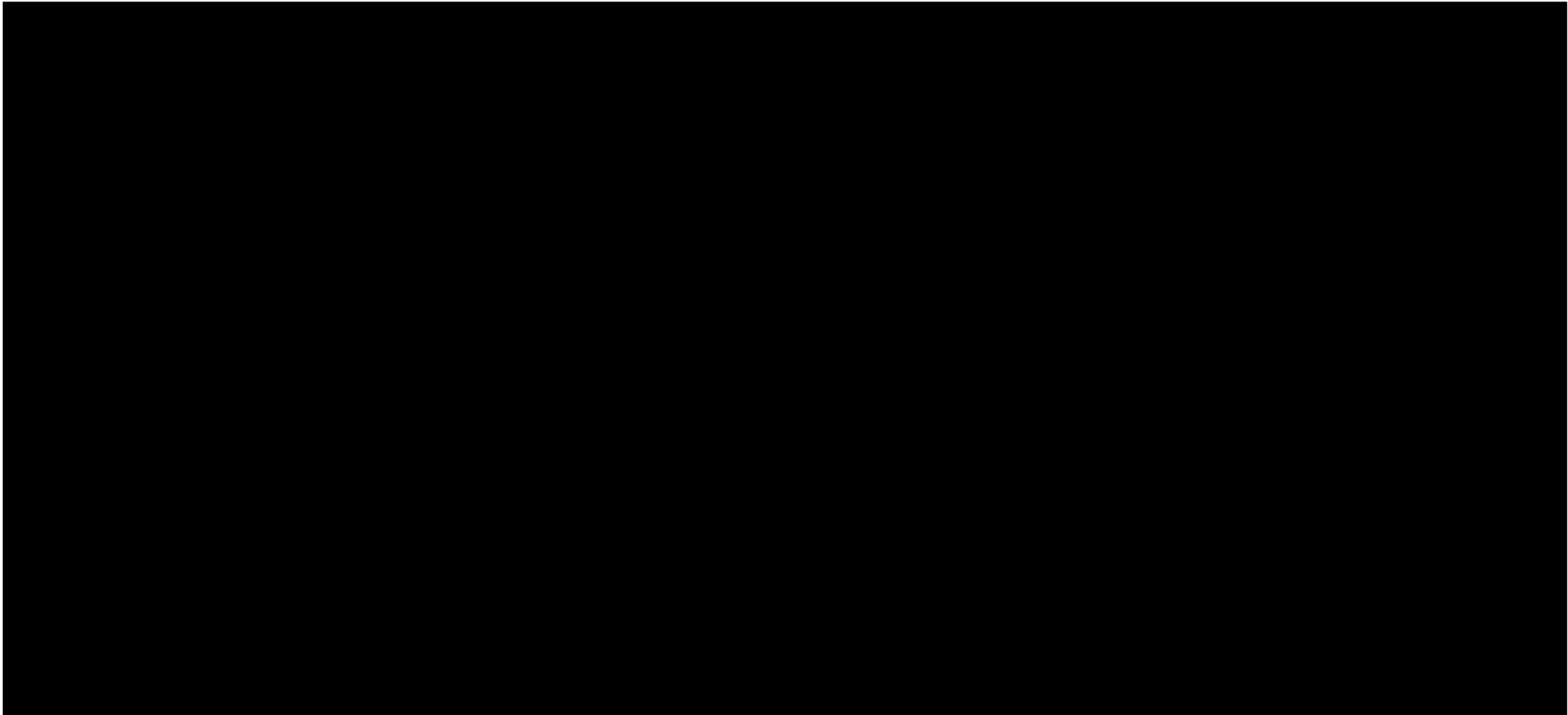
### Scenario B3







**6.5 Appendix E – Movement Trend Period 10 to Period 13**



## **6.6 Appendix F – Presentations to Joint Sponsor Board**



# Crossrail Cost Scenario Review

Feedback to Crossrail Sponsor Board – 22 March

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# Safety Moment – Bond Street Site Visit 19 March 2018

## Observations

- PPE compliance was good
- Access routes were clear
- Housekeeping was good
- Escape routes were well marked
- Safe working practices

## Reflections

- Pre-visit briefing was appropriate – it told us what we needed to know for a 45 min escorted tour
- Challenge is to maintain and continuously improve HSE as work levels increase with the inevitable schedule pressure to complete.



*Photo: Bond Street Station Construction, Google Images.*

# Introduction & Methodology

## Introduction

- CRL is in the process of updating its cost projections to reflect the move to a revised schedule (MOHS 18). This includes a top down contract by contract assessment of potential cost increases primarily due to outstanding work and prolongation, and subsequently generating a revised total programme outturn based on six scenarios.
- Jacobs were requested by JST to perform an independent review of the CRL generated costs, focusing on the approach utilised and corresponding reliability of the cost forecasts generated.
- Ultimately JST are seeking to understand the upper and lower limits of the cost forecast range (book ends), such that budgetary provision may be made as necessary.

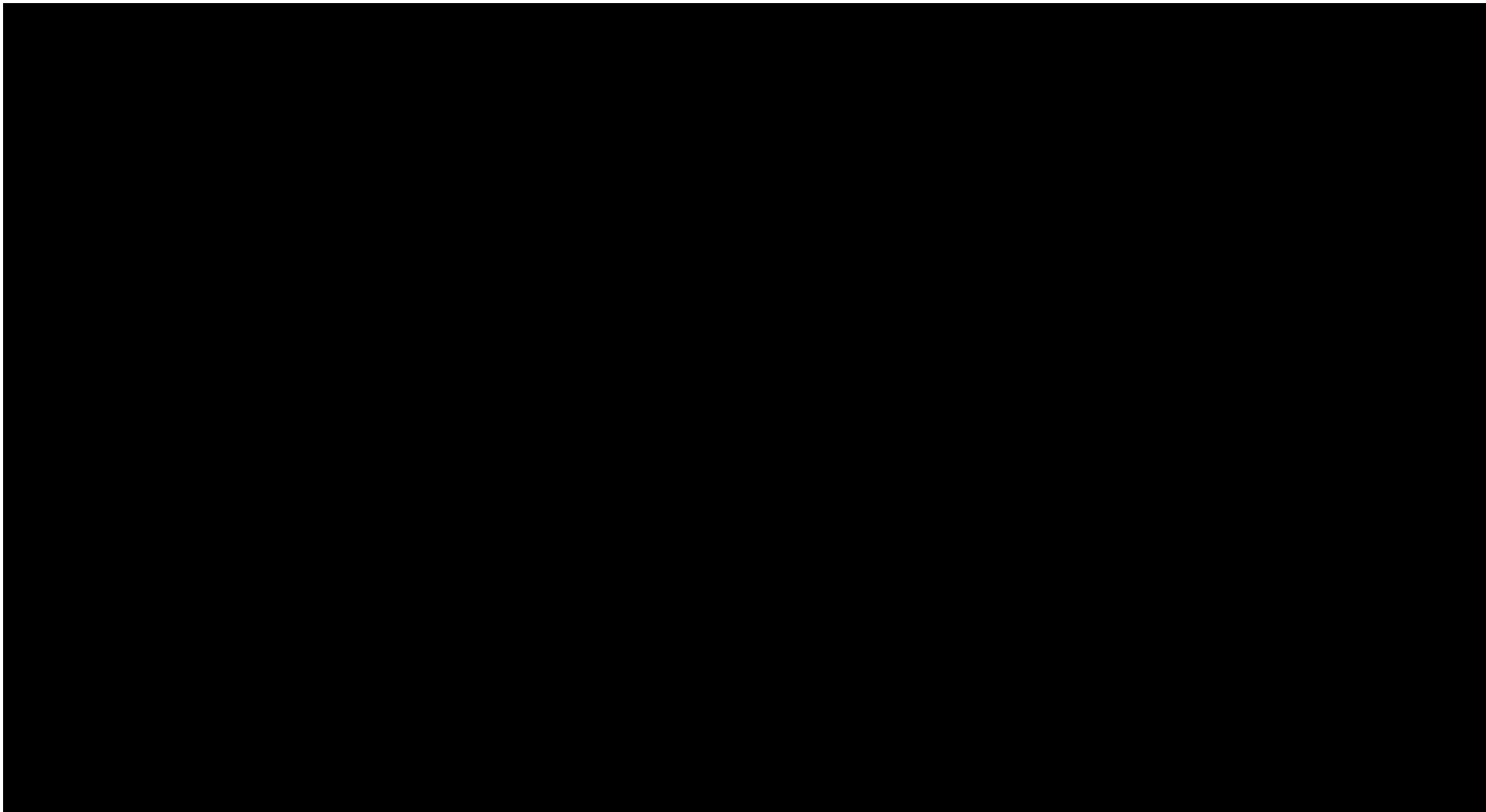
## Methodology

- A three step approach has been undertaken comprising:
  - Data gathering on the scenarios and corresponding contracts including the scope, cost, schedule and risk.
  - Review all the scenarios to understand the approach taken and identify uncertainties, issues and inconsistencies.
  - Interview key personnel involved to understand the logic, approach and thinking employed.
- The output comprises scenario flow diagrams and data uncertainty assessment, coupled with an overview of the main threats regarding cost to go.

# Scenarios

The following scenarios were developed by CRL within which the cost impact vs. the P10 (2018) reported outturn for each live contract was assessed, generating a revised total outturn for the scenario which was then compared to approved investment (IP2).

Scenario	Range	Description	Increase to IP2 (mln)
A	1	Work proceeds as per current MOHS and P10 AFCDC used as basis for costing. Outturn per contract based on updated management view.	£140
	2	Work delayed vs current MOHS but recovered (acceleration, resources and work around), with Scenario A1 used as basis for costing.	£231
	3	Work delayed further vs current MOHS requiring substantial recovery (acceleration, resources, prolongation and work around), with Scenario A2 used as basis for costing.	£283
B	1	Physical works completed on schedule, but delay in systems testing and commissioning, or incurring a 3 month delay to Stage 3 opening. Scenario A2 used as basis for costing.	£285
	2	Physical works completed on schedule, but delay in systems testing and commissioning, or incurring a 6 month delay to Stage 3 opening. Scenario A2 used as basis for costing.	£314
	3	Physical works completed but major commissioning event occurs resulting in a 12 month delay, with extended care and commissioning. Scenario A2 used as basis for costing.	£344





# Uncertainty Analysis - Scenario Outturn Cost Change

## Analysis Completed

- A qualitative assessment of all the data inputs and calculations in terms of the data utilised against the following three categories:
  - Recognised – P10 Board Report, Project Risk Register, etc.
  - Supported – Combination of recognised source data and experience led best practice to generate cost data.
  - Subjective – Experience led assessment and data generation only.
- Process data maps for each scenario were generated.
- The assessment also considered both uncertainty distribution and magnitude for each scenario OT increase.
  - Heat maps have been generated to show the distribution
  - Pie charts have been prepared to indicate the magnitude and relative proportion
- It is important to note that the only “Recognised” data point as per the above definition was the P10 AFCDC value (i.e. the starting point).
- Work has also been completed to understand the distribution and magnitude of data/calculation inconsistency or source uncertainty.

# Data Process Maps – Scenario A

## Scenario A1



## Scenario A2



## Scenario A3



# Data Process Maps – Scenario B

## Scenario B1

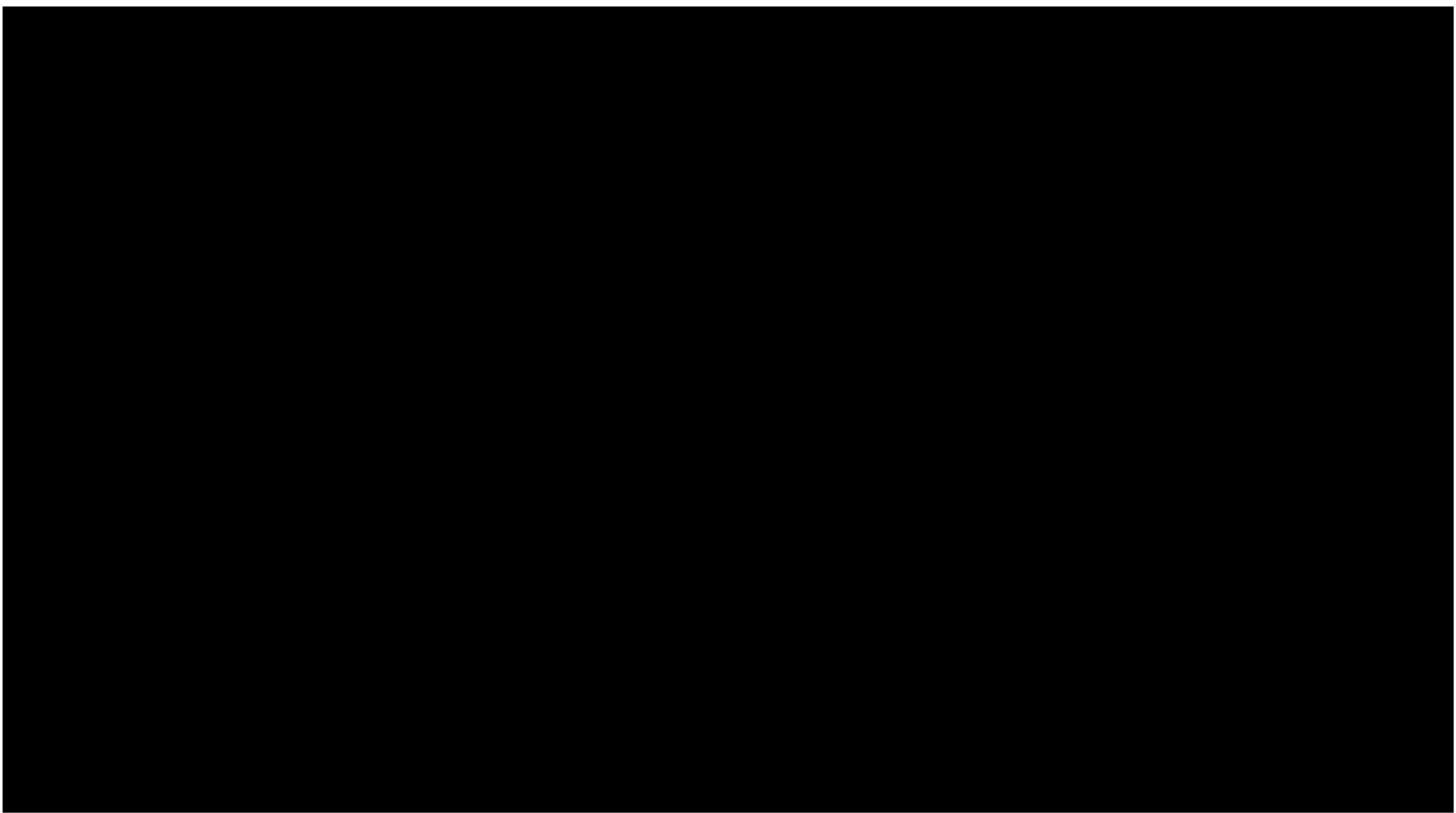


## Scenario B2



## Scenario B3





# Emerging Findings

## Context

- CRL had limited time to prepare the analysis and consequently they have used data to hand and tacit knowledge, top down analysis undertaken by competent and experienced people, with a desire to isolate from project delivery teams. This is understandable and reasonable.
- Overall to be reviewing single digit cost variations in the final stages of a major programme of this complexity and size is commendable.

## Approach Followed

- Overall it is a logical process and an expected approach to answer the question posed by the Joint Sponsors.
- The methodology favours tacit understanding over forensic analysis, using the current and forecast cost position to determine potential outcomes.
- The scenarios are understandable but not necessarily all encompassing, and there is considerable subjectivity and experience led input and assessment.
- The acceleration and recovery costs are based on the prolongation costs and not a bottom up quantification of actual resources needed to accelerate, and they assume acceleration is achievable.

## Outer Limits – “Book Ends”

- [REDACTED].
- The scenarios assume rigid boundaries, whereas reality is likely to have variability in project completion and transition operations.
- The costs and schedule are based on an optimised demobilisation at the end of Q3 2018 and the current MOHS18 is under review.
- Dynamic testing complexity is understood but not clear how this is reflected throughout the programme costs and the programme is currently losing time at the back end to thoroughly test. This is a concern.
- Changes in commercial models from Option C to hybrid arrangements may erode commercial incentives for completion and expose CRL to subcontractor claims.
- There are differences in the CRL vs. Contractor views on the defined cost position, and one month delay equates to [REDACTED] in time related (only) costs.
- The current scenarios provide an overview of potential cost increase ranges, but are not definitively the “book ends”.

# Emerging Recommendations

## Context

- The extent to which further review and analysis should be undertaken depends on the forecast accuracy desired in consideration of the budget impact for future investment plans.

## Recommendations to Support a +/- £100mIn Accuracy

- Review the updated MOHS18 schedule and re-assess the cost impact through the existing scenarios.
- Undertake a focussed review of contracts [REDACTED] with a view to substantiate and quantify:
  - Prolongation cost and risk
  - Recovery cost and capability to achieve
  - Risks and unresolved trends
  - Subcontractor positions and overall validity of Contractor view.
  - Hybrid contract risks and potential cost impact.

## Recommendations to Support a +/- £10mIn Accuracy

- Complete as for +/- £100mIn.
- Extend focussed review to the top 10 contracts.
- Build a more complex model and run multiple scenarios to generate a potential OT probability distribution.
- Evaluate the distribution tail and develop mitigations to manage.



# Crossrail Cost Scenario Review

Feedback to Crossrail Sponsor Board – 19 April 2018

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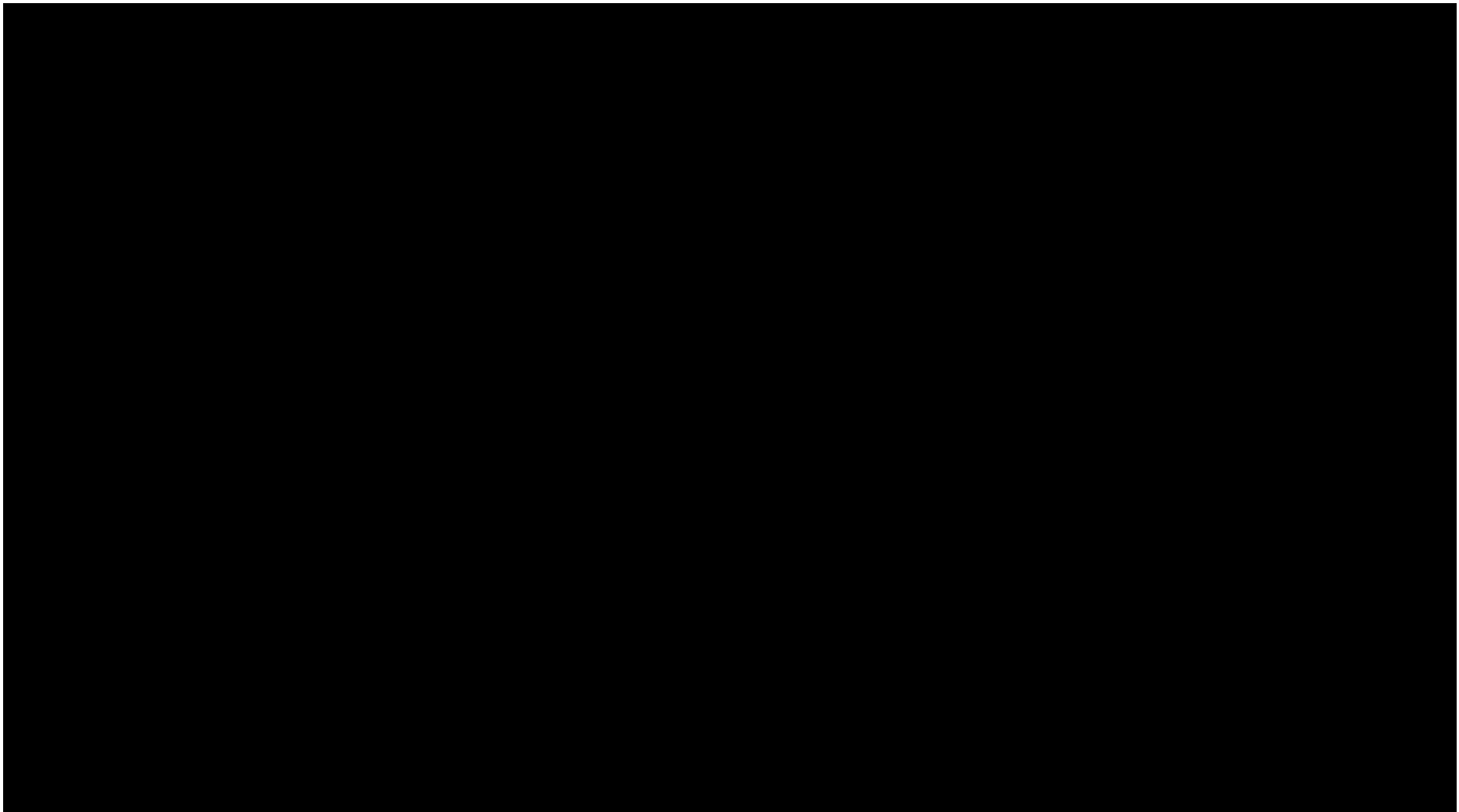
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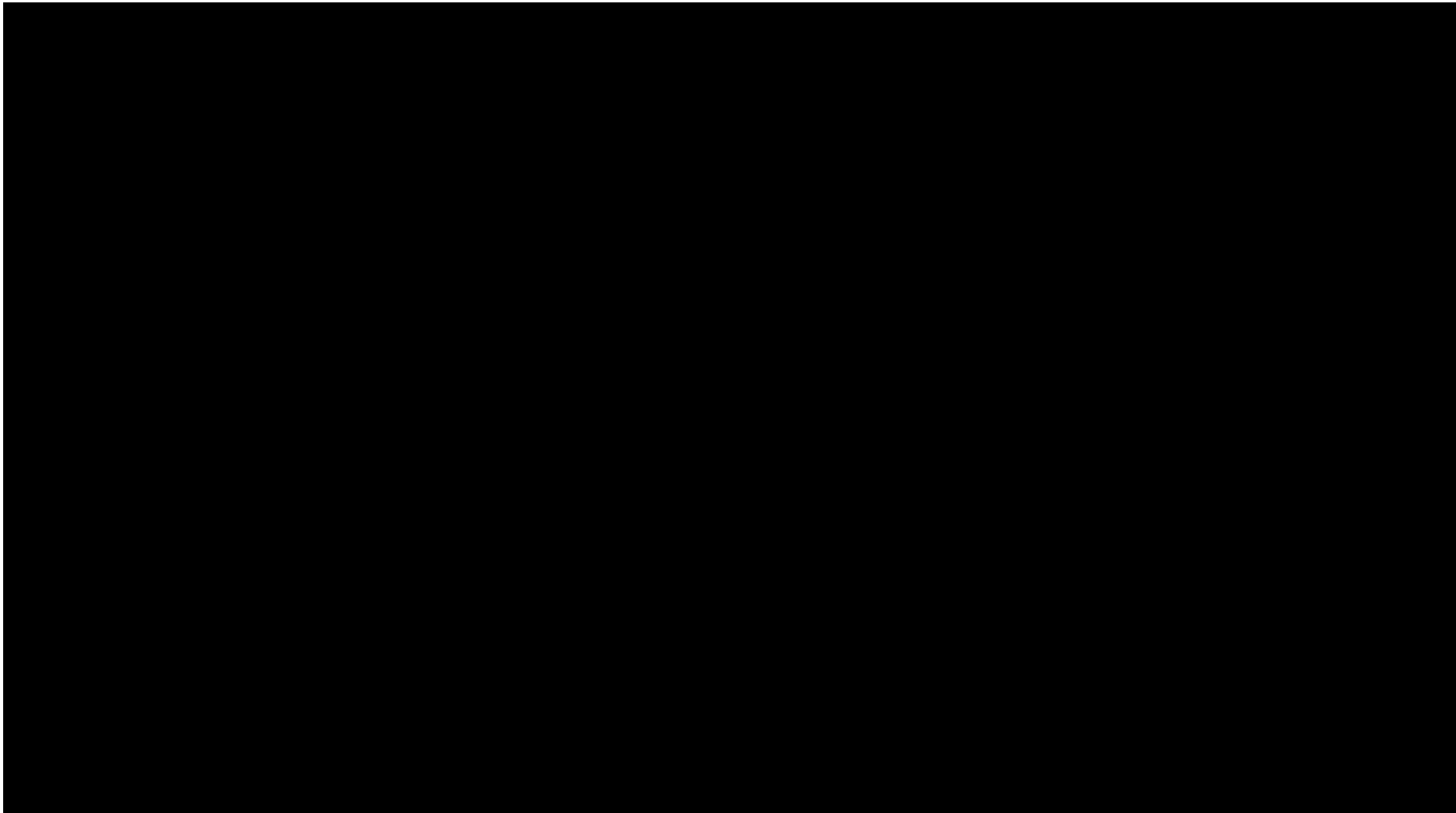
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# Emerging Findings

## Programme Schedule

- All projects are experiencing a concertina effect as work is compressed against a hard finish of 9 Dec 2018, with negligible float for future problems, delays and defects correction, and all are continuously working to recover progress.
- Consistent concerns exist re specialist resource constraints (e.g. MEP), project management teams appear at capacity, and the blockade approach will be critical to success and a real test of the project's ability to meet schedule commitments.
- The programme is strongly focussed on achieving Stage 3 opening as planned, yet the volume of physical work remaining, including O&M documentation, and the complexity of system integration, testing, commissioning, and operational handover is significant.

## Programme Cost

- The data and evidence reviewed to date supports a position that [REDACTED] currently the most optimistic scenario based forecast OT, and therefore budget provision should be made accordingly.
- The costs associated with post-Stage 3 project completion warrant further consideration as they are potentially exposed to constraints from construction in live operating environments and a prolonged duration.

## Overall Programme

Combining the data, evidence, tacit knowledge and observations made leads to the following emerging key points:

- The very strong focus on schedule is driving the projects to deliver Stage 3 opening and costs are increasing in order to achieve this.
- The likelihood of full completion as planned is low and therefore there is a high potential of significant residual work extending into 2019.
- The additional costs associated with a long project completion tail require further detailed analysis to inform the Joint Sponsors of the likely quantum and duration, and hence impact on overall budget.