

A person is walking away from the camera down a long, brightly lit tunnel. The tunnel's walls are covered in a curved, metallic lattice structure that glows with a vibrant purple light. The floor is also illuminated with a similar purple glow. In the distance, a person is walking away, and a blue scissor lift is visible on the right side. The overall atmosphere is futuristic and high-tech.

Crossrail programme recovery

1 Introduction

Authors:



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In early 2020, following the 2018 announcement of significant delay to the opening of Crossrail and the associated cost increases, the Crossrail programme was hit by yet another blow – COVID-19. The programme stopped all work in March 2020 and set about developing a recovery strategy to achieve the original objectives as closely as possible, while working out how to deal with this unknown and unforeseen threat.

In August 2020, the Crossrail Ltd (CRL) Board endorsed a Recovery Strategy and schedule that set targets for Entry into Railways and Other Guided Transport Systems (ROGS) regulations and Trial Running of 26 March 2021, Entry into Passenger Service for the Central Operating Section (COS) in the first half of 2022, partial through running from the Great Eastern and Great Western networks in December 2022 and full through running of 24 trains per hour (tph) in mid-May 2023. Since then, all these objectives have been met, with the programme on target to achieve 24 tph on 21 May 2023.



Rob Carr

Routeway Delivery Director, Crossrail

This paper describes the Crossrail response to the programme challenges experienced since the announcement of the delay to passenger service opening in 2018. There are no groundbreaking or extraordinary insights here; rather, the Crossrail programme's response serves as a case study of how the deployment of programme management tools and recovery techniques can result in an extraordinary outcome despite the challenges.

Three dominant strategic focus areas emerge:

- Generation of a recovery strategy and adjustment to emerging information and threats
- Ongoing evolution of the organisational structure to create the right environment and recruit the right people for the final integration phase of the programme
- The use of management tools, in particular a Delivery Control Schedule (DCS), to control and manage recovery to the committed programme



Rob Scopes

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The success of the recovery programme has been largely down to the willingness of CRL, its stakeholders, and its sponsors to confront new and challenging circumstances, and to adapt quickly. This has been through a combination of organisational change to reflect the transition from civils construction to systems integration and bringing the railway into use, coupled with the creation of an agile recovery strategy. Underpinning this has been the provision of accurate and timely management information on a rigorous four-week reporting cycle, feeding into an overarching Delivery Control Schedule owned from shop floor to CRL Chairman and latterly the Transport for London (TfL) Commissioner.

This paper has been written chronologically to describe the key activities and interventions that the CRL, Rail for London Infrastructure (RfLI), London Underground Ltd (LUL) and MTR joint team implemented to recover the Crossrail programme. It describes some of the key complexities and impacts that affected the programme, and pulls out strategic insights (Blue Boxes), tactical insights or lessons learned (Green Boxes), and identifies risks that affected the CRL recovery programme but could be mitigated on future programmes (Purple Boxes). A summary timeline is presented in Appendix 1, aligning the Recovery Strategy, organisational change and Delivery Control Schedule events.

Finally, these 43 call-outs are refined into 21 summary recommendations, each aligned with the three strategic focus areas above and the Department for Transport (DfT) paper on *Lessons from Transport for the Sponsorship of Major Projects* (see Appendix 3). To the five themes emerging from the DfT sponsorship paper, we propose to add two more programme management themes, creating seven key programme themes for any major programme to consider.

The five DfT sponsorship themes are:

- A – Accountability must be unambiguous
- B – Behaviours matter more than process
- C – Control schedule and benefits as well as cost
- D – Deal with systems integration
- E – Enter service cautiously

To these we have added two programme management themes:

- F – Facilitate investment in leadership and team
- G – Generate and maintain an agile delivery strategy that is regularly tested

2 Emerging crisis

Second half of 2018

For the majority of the Crossrail programme, passenger operations were scheduled to open in December 2018; however, in late 2018, it became clear that the programme to deliver this was no longer credible. In response, there were changes to the Chairman, CEO, Executive Management team and Board.

While much has been written about the Crossrail programme in late 2018 and the decisions taken, the following are the undeniable facts.

- The programme schedule in place in December 2018 – the Master Operating and Handover Schedule (MOHS) – was no longer credible and did not contain all the work required to open the railway.
- The Programme Controls team had been largely demobilised, including supporting cost and risk management systems, meaning the quality of management information on which decisions were being made was low.
- There remained a substantial 'orange army' of construction resources with high associated ongoing costs.
- Commercially, the remaining contracts in place had long since lost any target cost incentivisation, and at that time were essentially 'cost plus'.

Collectively, this required a reset of both the organisation and the programme itself. In the first half of 2019, the Crossrail leadership had to balance priorities across the programme and complete strategic planning of the 'Earliest Opening Programme' (EOP), while recruiting an experienced systems integration team to deliver it.

The new CEO set about assembling a team of experienced railway delivery people to augment the talent already working on Crossrail, including people who had commissioned LUL stations, people who had commissioned 24-tph services on the classic network and people who had run major blockades in complex live-railway environments. These people needed to be on board early enough to make sure that the new recovery and staging strategy was robust. This took time and did not conclude until early 2020.

Strategic insight: Programmes go through different phases. Each phase needs a critical review of the organisation to make sure the best and most experienced people for that phase are part of the team. At this time, the programme needed a leadership/management team experienced in commissioning complex railway systems, but it took time to assemble the team.

A Strategic Delivery Office (SDO) was established by the CEO to support the resetting of the programme strategy or 'programme reboot'. This comprised rebuilding the organisation (building capacity and capability across core teams), redesigning and implementing fit-for-purpose governance, and establishing the right management information to diagnose the most critical areas of the programme.

The SDO oversaw activities that included those listed below:

- Setting up a CEO 'War Room', providing **organisational performance** management information on rebuilding the Crossrail Ltd organisational capability
- **Executive sprint planning**, where the CRL leadership developed strategic objectives and monitored plans to enable momentum to be created and provide clarity down into the programme organisation
- A review of the '**programme architecture**', which included resetting governance and reviewing meeting objectives, agendas and attendees, to ensure they fitted the new strategy
- **Management coaching and leadership workshops** to support the development of collaborative and winning culture leadership objectives
- **The establishment of enterprise risk** and alignment to TfL's enterprise framework, with 12–20 strategic risks that had Executive ownership and clear mitigation plans
- The introduction of **visual management** to provide **programme performance** to reconnect the programme, sub-programmes and projects, providing quantity tracking on asset and assurance completion. When introduced at programme, sub-programme and project levels, it helped build team and stakeholder confidence in the day-to-day delivery of the programme; however, it was recognised as an interim fix while a new baseline recovery plan was established to replace the MOHS

Lesson: At times of major programme recovery, a multidisciplinary SDO is required to deliver organisation development activities concurrently with the resetting of the programme.

Lesson: There is a need for different types of management information at different times in programme recovery. It wasn't possible for a fully re-baselined schedule to be developed before performance management was initiated, as there was a need for near real-time data on what was happening day to day, both around organisational development and around programme performance, to get the programme moving coherently again.

3 The Earliest Opening Programme (EOP)

The new opening strategy (first half of 2019)

The Crossrail programme had a high-level five-stage opening strategy that opened overground to the east and west (Stages 1 and 2), and then opened the COS in three stages: central services between Paddington and Abbey Wood (Stage 3), followed by increasing services and through running east to west and then full through running east and west (Stages 4 and 5). This was a good strategy, and one that, to some extent, mitigated the risk of opening the whole service. However, this treated the complex COS as a single-stage opening. The COS had nine large, brand-new central stations including integrated vent shafts and platform screen doors (PSDs), plus a tenth terminal station (Abbey Wood), five portals, five separate main ventilation shafts and an underground (Communication-Based Train Control) signalling system integrated with the national network signalling systems (European Train Control System and Train Protection and Warning System) at the east and west mainline fringes.

It became clear that this was a massive systems integration challenge and an almost impossible task to bite off in one chunk. Further staging was a necessary next step. This would not be easy because the COS had not been designed for staged opening. This would require agile thinking around systems integration and safety assurance.

In the latter months of 2018, the new Crossrail leadership and Board commissioned work to investigate a minimal viable passenger railway through the COS at opening that met the necessary safety cases but could be implemented in a staged approach to deliver the full COS functionality. Crossrail leadership set out to achieve this as quickly as possible. By January 2019, the CRL Board was presented with and noted the strategy and approach latterly referred to as the Earliest Opening Programme (EOP).

The opening configuration would need to be a safe, assurable, acceptably reliable, maintainable and operationally sustainable railway. A set of *de minimis* requirements were developed that had to be delivered at the opening of the first stage. These are contained in Appendix 2.

A key shift in the mindset of CRL at this time was a focus on the more widely recognised challenges of the software interfaces between train, signalling and the Supervisory Control And Data Acquisition systems (SCADA). The Crossrail response to this was to strengthen and empower the Systems Integration (SI) team that existed within the Technical Directorate and create 'Plateau' teams responsible for managing common configuration states for SI. These teams contained representatives from Crossrail, the Tier 1 contractors and the Infrastructure Managers (IMs). This is covered elsewhere in Crossrail's Learning Legacy: *Crossrail System Integration – The Practicalities of Integrating Europe's Most Complex Rail Project*.

Strategic insight: Technical and programme integration has to be led by the client – you cannot outsource this to Tier 1 contractors and rely on contract clauses to 'make' the supply chain address the millions of issues that emerge on-site as the various elements are integrated.

Strategic insight: Create the right collaborative environments for contractors to work together. CRL implemented 'Plateau 1' for routeway contractors and stakeholders, and then created 'Plateau 2' for station contractors and stakeholders. This is difficult to do after the event, so it needs to be factored into the contracting strategy at the beginning, and should be led by the client. See the paper referenced above for more detail.

In parallel with the top-down EOP strategy, work was ongoing to build bottom-up schedules that would deliver the work to enable the EOP. This bottom-up schedule became the DCS and contained much-improved schedule logic and a clearer view of the work to be delivered. This schedule was subject to scenario analysis and subsequently went live from August 2019 as DCS 1.0. This increased the level of control; however, it remained in places overly optimistic, with challenging deterministic dates set by the project teams themselves, subsequently found to be too challenging regarding productivity and production forecasting accuracy.

The programme's master schedule was rebuilt using project-level forecasts containing no time contingency or time risk allowance (TRA). These were extremely challenging to deliver. As a result, the programme's DCS came under pressure relatively early on. To absorb this, while the underlying confidence in the schedule was improved, the use of 'opening windows' was implemented. Instead of specific target dates for external key milestones, opening windows were published to provide stability while the underlying issues with schedule confidence were rectified. The internal programme control activities managed performance within these windows, targeting achievement as early as possible.

Strategic insight: In times of major programme recovery, there is significant pressure to commit to a single opening date; however, this is inadvisable. To build stakeholder confidence, it's more important to have a reset plan that holds to key date windows and builds confidence, than to be overly optimistic and then have to reforecast frequently.

To gain Board and stakeholder confidence in the EOP and DCS, independent insight and assurance was sought at regular points throughout the recovery. This included a set of third-party expert 'red and black' reviews, where panels were asked to review the schedule (red review) and the commercial and cost positions (black review). The outcomes of this approach were incorporated into the programme controls reporting and the review teams' summary outputs were shared with stakeholders to increase confidence. Later in the programme, Crossrail's assurance function was brought closer to programme activities to provide more progressive real-time assurance.

Lesson: Use third-party independent expert panels and independent assurance proactively and openly at regular points in the programme, to gain sponsor and Board confidence and trust in the new approach.

4 'How deep is the hole?'

Handing over the Shafts and Portals (second half of 2019 to February 2020)

The handover of the Shafts and Portals was selected as a test case for the asset handover processes. This was because they were due to be handed over early in the sequence of assets and were considered to be relatively simple compared with the other Crossrail assets. In practice, this brought to light some interface issues concerning how the work was being measured. The civils works contractors were claiming (in schedule and commercial terms) that the work was complete when it was physically installed; however, the Engineering and Operations team was not accepting the work until it had been fully integration-tested and the relevant documentation had been completed. There was a clear mismatch in reporting of 'completion' across the disciplines and this exacerbated the lack of trust between project delivery teams and those parties accepting the assets. In many instances, the integration testing and associated documentation required was a 'many to many' relationship, meaning that it was hard to track progress accurately without a configured relational database; this was never attained on the programme and so required tactical workarounds.

Lesson: There is a need for a clear and agreed definition of 'complete', with common formats for recording status in the relevant management systems across the delivery and acceptance teams. A relational database, mapping the links between completion evidence, is also advisable.

Historically, the Shafts and Portals had been grouped with stations for delivery management, but in reality, they needed to be linked to routeway as they were fully integrated into a number of core routeway systems.

The Shafts and Portals were typical of all elements of the programme in that schedule adherence was consistently and doggedly around 33%, meaning that only a third of the planned activities for any given period were being delivered. Through analysis it was clear that this was driven by complex work interfaces in this phase of the programme. Remaining physical installation locations became much more congested, and the commissioning and testing processes were non-linear and highly integrated.

The delivery window was set between the deterministic date and the dates that had a 50% probability (P50) and an 80% probability (P80) of being met as determined through Quantified Schedule Risk Analysis. Crossrail traditionally performance-managed the programme to deterministic dates (i.e. including no risk) and managed the sponsors and Board to P50. Due to schedule performance issues and the lack of resilience in the plan, the CRL team consistently did not meet deterministic dates, and this had a real impact on team motivation.

Lesson: Delivery plans need to be achievable for teams to buy into them. In subsequent iterations of the DCS, deliberate schedule contingency and 'fire breaks' were included as part of the planning logic, which meant it was no longer a zero-probability (P0) delivery schedule and allowed for some flex in delivery. This approach meant schedule forecasts became more stable and supported.

While the works remaining still included some civils elements, such as the tunnel pump drainage, the majority of the remaining effort would be around systems integration.

To support this transition, the delivery philosophy was adapted from one of a construction project with some testing, to one supporting joint priorities – with three days allocated for civils and unit testing, and four days allocated to Dynamic Testing. This required roles and responsibilities to be updated, and the development of the Trace Access Matrix, a co-ordination tool to manage access priorities in four dimensions (including location and time). The governance of the Trace Access Matrix allowed effective triage of trade-offs between different competing demands.

Lesson: Where integration work is complex and integrated, programmatic governance needs to be nimble and adapted to allow controlled but quick decisions about priorities.

A Key Performance Index (KPI) 'tree' was developed to complement traditional programme controls metrics (Schedule Performance Index, Cost Performance Index, Earned Value, etc.) to provide an objective view of progress and performance. It set out a strategic framework aligned to the assets required for 'Entry into Trial Running' (the first configuration state). Each asset was assessed along its value chain to simply lay out the steps it would need to undergo to be ready for the first configuration state (e.g. design, build, test and commission, assure and handover). The aim was to show how each step along the value chain was progressing and the relative performance of each step. Assessing progress at this stage of the programme life cycle was difficult due to the different types of work being undertaken across the railway. As a result, an approach that relied on trusted data to demonstrate performance was taken. The key documents to evidence the completion of each asset were mapped along the value chain, with their status continually tracked to provide an objective view of progress. This KPI tree was a key tool in enabling stakeholders to understand performance across the programme.

Lesson: In areas of programme uncertainty, there is value in creating a single view of the elements of production and quantities across the programme that need to be delivered. Holding this separate to the schedule allows a deliberate focus on the work, not timings.

A key organisational response was to implement project-level Integrated Delivery Teams (IDTs) – which had representation from the various parties involved in delivering, handing over, and subsequently operating and maintaining an asset – and make these jointly responsible for developing and agreeing the project-level plans and managing to them.

This promoted an integrated response at project level, but with up to 30 IDTs at any one time competing for resources and access, it was essential to centralise co-ordination in order to maintain the overall strategic intent. This was required to prevent the individual IDTs ploughing their own furrow, potentially at the expense of others. A strong central 'guiding mind' covering technical, delivery and operations was needed. To provide this, senior CRL executive staff accountable for these areas, including the CRL CEO, met weekly with the leads across the CRL and RfLI organisations to enable the right strategic calls to be made on issues, conflicts and blockers against a single programme strategic objective.

Each single programme strategic objective was carefully chosen to galvanise all organisations and teams around a major programme event that everyone was incentivised to achieve. These were: Entry into Trial Running, managed weekly through the Trial Running Mobilisation Board (TRMB); Entry into Passenger Service, with the TRMB replaced by the Passenger Service Steering Group (PSSG); and Completion of Stage 5, with the PSSG replaced by the Stage 5 Mobilisation and Blockers meeting.

Strategic insight: Where performance is challenging, there needs to be organisational collaboration and joint planning and ownership across delivery, operations and maintenance, to avoid a first-past-the-post mentality, which may often result in sub-optimal decision making. What is best for the programme may require trade-offs at site level across the three disciplines. Weekly strategic sessions led by an independent chair are essential for co-ordination across the programme of individual projects, with a clearly defined strategic objective to galvanise activities around and make prioritisation easier.

To support the delivery of the EOP, the SDO team developed strategic plans to track progress and showcase strategic events that could prevent the programme from achieving its EOP objectives. An End to End (E2E) integrated plan, paired with a detailed description of how the scope should be delivered, was developed through a series of 'right-to-left' planning exercises and through understanding the critical sequences from the DCS. CRL leadership referred to these exercises as the 'backwards pass' approach, the name given to strategic right-to-left planning.

'Backwards pass' sessions were conducted with leadership and key programme representatives to further enhance the collective understanding of specific entry and exit criteria, and 'what needs to be true' to achieve programme milestones. The focus was working back from Stage 5 (through running), Stages 4 and 3 (operation in the COS), Trial Operations, Trial Running, and Entry into ROGS.

Strategic insight: The schedule must be assessed against 'right-to-left' logic testing, not the classic 'left-to-right' approach. Start with Entry into Passenger Service, Trial Operations, Trial Running, assurance, testing and commissioning and so on. The CRL schedule pre-2019 totally underestimated the system integration requirements, despite this being the most complex digital railway ever delivered. It needed a significant amount of time for all the various systems to be brought online.

Lesson: Overall, this 'horizon-scanning' approach, built on 'backward pass' workshops and a strategic E2E plan, was a valuable adjunct to the day-to-day controls cadence. As a whole, it would be appropriate to deploy 5–10% of total programme control resources to this activity, ring-fenced from the day-to-day business-as-usual (BAU) control activities. Without this ring-fencing, the ability to think and plan strategically is reduced by the need to 'firefight', which tended to be required over long periods.

As a result of this long-term view, Crossrail executives were able to have a clear understanding of the overall upcoming challenges and gaps to be addressed, enabling them to increase the maturity of the plan and grow confidence in the deliverability of the programme. The development of the E2E plan (and the application of 'backwards pass' workshops to develop it in detail) was separate to the development of the DCS baseline. The outcomes identified in the E2E plan supported the DCS, but they were ultimately two separate artefacts that were used in parallel. The E2E focused on strategic requirements for achieving subsequent stages of the programme (i.e. achieving sufficient reliability for Entry into Trial Operations), while the DCS tracked and measured the activities that needed to be delivered to achieve that requirement (i.e. specific days when the COS was used for Dynamic Tests).

This overarching E2E plan also helped provide the delivery teams with an understanding of the bigger picture and the value that their work brought in delivering the Elizabeth line.

This strategic work also enabled Crossrail to develop a horizon-scanning approach that was used as the Executive and senior management's tool to promote thinking beyond the next target or milestone. Through horizon scanning, 'what if' scenarios were developed to identify 'hotspots' and mitigations, allowing the deployment of interventions as early as possible to rectify off-track trajectories.

Crossrail benefited from these approaches in several ways, from increasing co-ordination and integration across delivery organisations and the operator, to early resolution of long-term risks, releasing pressure from day-to-day operations, allowing CRL to focus its attention on the bigger picture.

As part of this work, the SDO also performed 'heuristic' risk analysis in parallel. This responded to stakeholder concerns about the veracity of the bottom-up probabilistic programme controls-derived data. This alternative approach looked at circa five mega risks (train reliability, software, etc.), and looked at a mixture of scenarios to get best- and worst-case outcomes, plus some interim scenarios. This was referred to as 'headwinds and tailwinds' analysis.

Lesson: 'Heuristic' risk analysis proved a better approach than standard QSRA/QCRA analysis when engaging meaningfully on the recovery programme with the Board and sponsors.

At the beginning of 2020, the final pieces of the Executive and Systems Integration Delivery team were put in place. A new Chief Programme Officer was appointed, along with a new Chief Finance Officer to complete the CRL Executive team, and new appointments were made to provide strength and depth to railway systems integration and commissioning knowledge in the delivery functions.

From January 2020, before the impact of COVID-19, there were delivery performance issues – especially in the Shafts and Portals and stations – that were manifesting as schedule slippage. The approaching COVID-19 pandemic would further exacerbate this schedule pressure.

5 COVID-19 crisis

Stop, restart and an opportunity for a new strategic approach: March to June 2020

In March 2020, at the time of the first COVID-19 lockdown, CRL instigated a Safe Stop for all works on the Crossrail programme. While this was a very difficult decision to take, it was a necessary step to protect the workforce. It was also a golden opportunity to put our foot on the ball and take a step back to reappraise the situation. More than 4,000 people had been working on the programme up to that point, with poor productivity reported (around 33%). The SDO migrated into the Silver Recovery teams.

CRL immediately implemented a 'working from home' policy for everyone except those absolutely required at site. This helped manage the initial threat, with regular personnel updates via Zoom calls to keep the workforce updated on the developing events.

Strategic insight: 'Never waste a crisis'. COVID-19, while terrible for the country, was an opportunity to reset the programme. Don't be afraid to stop and reset the programme if the circumstances dictate. Harness the talent that was too busy fighting the fires and set it to work to strategically solve the route to closure and, in doing so, tackle the crisis.

At this point, the programme was moving into the assurance stage with assurance activities on the critical path. The Elizabeth line is a highly complex integrated digital railway. On top of that, the level of effort required for the assurance pyramid was a huge challenge. We were assuring a brand-new railway for the Office of Rail and Road (ORR) as well as the standing-up of a new Infrastructure Manager (RfLI). The CRL Executive members had to chair assurance close-out forums, not a common requirement on established networks such as Network Rail and London Underground.

As a result, significant assurance documentation was required for the regulators to authorise the railway to be placed into passenger service. Working from home suited these activities and allowed staff to focus and concentrate on generation of the completion paperwork. The extra time at the beginning and end of the day gained from not commuting (two to four hours) aided this, but those members of staff with young families were particularly impacted, with some opting to return to the office in order to work effectively. This was managed in a controlled way to minimise risk to our personnel, both from a COVID-19 and wellbeing perspective.

Lesson: Quick development and deployment of new working rules, with an opportunity for exceptions to be granted in a controlled way, assisted the programme recovery. Gold, silver and bronze command levels were set up and led by programme personnel. Weekly reviews adjusted the programme approach.

Once new COVID-19 safe-site protocols had been determined, teams were only allowed to start with defined works packages and areas of work that maintained social distancing and observed the COVID-19 guidelines. This was an opportunity to exert absolute control on the deployment of personnel. Safe working rules meant work could be delivered more efficiently, but over a longer time frame. Previously congested work fronts were now easier to work in. The workforce reduced from over 4,000 to around 2,000 under controlled deployment, which improved cost control.

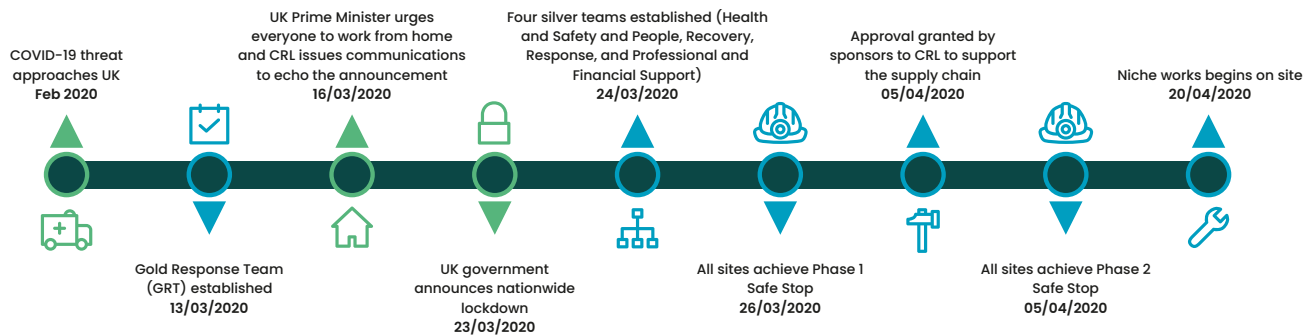


Figure 1 The impact of COVID-19 on the CRL programme

Dynamic Testing with the trains was restarted once agreement with ASLEF was reached (a maximum of eight staff on any train, only two personnel allowed in the cab and socially distanced welfare arrangements in place). This was a low COVID-19 risk activity but had high impact on programme achievement, allowing the high-level schedule to be maintained while replanning to absorb the COVID-19 impact elsewhere.

With the complete uncertainty that COVID-19 brought, the recovery team used techniques to describe the range of impacts that COVID-19 could have. This was characterised by using ‘Dials of Disruption’ to describe potential COVID-19 scenarios and articulate the potential impact of COVID-19 disruption on the Crossrail programme as the severity or longevity of disruption increased. Figure 2 is a snapshot of the thinking from April 2020.

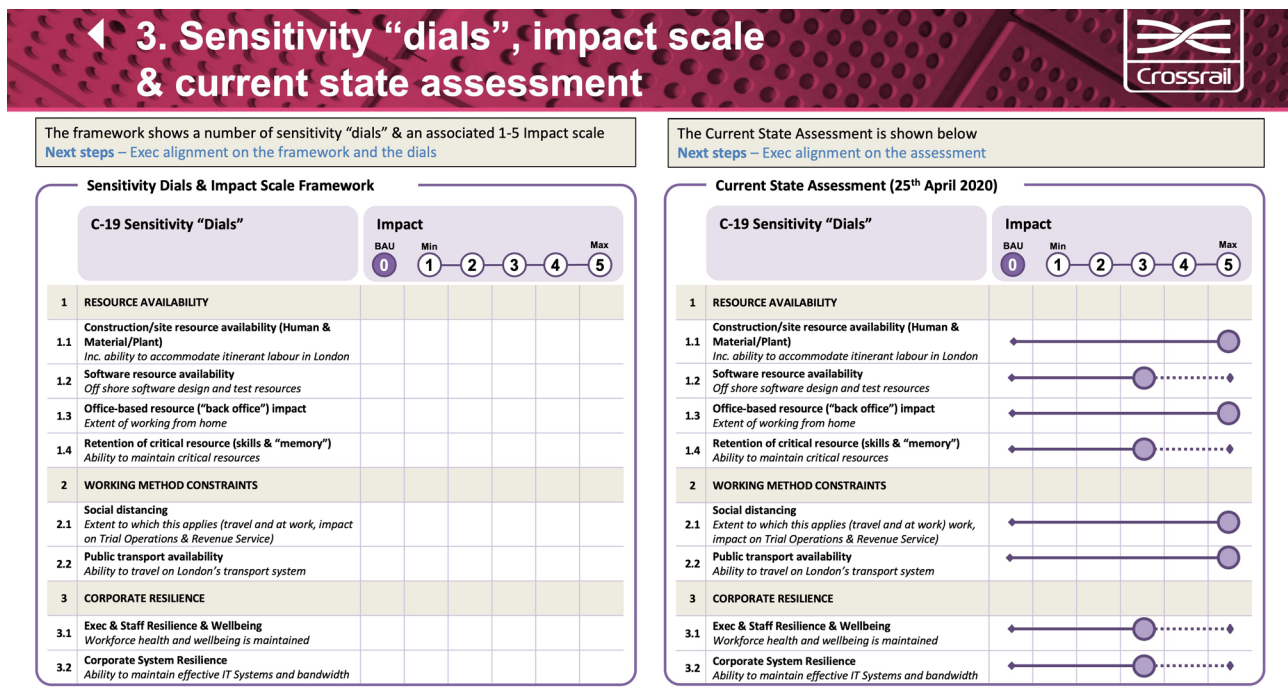


Figure 2 The ‘Dials of Disruption’

Describing an unknown threat in terms of its potential impact helped manage the uncertainty and develop the necessary short-, medium- and long-term mitigation plans. This then provided reassurance to the Board and sponsors that the mitigation plans could be deployed to restart safely.

Lesson: Describing the likely impact of a threat on the programme and how it varies (rather than attempting to characterise the unknown threat) quickly led to the identification of the required mitigation plans.

The short-, medium- and long-term mitigation plans assured the sponsors, Board and Non-Executive Directors that CRL was in control, while we developed the outline recovery strategy and revised the DCS.

The Panel of Independent Strategic Advisors retained by the CRL Board facilitated engagement with other UK programmes and operators (Hinkley Point, Network Rail, Sellafield, Thames Tideway and HS2) to learn about how others were handling COVID-19 impacts. Their independent review of the mitigation plans in place, added to the adoption of best practice from other programmes, gave confidence that we were applying or adopting best practice while dealing with this threat. The panel provided a vital role throughout programme recovery, being deployed as individual subject-matter experts or as a panel, by critically and independently reviewing key aspects of the programme and advising the executive and Board.

Strategic insight: Retaining a panel of independent strategic advisors that can be deployed quickly on key programme issues provides independent critical and experienced advice to the Board, Executive and senior leaders in the programme. This can be crucial when steering a recovery programme through uncharted waters.

Lesson: To record the emerging schedule, the DCS was modified under change control to reflect the emerging strategy; this was characterised as DCS 1.1, which was not a wholesale change but a significant departure from DCS 1.0 (the EOP). To provide confidence to the assurance teams (Lines of Defence 2 and 3), the programme adopted a DCS Maturity Matrix to increase transparency of schedule quality, and improve the maturity of the schedule discussions with the assurance team, Board and sponsors against specific modules of the recovery strategy.

The COVID-19 pandemic allowed the programme to reassess the software deployment programme and identify more advantageous software configurations that would improve the outcomes of the testing. This was both in terms of verifying better, more mature software configurations, but also by identifying earlier – through Dynamic Testing – the key issues to resolve from an operator point of view.

Programme controls and periodic reporting were a dominant part of the recovery approach. The regular four-week reporting cycle kept people focused on the programme and the issues, while providing good management information to validate the schedule and approach, or adjust it as required. This also gave confidence to the Board, sponsors and stakeholders that the recovery plan was working. Visual management was operating in support, but it is no substitute for a well-constructed and resourced schedule that is bought into by all levels of the programme.

Lesson: Key points from this period are:

- Use of the 'Black Swan' crisis event (COVID-19) as an opportunity to reassess the programme, e.g. software upgrade availability and opportunity for better configurations to be deployed at key stages, reducing risk
- Taking advantage of the medium- to long-term uncertainty to set an achievable near-term objective (Entry into Trial Running) that the programme could be galvanised around, while gathering intelligence on longer-term COVID-19 impacts on programme capability to firm up later stages
- Focusing on finishing the Shafts, Portals and routeway – 'the pipe' – first to complete the initial Dynamic Testing for software development, then finishing stations
- The switch from a split week sharing construction works with Dynamic Testing on a four-day/three-day split, to longer Dynamic Testing windows (weeks/months) with a blockade approach for concentrated works delivered with meticulous planning (hour-by-hour activity scheduling and reporting)
- The use of planned firebreaks to absorb any poor performance or unexpected outcomes

6 A new approach

Solidifying scope, increased productivity and emerging confidence: the second half of 2020

The COVID-19 Recovery Strategy was developed as a set of 10 modules, each with a senior programme owner. It was written as a complete document with integrated strategies for each module (Routeway Delivery, Station Delivery, Testing and Commissioning strategy, Ops Readiness, etc.). Writing the complete strategy down helped capture all the work, and determine and iron out any discrepancies between the individual modules and module owners. The plans for each module were used to develop the DCS 1.1. These were then critically reviewed through an internal assurance process.

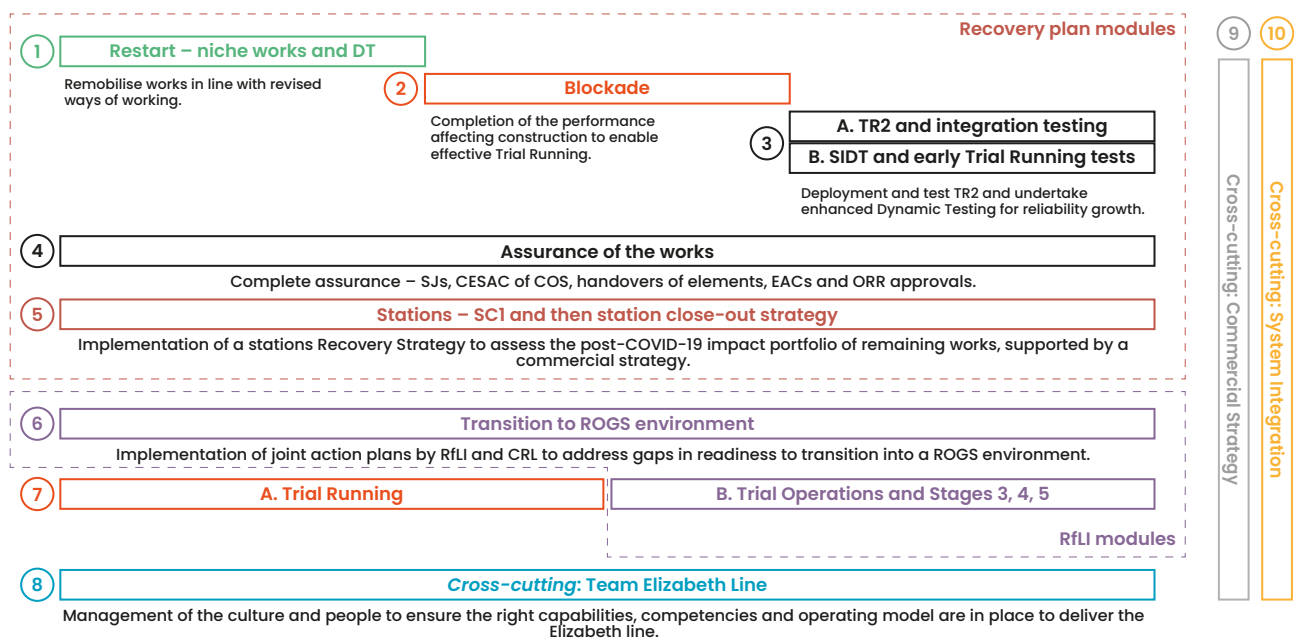


Figure 3 The 10 modules in the COVID-19 Recovery Strategy

Assurance at CRL followed the classic ‘three Lines of Defence’ (LoD) approach, where LoD 1 consisted of internal peer-on-peer checks and validation, LoD 2 consisted of semi-independent assurance and challenge, and LoD 3 consisted of independent and external assurance. LoD 1 checks were presented to the LoD 2 team, who reported their findings to the CLR Executive, CRL Board and Commissioner. LoD3 reports were issued and published externally.

The progressive and semi-independent LoD 2 assurance review carried out on the Recovery Strategy and DCS 1.1 gave confidence to the Board and sponsors that the plan was credible. While not agreeing with everything in the Recovery Strategy, a constructive dialogue between the programme team and the LoD 2 team identified and resolved weaknesses and built-in recommendations from previous LoD 2 reviews (for example, ensuring contractor and stakeholder involvement and buy-in to the emerging schedule before baselining).

The schedule implications of each module were incorporated into the emerging DCS 1.1, and this was used for the Quantified Schedule Risk Analysis that determined the opening window.

Lesson: By applying a rigorous project management approach to the programme and writing down a coherent strategy in this time of high uncertainty, we were able to describe a strategy that all stakeholders could get behind and focus on, even if only in the short term until Trial Running. LoD 2 review and engagement helped deliver a more robust approach and give confidence to the Board.

As the modules were developed, the DCS reflected the emerging activities from all the partners, not just CRL and the IM and operator RfLI, but also the train operator MTR. This would continue with each DCS refinement (DCS 1.2 and DCS 1.3), building more transparency and linkages into the strategy.

Strategic insight: The schedule baseline has to reflect all of the work, which includes not just the physical, but also testing, rework and assurance activities. Productivity needs to be factored into the schedule times and productivity will be a function of the environment the leadership creates. The paperwork mountain is as big as the physical one, but is often left until the end. It needs to be progressed in real time as the job is built.

A key technique deployed as part of the strategy was the use of a 'blockade approach' used on national network projects for focused construction delivery. This required meticulous planning against a fixed scope of works, refined into a set of activities that were planned on an hour-by-hour basis through the blockade. The blockades could be between one and nine weeks long, but all had to adopt the same rigorous approach. Despite some initial scepticism, the blockades deployed in the summer of 2020 achieved productivity levels of over 95% and allowed Dynamic Testing to be carried out in the periods around the blockades, facilitating efficient and effective testing periods. This performance underpinned the credibility of the recovery strategy and gave further confidence to the Board.

Strategic insight: Demonstrated performance does not lie; CRL productivity was typically 33% against the planned activities between 2019 and the start of 2020, so slippage was constant. The leadership had to recognise this and act, either by accepting it and reflecting it in the time allowances or by changing the environment. We introduced a blockade strategy to complete the works in the routeway, which raised productivity for the works undertaken in that environment to 95–100%. This was because the whole programme galvanised to deliver this level of output (planning, logistics, management, reporting, etc.).

Lesson: While detailed hour-by-hour planning is usually unsustainable for long periods, for short periods of intense well-planned activity it can deliver extremely high levels of productivity, freeing up time for other activities such as testing and commissioning or Trial Running.

The programme management leadership continued to drive better schedule adherence through the deployment of simple productivity measurements via the Programme Controls team. Each period, the achievement of 'start activities on time' and 'finish activities on time'

was measured for each project, and a league table was published that all projects could see. The final handover deliverables were also monitored on simple Red/Amber/Green (RAG) status tables and published as a complete set for all projects in each period. This visibility and clarity allowed the senior management team to focus on the key areas that needed help, and the projects to gauge how they were doing against each other. As a result, schedule adherence in between blockades rose from 33% to around 70%.

Lesson: Simple project metrics and management information for key deliverables compared across projects and discussed at executive level on a periodic basis can galvanise teams into improving delivery in key areas.

As part of the Recovery Strategy, the delivery schedule for the 10 COS stations was critically reviewed. The EOP had assumed that the stations could be brought online two at a time, two weeks apart. Resource-loading the schedule for critical resources such as Fire Engineers and Commissioning and Testing Engineers showed that this could not be achieved. A 12-week T-minus station commissioning countdown process was enforced for each station, with an associated critical resource assessment to 'spread' station commissioning out in order to not overload key resources (engineering/technical/control and communications). This helped justify moving from two stations every two weeks prior to commencement of Trial Running to a more streamlined and resource-supportable programme of a station every 12 weeks during Trial Running, with an overlap of four to six weeks between stations from March 2021. All stations, with the exception of Bond Street, would achieve 'SC3ROGS' (see Appendix 1) by Entry into Revenue Service.

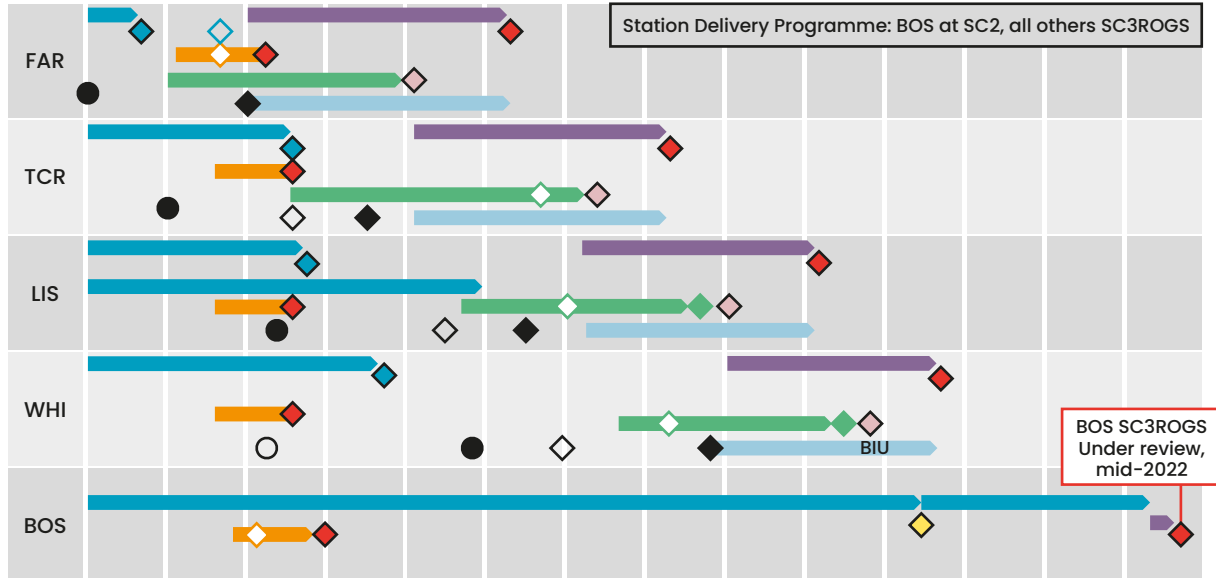
Lesson: Assess what has to be delivered as a minimum for any cardinal milestone (e.g. Trial Running under ROGS) and reschedule the rest using critical resource levelling to create a more sustainable programme.

Strategic insight: A staged opening strategy, with opening windows driven by prioritisation, is a more pragmatic way to deliver a complex, highly digital, first-in-class system such as Crossrail. In the case of Crossrail, commissioning the routeway plus shafts and portals first (the pipe) and then commissioning the stations onto the pipe in two 'swim lanes' – RfL stations and LUL stations – enabled the teams to understand the prioritisation needed when we had resource clashes or access priority calls to make. When set, this needs to be communicated to the teams, contractors, sponsors and the Board.

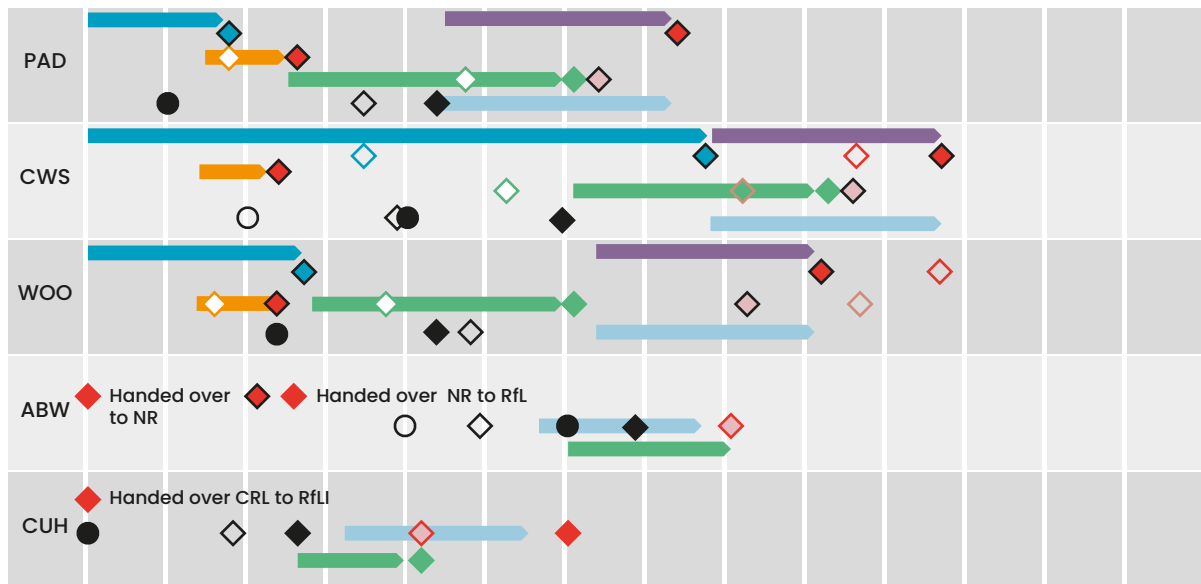
As part of the review, it was clear that two of the stations – Canary Wharf and Bond Street – would struggle to be integrated and ready in line with the operators' standards and revised programme. As a result of COVID-19 and given the volume of works still outstanding, CRL took the difficult decision to bring the delivery of these two stations in house; CRL and its partners had sufficient strength and depth to do this. As other stations were delivered, key personnel were switched from these stations to lead the completion of Canary Wharf and Bond Street.

2020			2021										2022
Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct-Dec	

LUL Stations Handover Programme: Farringdon (FAR), Tottenham Court Road (TCR), Liverpool Street (LIV), Whitechapel (WHI) and Bond Street (BOS)



RfLI Stations Handover Programme: Paddington (PAD), Canary Wharf (CWS), Woolwich (WOO), Abbey Wood (ABW), Custom House (CUH)



- SC3
- C&C final safety inputs
- SC3 ROGS
- SC1 Enactment
- C&C Site Works Complete
- Handover
- SC2
- Final Integration
- (T-4 Go) SC3ROGS, SOR Ready
- SC3
- Works
- Assurance & Handover
- Assurance approved
- Bring into use
- Safety Assurance

4-wk (T-12) handover overlap with previous station except WOO (6-wk overlap with CWS). CUH - Final integration tied to the start of Trial Running, removing requirement for SC11.

Figure 4 Emerging Stations Deterministic* Delivery Programme @November 2020 (* no client contingency added)

Regular touch points with executives and the Board at key events helped build confidence that we were developing a credible plan. At the May Board meeting, the outline Recovery Strategy received support. At the June Board meeting, the routeway recovery strategy (essentially for Trial Running) was approved. At the July Board meeting, the stations recovery strategy was approved, which comprised a 'swim lane' for LUL stations and a separate swim lane for RfLI stations, and a proposed staggering of the T-minus process to handover. At the August Board meeting, the DCS 1.1 and the supporting Recovery Strategy were endorsed subject to action close-out, and these were then signed off at the September 2020 Board meeting with LoD 2 assurance commentary. Figure 5 compares the overall DCS 1.1 recovery plan with the actual milestones achieved.

Notwithstanding the impacts of COVID-19, a significant amount was achieved over the summer of 2020. The Shafts and Portals team was expected to achieve full handover by early November 2020. The train and signalling software had progressed well, with signalling software TR2 ready to be tested on the COS from early September for multi-train testing in defined windows during the blockade. Routeway assurance (Engineering Safety Justification) submissions had been completed and the major blockade was being successfully delivered.

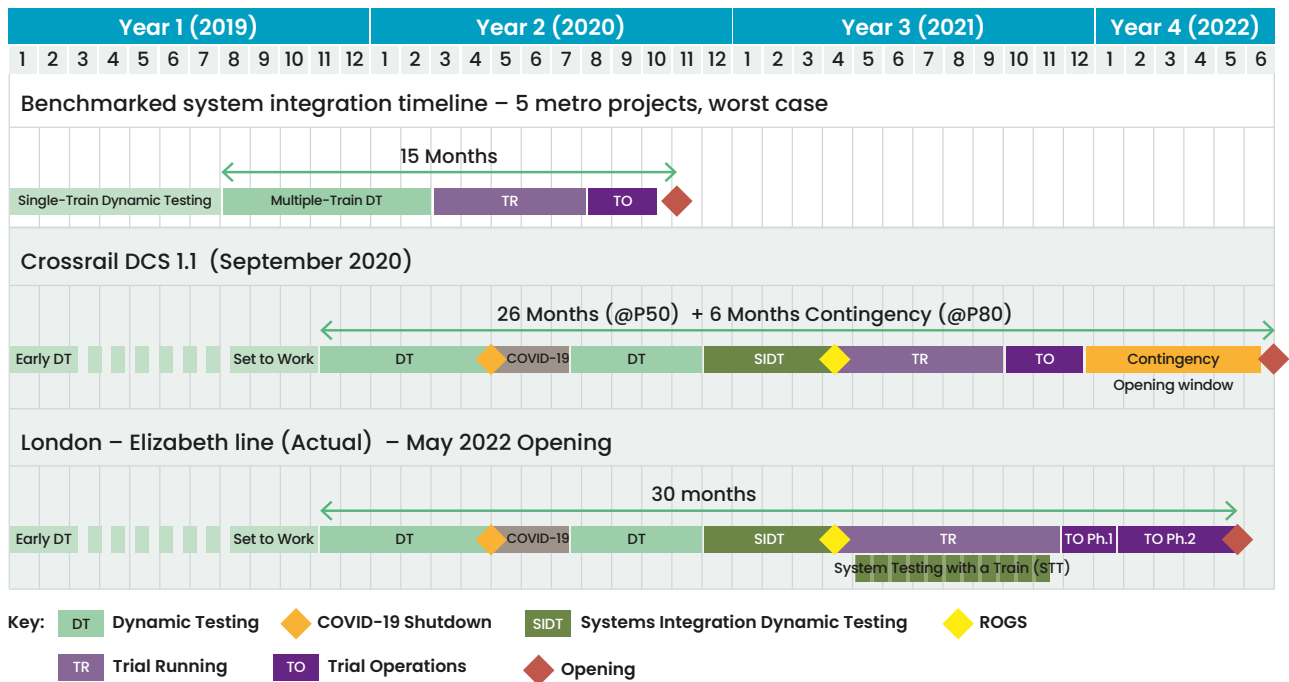


Figure 5 Comparison of DCS 1.1, approved by the CRL Board in September 2020, with the achieved programme

The DCS1.1 became the main recovery close-out plan for Crossrail. It would have two subsequent updates to reflect the actual position following major milestones (Start of Trial Running and commencement of Stage 3 passenger services in the COS). It took approximately six months for DCS 1.1 to go from the start of COVID-19 recovery planning to Board approval in the early autumn of 2020.

In September 2020, a new TfL Commissioner was appointed. The Commissioner made it clear that for the Elizabeth line to be delivered successfully as soon as practicable, it was essential that Crossrail join the TfL fold and the CRL Board was stood down. This was agreed and the process of TfL pulling the Elizabeth line into the estate was accelerated. The CRL CEO now reported to the TfL Commissioner.

Within days, a new client focus was in place, with weekly and then daily Commissioner calls to monitor progress and confirm delivery against the plan, or agree changes to the strategy. The CRL Board was replaced with the Elizabeth Line Delivery Group (ELDG), chaired by the Commissioner. As a result, the CRL Executive was able to get decisions from the Commissioner on a weekly basis, rather than previous four-week Board cycles.

Strategic insight: With the ultimate client pulling the Elizabeth line into the TfL estate, a new client focus and drive facilitated quick assimilation of information and agreement to make strategic changes to the Recovery Strategy.

7 From civils to systems

Testing and asset handovers: first half of 2021

With the review of the available software configurations against the revised DCS, a more developed software configuration was identified as a suitable candidate for Dynamic Testing (DT). At the same time, an application to the Office of Rail and Road (ORR) was made to increase the number of available test trains from four to eight in any one test period. The increased train availability improved the testing confidence and achieved the test and commissioning programme earlier, such that an augmented testing period – System Integration Dynamic Testing (SIDT) – was agreed to be deployed early in December 2020. Critically, this allowed systems integration testing to be performed with a train early enough in the revised schedule to affect software design for the configurations that would be deployed for Trial Operations the following year. The test results in December 2020 identified issues and fixes required to inform design of the later software deployments for Trial Operations and beyond. Safety approval cycles for critical safety systems can take up to six months, so early systems integration testing is essential to identify any major software updates required.

Lesson: By providing a period of System Integrated Dynamic Testing with a train early enough in the programme (approximately a year in advance), software bugs that would affect the Trial Operations phase could be captured and incorporated into the software cycle so as not to delay Trial Operations.

Strategic insight: Plan for rework because it will happen. Client inspections will generate rework. Software drops will experience regression, so factor these into your schedules so that plans have resilience. Plans also need the float to be visible (float is not client contingency), especially when there are handovers between contractors.

A key LoD 2 recommendation from the earlier EOP assurance reviews was to get suppliers to underwrite the schedule and commit to it. All the individual project schedules were discussed and developed with the relevant contractors, and the overall programme received endorsement at the supplier forums.

Strategic insight: Supplier engagement in the development of a recovery plan is essential to underpin its success. Further regular engagement is also essential to continue this support in the face of a continuing external threat.

As part of the development of a transparent weekly reporting pack, the programme management leadership team moved project controls from historic 'reporting what's happened' to forward-looking 'forecasts and burndown curve' predictions. This data was summarised into a weekly reporting pack that went to all stakeholders including the Commissioner, the Mayor's Office and No. 10.

This high-level transparency helped drive delivery focus and completion against future promises rather than historic completion.

Lesson: Management of the IDTs in weekly, short, sharp (30-minute) updates for handover deliverables listed on forward-looking delivery date trackers and planned-versus-actual burndown curves was essential to drive completion. Sharing this simple graphical management information with the programme extended leadership team, all the way up to the Commissioner and beyond, underpinned its importance.

For major milestones the programme employed a rigorous, detailed T-minus process to get to Trial Running under ROGS. This covered all aspects of the railway – reliability, operations, maintenance, assurance, etc. – and each Directorate in CRL and RfLI had readiness questions to report on each week. Each question was designed as a ‘closed’ yes/no question to prevent ambiguity and drive towards affirming readiness. The deterministic date for the start of the Trial Running period, as set in the Recovery Strategy DCS 1.1, was achieved on 26 March 2021. Achieving this milestone against the deterministic plan was hugely significant. It signalled the end of the railway being managed under the Construction Rule Book and the start of it being managed under the ROGS rule book. Basically, the COS now needed to be treated as a fully operational railway, just with no passengers. However, Trial Running main activities could not start immediately as RfLI needed further familiarisation on the handed-over assets. Full Trial Running did not start for a further six weeks. The movement into a ROGS environment was a huge step for the programme and truly galvanised all parties to push on towards starting Trial Operations, and opening the COS in the first half of 2022.

Strategic insight: The programme delivery leadership needs to think like a maintainer and operator – what is important to it, what will impact on the traffic managers in charge of signalling and control and communications in terms of operational restrictions – and focus on minimising them. The best protection for this is to get the operations and maintenance organisations fully bought into the strategies and the scheme designs during the early development of the engineering ‘V’ life cycle, then hold joint ‘T-minus’ countdown reviews with operations and maintenance for all major commissionings on the railway.

Risk for future programmes: Make sure all receiving organisations or parties have sufficient time to prepare and rehearse for taking on responsibility for the new product or service. While RfLI Operations had instigated a four-week period of 4 tph at the start of Trial Running to get up to speed, RfLI Maintenance had not been given sufficient opportunity to familiarise themselves with the integrated operational railway. Future programmes should allow for all receiving parties to adequately prepare, and this readiness should be tested in good time.

8 Light at the end of the tunnel

Trial Running and Trial Operations (late 2021 and early 2022)

The programme achieved Trial Running under ROGS on the deterministic date of 26 March 2021, which had been set in the Recovery Strategy in 2020. However, it was clear from the work done in 2020 that there were still significant delivery issues to be faced. Rather than continue with the DCS 1.1 as set in 2020, the decision was taken to reset the DCS (DCS 1.2) to reflect the new information available (work to go/resources available/access constraints) and structure the programme to achieve the original stated intention of opening in the first half of 2022 but sequencing the work to the available resource.

Strategic insight: Reset the schedule when sufficient information is available to support this, spending time to spread the workload to achieve the original opening window. This maintains supplier and workforce confidence while maintaining the vision.

Even though the programme had more certainty, the CRL Executive decided to maintain the opening window as before and not narrow it down. This was driven by the regular QSRA analysis, which backed up the date range, plus the recurring waves of COVID-19 mutations and the concern that a more virulent strain could affect programme completion.

Strategic insight: Resist the temptation to narrow to a date for opening when significant uncertainty still exists in the programme.

With the implementation of Trial Running under ROGS, access onto the railway became significantly more difficult for many reasons, the key ones being:

- control of the railway had to be placed under the new operator under ROGS regulations
- construction and testing access on the operating railway had to be applied for and agreed under a new Rule Book
- the emphasis switched from construction priority to operational priority
- a new operational team was getting to grips with operating a new and highly digital railway

All of this took time to embed. CRL maintained a strong access management team that knew the railway and could ensure access was applied for and obtained in good time.

Some desktop exercises were carried out, but only to validate the operator processes and resource levels for the operation. Significant shortfalls in safety and track access resource competent under the new Rule Book at the start of Trial Running hampered access for the project to complete the works.

Strategic insight: Recognise the potential for lower productivity when you move from a construction railway to a fully operational railway under ROGS. Access becomes constrained; you need to retrain the whole construction workforce and productivity drops unless you plan for it.

Risk to future programmes: If a new Rule Book and operator are taking over the railway or integrated system, the Rule Book should be critically reviewed to ensure a pragmatic approach has been adopted, and that the benefits of the new infrastructure have been correctly reflected in the rules *before* implementation. Rehearsals and desktop exercises should be carried out as a minimum in the 12-week run-up to Trial Running, with coaching provided by the delivery teams. For example, there was a significant increase in electrical switching operations during Trial Running and Trial Operations compared with the construction period. This was because the Rule Book required full electrical isolation for all activities on the trace. This was implemented through manual switching, even though the system had autoswitching functionality that completed switching in minutes. Manual switching took longer and reduced the overnight productive hours available during 2021 and the first half of 2022. Autoswitching was not standard until mid-2022.

From a programme point of view, Trial Running was characterised by key activities: handover of major stations on a drumbeat 12-week cycle, integration testing of the systems as the number of trains per hour was increased from 4 to 12, and identification and resolution of systems integration issues.

With the transition from construction site to operational railway, sponsorship of the weekly strategic guiding mind meetings (TRMB) moved from Crossrail delivery to RfLI Operations with the setting-up of the PSSG. Further, the weekly T-minus readiness reviews previously chaired by the CRL Chief Programme Officer were now chaired by the RfLI Chief Operating Officer.

One key area underestimated in impact and importance for overall Crossrail systems integration was the tunnel ventilation system (TVS). This was significant because:

- personnel could not gain access to the TVS rooms in the airpath to complete works and test and commission other systems unless the TVS system was isolated in a similar way to the electrical systems
- the TVS impacted the operation of the PSDs as the air pressure changed depending on the TVS settings. When set at full design 'congestion' mode for maximum ventilation, some PSDs did not operate because of the air pressure
- when trains operated in close headway, this caused fan stalling at certain TVS settings

Risk to future programmes: Identify all critical and highly integrated systems. Treat all of them as critical safety systems. Complete all works, testing and commissioning of other systems components in these critical system rooms (where possible) before full commissioning. Allow time to carry out integration tests where the key operational variables (e.g. fan speeds) are varied to establish the failure point for any other integrated systems (e.g. PSDs), and calibrate the system settings to prevent this before handing over to the operator. Resolving these issues during Trial Running, Trial Operations and Passenger Service takes longer and costs more the later they are left.

With the completion of Trial Running and the System Integration tests, the countdown to Trial Operations was initiated. The intention to enter full Trial Operations exercises from the start – e.g. mass evacuation exercises at the stations – was critically reviewed as the systems integration testing had highlighted a number of deficiencies that needed rectifying before ‘non-staff’ volunteers could be allowed onto the railway. The Trial Operations programme was recast, with low-impact Trial Operations exercises completed prior to commencement of a Part 2 Trial Operations period for the more intensive exercises, which required non-staff volunteers.

Lesson: The Trial Operations period can be a potential programme firebreak; however, it is essential to make sure that the early Trial Operations activities can be completed while the final systems integration issues are ironed out.

9 Crossing the winning line together

Following the successful completion of Trial Operations, the COS opened to service on 24 May 2022, within the opening window defined in the DCS 1.1 recovery strategy. While the deterministic start of the Trial Running period had been achieved against the deterministic plan, Trial Running and Trial Operations had proven more difficult to close out as CRL continued to resolve complex software integration issues, and operations and maintenance teams learned how best to utilise this new railway. The use of an opening window informed by schedule risk assessments has proven a credible way of managing a programme towards the delivery of a major opening event milestone.

The DCS 1.1 targeted the commencement of passenger services in the COS with 12 tph services, nine stations open to passengers and Bond Street station at SC2 configuration, which meant it was available for emergency evacuation only. That is what was delivered on 24 May 2022.

With the programme converging on an opening date, the decision was taken to recast the DCS once again as the ownership passed from the delivery team at Crossrail to the operator for delivery of Phases 4 and 5 of the programme. This was because the final phases would be driven more by operator performance and timetabling than construction completion. As a result, DCS 1.3 was 'owned' by the Elizabeth line Director rather than CRL's Chief Programme Officer following passenger service opening on 24 May 2022. Philosophically, the programme had moved from a delivery 'baton pass' to operations at system handover to the joint teams crossing the winning line together. The baton pass happened in the weekly strategic 'guiding mind' and 'T-minus review' sessions.

Indeed, at the start of 2022, the Elizabeth line Director developed a revised Post-Stage 3 Stageworks strategy by implementing a two-part Stage 5, which would realise benefits earlier. These are known as Stage 5B Minus and Stage 5C. On 6 November 2022, the programme successfully delivered the next stage (Stage 5B Minus with 22 tph through running) on time, with forecasts for the final stage (Stage 5C with 24 tph) holding at the mid-May 2023 timetable change date.

Lesson: At each phase of the programme, the overall End-to-End schedule should be owned and maintained by the organisation with the most influence on its ability to delivered.

As the station contracts were driven to closure, CRL recycled the experienced personnel coming free from other stations to be involved in a bottom-up review of the Bond Street station delivery schedule to confirm a realistic programme for opening. The re-baselined Bond Street station schedule was approved in February 2022, with an opening window of November 2022 to February 2023. The station actually opened on 24 October 2022, well within the DCS 1.1 equivalent opening window of the second half of 2022 and on the DCS 1.2 P50 date.

Lesson: Reviewing and confirming the scope, schedule, and Test and Commissioning programme with key stakeholders, and carrying out a Quantified Schedule Risk Analysis (QSRA), allowed the delivery team to gain support from the station’s workforce and contractors, and gave them an opportunity to better the P50 (50% probability) opening date rather than continually failing to achieve a best-endeavours deterministic date. Bond Street opened on 24 October 2022, beating the revised DCS 1.3 deterministic date of 14 November 2022.

Throughout the recovery, the DCS has been the route map for the programme management team, CRL Executive, Board and sponsors. By adjusting the DCS to deal with known and unknown threats, it stayed current, credible and useful for all to know how CRL was performing in achieving the target opening window. The table below describes the various iterations and reasons for change, and key milestones.

DCS version	Endorsed	Key events and reason for change
DCS 1.0	Q3 2019 CRL Board	EOP sets new delivery dates following announcement of delay. First Delivery Control Schedule to deliver EOP baselined.
DCS 1.1	Q3 2020 CRL Board	COVID-19 delay. Recovery strategy and DCS developed, routeway recovery strategy with blockades introduced, station schedule spread with respect to critical resource, opening window set for COS in first half of 2022, with nine 12-tph stations and BOS at SC2.
DCS 1.2	Q3 2021 ELDG	Entry into ROGS and Trial Running period started 26 March 2021. Adjustment to DCS 1.1 through stations sequencing and Trial Running/Trial Operations durations for emerging learning. Opening window held.
DCS 1.3	Q3 2022 ELDG	Opened COS to passenger service (12 tph) 24 May 2022, all stations except BOS. BOS schedule critically reviewed and updated. DCS ownership transferred from CPO to Elizabeth line Director, introduced Stage 5B Minus (22 tph). Achieved 6 November 2022.

Figure 6 The iterations of the DCS and drivers for change

10 Summary

Through a combination of Recovery Strategy development and refinement, organisational change to create the right environment and the creation of a robust but agile DCS, CRL and its partners were able to recover from the delay announced in 2018, deal with the impact of a once-in-a-generation global event and deliver a truly world-class railway through one of the world's busiest cities to great acclaim.

We have taken the 43 strategic insights, lessons learned and avoidable risks, and developed a matrix of 20 high-level lessons learned aligned with the DfT paper on *Lessons from Transport for the Sponsorship of Major Projects*¹ (see Appendix 3).

The five key DfT sponsorship themes from the paper are:

- A – Accountability must be unambiguous
- B – Behaviours matter more than process
- C – Control schedule and benefits as well as cost
- D – Deal with systems integration
- E – Enter service cautiously

To these we have added two programme management themes:

- F – Facilitate investment in leadership and team
- G – Generate and maintain an agile delivery strategy that is regularly tested

While every complex programme is different, it is hoped that the themes identified – along with the highlighted strategic insights, lessons learned and identified risks – may go some way to helping future programmes prepare for both foreseeable and unforeseeable events that may impact them.

¹ <https://www.gov.uk/government/publications/lessons-from-transport-for-the-sponsorship-of-major-projects>

Appendix 1

Summary timeline illustrating the events in each theme

Year	Qtr	Recovery strategy development & adjustment to emerging threats	Organisational development to create the right environment	Control & management through Delivery Control Schedule
2018	Q2		Sponsors informed of delay	
	Q3		Delay announced publicly	
	Q4	EOP developed	New Chair & CEO. Exec recruitment starts	
2019	Q1	Board signs off EOP	SDO office stood up. Plateau 1 (routeway) created	
	Q2			DCS 1.0 Development to reflect EOP
	Q3			DCS 1.0 Board approval
	Q4		Integrated Delivery Teams stood up	
2020	Q1	COVID-19 Safe Stop	Exec complete (CFO, CPO) gold/silver/bronze in place	
	Q2	Routeway recovery strategy CUH @ SC3ROGS		DCS 1.0 updated to reflect recovery strategy
	Q3	Dynamic Testing restarted Stations recovery strategy	Plateau 2 (stations) created Commissioner appointed	DCS 1.1 Board approval
	Q4	1st Blockade 97% productive SIDT initiated December	CRL Ltd Board stood down. CEO reports to Commissioner	
2021	Q1	FAR @ SC3ROGS Entry into TR & ROGS 26 March 2021	T-minus reviews to ROGS chaired by CPO	
	Q2	TCR/WOO @ SCROGS	T-minus reviews to Trial Ops chaired by COO	DCS 1.2 development – TR delay & stations adjustments
	Q3	LIS/PAD/WHI @ SC3ROGS		DCS 1.2 endorsed by ELDG
	Q4	Start Trial Ops P1		
2022	Q1	Start Trial Ops P2 mass evac. CAW @ SCROGS		
	Q2	Elizabeth line COS opens 24 May 2022 (Stage 3 & 4)	Plateau 1 transitions to RfLI CEO stands down	DCS 1.3 development starts, transitions to RfLI
	Q3		CRL Exec dissolved CPO reports to Commissioner	DCS 1.3 issued to reflect modified staging (22 tph)
	Q4	BOS opened 24 October 2022 Stage 5B Minus (22 tph) opens 6 November 2022	Transition to CRL close-out	
2023	Q1		CRL close-out team formally stands up. CPO stands down	
	Q2	Stage 5C (on target)	CRL delivery team disbands	

Appendix 2

De minimis requirements and structured approach to the EOP (2019)

Crossrail recognised that the following requirements could not be compromised.

- Full end-to-end railway (trains running from Abbey Wood to Paddington) operating at least 12 tph.
- An absolute minimum of five stations opened to the public including Paddington, Tottenham Court Road, Farringdon, Liverpool Street, Canary Wharf and Abbey Wood.
- A clear migration plan for subsequent full Stage 3 (stations and functionality)
- Stage 4: Great Eastern connection of services with Shenfield to be capable of opening no more than six months later.
- Stage 5: Great Western services to be fully connected into the COS no more than 12 months later.

Within Stage 3, Crossrail created tranches that split the completion, assurance, handover and operational readiness of infrastructure.

- Tranche 1: Shafts and Portals – prior to EOP, the degree of complexity of the Shafts and Portals was not fully understood in the baseline MOHS, and completion of the Shafts and Portals was linked to stations. This created a delivery risk on the programme that needed to be uncoupled.
- Tranche 2: Abbey Wood, Woolwich, Custom House and Canary Wharf.
- Tranche 3: Routeway, Paddington, Tottenham Court Road and Liverpool Street.
- Tranche 4: Farringdon and, subject to further planning, Whitechapel and Bond Street.

The completion of all four tranches made up Stage 3.

A key enabler to achieving the staged delivery and the tranches within Stage 3 was the introduction of a three-part configuration approach: asset completion, assurance and handover to operations. To do this, Crossrail introduced the concept of 'configuration-staged completion' (SC1, SC2 and SC3).

SC1 included the completion and assurance case for PSDs, platforms and signalling rooms, providing the infrastructure to support the railway and allow full-scale Trial Running. SC2 included the safety case for a station to have suitable evacuation routes. SC3 was readiness for passenger use.

This configuration-staged completion approach allowed Crossrail to plan an EOP with the option for Bond Street, Whitechapel and Farringdon stations to achieve a minimum of SC2 (available for evacuation) but not SC3 (open for passenger use) on Entry into Passenger Service.

Appendix 3

High-level lessons learned, linked to DfT paper on *Lessons from Transport for the Sponsorship of Major Projects*

