Crossrail BIM Principles

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1 Purpose

BIM is a term coming into increasing use within infrastructure construction. The purpose of this document is to outline the principles of what a BIM environment is to Crossrail; the benefits, impacts and implications it brings; and how Crossrail will exploit the opportunities of changing technology and migrate data to the Infrastructure Managers.

2 Scope

BIM is the process of creating and managing information throughout the whole life of the asset by using model-based technologies linked to a database of reliable information. The Crossrail BIM strategy seeks to maximise the life cycle utility that can be achieved from the advances in modelling technology linked to databases of information, so the future operator / maintainer can manage the railway assets effectively and efficiently.

Crossrail has worked in a 'BIM' environment for many years. Crossrail is one of the first major projects in the UK to use the collaboration processes defined within BS1192, and has developed a common data environment and management system. The rapid technology advances that have been made in the past few years will continue to play an increasingly important role in defining the way in which the use of data can be exploited. Crossrail needs to maximise the opportunities this brings.

The basic technical fundamentals of BIM have been achieved and we now need to exploit the opportunities of use through design, construction and into the operations and maintenance of the railway.

Our Crossrail objective with respect to BIM is:

CRL BIM Objective

To set a world-class standard in creating and managing data for constructing, operating and maintaining railways by:

- **Exploiting the use of BIM by CRL, contractors and suppliers**
- **Adoption of CRL information into future IM & operator systems**

The benefits in using BIM processes and techniques include:

- Reduction of risks from greater visibility into design and construction processes
- Reduced errors from using a trusted "single source of truth" approach to data management
- Reduced information loss between project phases, critical going into Operations / Maintenance
- Improved safety through increased construction awareness
- Improved collaboration through linked data sets, interoperable applications and ease of use
- Improved project delivery leveraging technology advances including data interoperability

BIM is a key enabler to help make Crossrail a 'Digital Railway'

3 Definitions

3D	Three-dimensional model data
4D	Three-dimensional model data linked to scheduling and project timelines
5D	Three-dimensional model data linked to cost data capability
AIMS	Asset Information Management System
IFC	Industry Foundation Classes
IFD	International Framework for Dictionaries
IM	Infrastructure Manager
BIM	Building Information Modelling
CAD	Computer Aided Design
CAG	Compliance Assurance Group
COBie	Construction Operations Building information exchange
CRL	Crossrail
eB	Enterprise Bridge
EDMS	Electronic Data Management System (EDMS for Crossrail is eB)
GIS	Geographical Information System
KPI	Key Performance Indicator
LUL	London Underground Limited
PPP	Public Private Partnership
PFI	Private Finance Initiative
MDM	Master Data Management
NR	Network Rail
RFI	Request for Information
RfL	Rail for London
ROI	Return on Investment
TfL	Transport for London
WLC	Whole Life Cost

4 Context

There is overwhelming evidence to demonstrate that the initial capital expenditure invested in the cost of buildings only amounts to typically some 20%-33% of their overall WLC (analysis by The Royal Academy of Engineering).The majority of cost sits within the operational and maintenance phases of use.

The recent use of PPP / PFI methods of infrastructure delivery has proven the benefits achieved by undertaking a much more holistic thinking for the creation and delivery and management of assets.

The UK Government has identified:

> *"How measurable benefits could be brought to the construction and post-occupancy management of assets (buildings and infrastructure) through the increased use of BIM methodologies"*

Government see BIM as the method by which a 20% saving can be achieved in the procurement and operation of publicly funded assets. The Government has recognised the importance that 'Lower Cost', 'Higher Value' and 'Better Overall Performance' are the stated priorities to achieve the necessary cost savings and meet legislated carbon reduction targets.

BIM is but one part of an overall improvement strategy which include 'Offsite Manufacturing' and 'Lean' techniques, which they see harnessed in a joined up approach which will lead to dramatic improvements in the performance of the construction sector.

Section 7.1 'Government BIM Framework' provides further details of Government requirements for BIM in 2016.

Crossrail has the opportunity to help set world-class standards in using BIM to create an exemplar, in the management of information for operating and maintaining railways, and unifying asset information across the regional railway network.

The structure of this document is as follows:

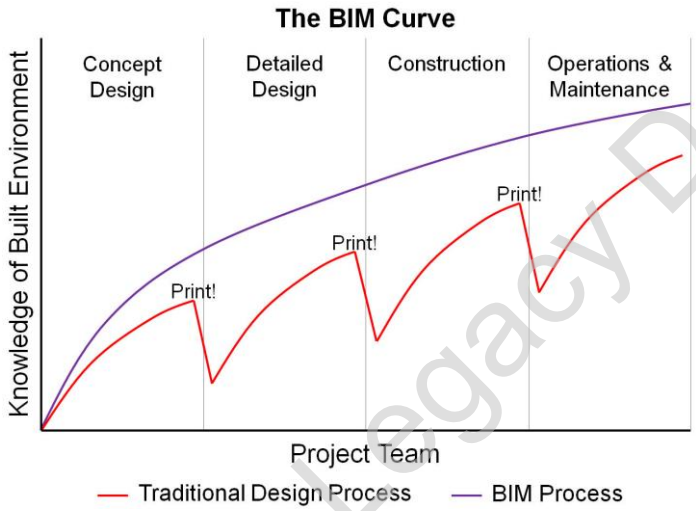
- In 'Section 5' we outline what is "BIM"
- In 'Section 6' we identify the benefits from working in a BIM environment, including the wider scheme benefits and project efficiency benefits.
- In 'Section 7' we baseline our position in the BIM world against Government's current framework
- In 'Section 8' we give an overview of Crossrail's current BIM strategy
- In 'Section 9' we illustrate the use of BIM in Crossrail

5 What is 'BIM'?

5.1 Background

It is difficult to find consensus for a single definition for BIM. In general however, it can be described as "a digital resource and environment of reliable information for decisions from initial conception to final disposal of a facility or asset, founded on open standards for interoperability and integration". BIM began some 25 years ago and is the technological and process successor to CAD that has now begun to change the way buildings and assets are designed, built and operated.

Using concepts that have matured in other sectors (such as 3D modelling in automotive manufacturing) it has fundamental implications in the way infrastructure projects are delivered. In traditional infrastructure projects, information is often created multiple times and lost during discrete changes in the project life cycle where new contracts are required to take the project forward, as shown in the diagramme below.



The use of BIM can increase efficiency and reduce errors. Virtual designs are built in three dimensions before work proceeds on site; the attributes of all the elements of the building can be found in the model; and spatial 'clashes' can be identified and resolved in the model instead of on site.

Ideally within a BIM perspective, the 3D model and related information (within databases) exist and are developed throughout the whole life of the asset – from initial conception to final disposal of the asset – and houses the on-going work and communication efforts of every team member, including planners, architects, engineers, constructors and owners.

The model helps users to visualise and, understand the relationships between the structure and its systems in regards to aesthetics, performance and programme issues.

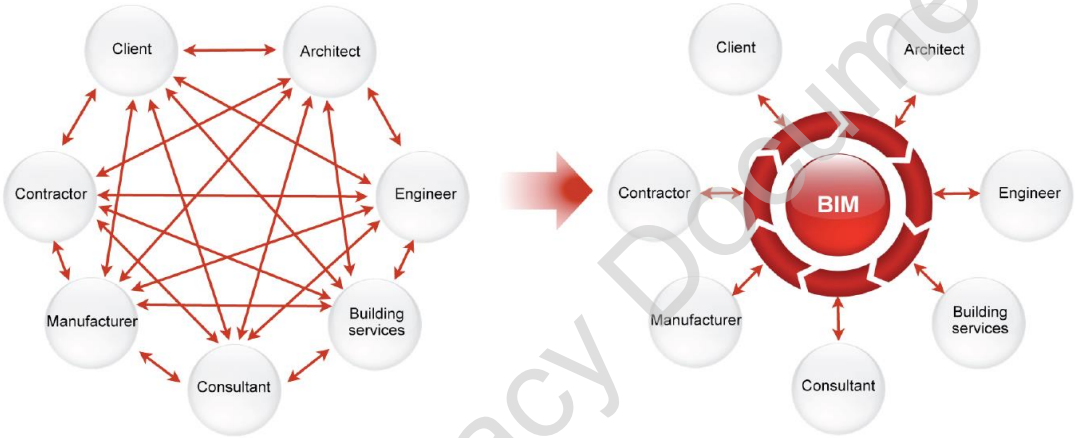
In a BIM environment, data and information is structured and managed to ensure only the right information is used and created at the right time for optimising the whole life usage of the infrastructure. This means the requirements during the operation and maintenance stages are key drivers for what data is required (and when).

5.2 Information Exchange

The way in which data is created and used collaboratively within in a BIM environment is also part of the fundamental shift in delivery of an infrastructure project.

The figure below illustrates the use of BIM thinking and modern technology to coordinate all aspects of the information exchange. Traditionally, information would be kept by many parties who continuously interact with each other, resulting in multiple copies, problems of version control etc. (as shown on the left hand side of the diagram below).

In a BIM world, data and information is held centrally from a "single source of truth", controlled and distributed as required.



The use of BIM therefore has the potential to streamline processes throughout an infrastructure lifecycle through the integration of design, engineering, construction, operation, maintenance and decommissioning on an asset into a single rich model of data that includes; 3D models, spatial mapping, asset information, documentation, financials and other vital information.

Interoperability between systems and applications is an imperative attribute to the management of data and information with Crossrail. The goal being that in the process of data transfer there is no loss or corruption of information.

5.1 Activity within a BIM World

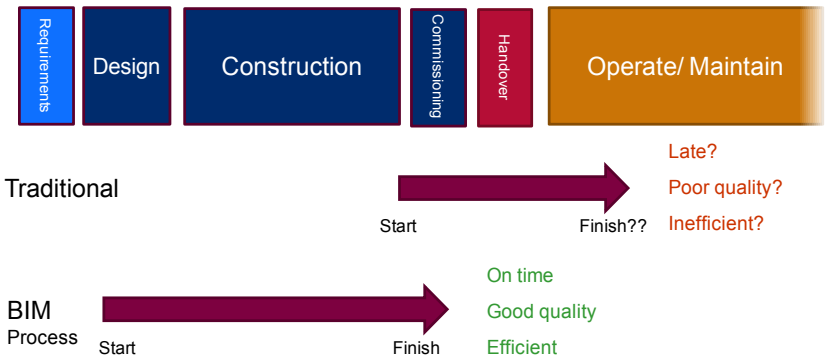
Government has identified "*exploitable information*" as the key driver to "*enable improvement*" and that Whole Life Cost (WLC) is one of the two key variables to achieve this (the other being Carbon Performance).

Typically within PPP contracts that deal with the hard commercial realities of creating and operating facilities for tens of years, considerable emphasis is paid to operations and maintenance particularly throughout the concept and design phases.

Their commercial cost models have been developed to ensure assets are created to optimise WLC's and that appropriate asset information is structured to manage and deliver the required performance.

In contrast, a characteristic of public works contracts is that their assets are designed to standards that have a limited maintenance definition and the handover of information

for maintenance and operations is often a residual task left too late within the construction cycle (see diagram below).

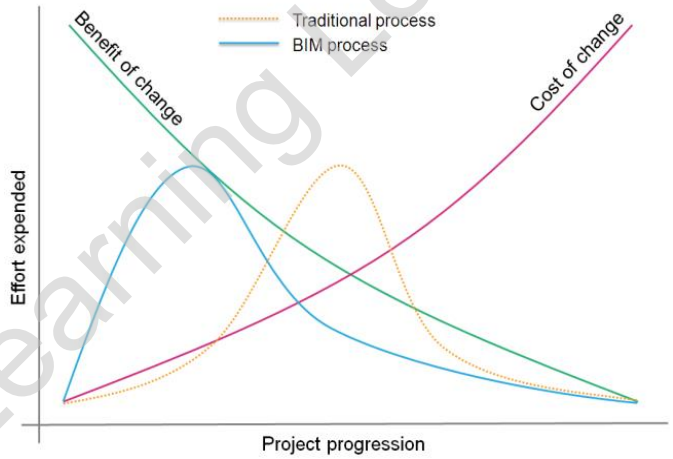


The benefits of early thinking about maintenance regimes that shape asset requirements, design and subsequent information migration to operators etc. is self-evident, but does not always happen to the level it should do so in public works.

In a BIM world this does happen, and the Government BIM strategy is already setting out what specific information sets (called COBie: Construction Operations Building information exchange) are required for data migration into operations.

This “information delivery approach” will effectively insulate public clients from the complexity of the process, technology change and competitive issues that will remain in the supply chain.

The diagram below describes how BIM users have reported that design effort increases at an earlier phase in the project but decreases later on.



In traditional thinking a key concern would be that costs are being incurred earlier than they need to be.

The reality is that in the earlier stages of design, the 3D models are being created earlier to help users to quickly visualise and understand the relationships between the structure and its systems in regards to aesthetics, performance and programme issues – ‘Design Virtually’ the ‘Build Physically’.

With this approach, modifications to the design can be made earlier in the project and the risk of overall cost of changes within projects actually reduces.

Whilst there is a marginal “Net Present Value” loss in undertaking the work earlier than in traditional delivery methods, the gain in early approvals and acceptance by future maintainers on definition and collection of asset data is of significance for project confidence.

6 The benefits of 'BIM'?

Data and information created for Crossrail should only be produced for one of two purposes:

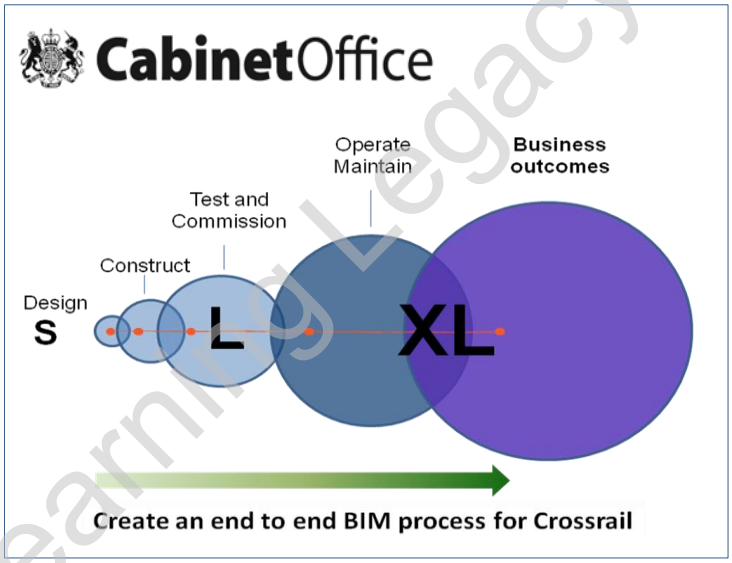
- A requirement or obligation
- To assist in decision making

BIM methodologies have a focus on what is required to operate and maintain facilities and infrastructure. This helps to optimise the process of ensuring the appropriate data will be delivered and:

- Not too little so that maintainers have to re-visit assets and collect more data
- Not too much that can be unmanageable, i.e. just because we can

6.1 Wider Scheme Benefits

Government recognises that much of the construction industry does not focus on its end purpose and either cannot see, or is not incentivised to see, how the process creates value for end users. Their push, as articulated [redacted] through *Rethinking Construction*, is that the greatest benefits can come from seeking to maximise the business outcomes of infrastructure investment.



The proposition by Government is that both clients and suppliers need a better understanding of how the relatively small up-front costs of design and construction leverage much higher cost / benefits downstream for end users in terms of facilities management, business costs and ultimate value.

These derived benefits can be measured in terms of business (financial), social (education, healthcare etc.) and environmental outcomes. Whilst Whole Life Costs that include maintenance are typically 3-5 times initial expenditure costs in buildings, these ratios are small when compared to the operating costs of the businesses occupying the building.

Studies estimate company staff costs to be some 100 to 200 times as much as their buildings' initial costs. These ratios illustrate that a small improvement in productivity/output of staff (because of improved facilities design) would effectively pay for the entire capital cost of those facilities.

In the context of Crossrail, much of the broad business and social benefits have been captured in the existing Business Case. However, significant opportunity still exists for us to influence the activity through the development of the remaining designs.

Business outcomes we can influence typically include:

- Designing assets to support maintenance regimes that minimise track occupations, resulting in more train availability for passengers
- Designing maintenance processes that will minimise intrusion or local station closure by innovative grouping and planning, increasing asset availability
- Use of smart technologies for monitoring asset performance which results in lower maintenance costs
- Developing models and visualisation to support interface requirements from outside parties e.g. Fire Brigade, Retail and reducing costs associated with digital and paper distribution
- Providing station staff with interactive learning applications and animated 3D simulations to deliver quality training without the need to create physical mockups
- Providing operations staff with information, such as visualisation models (from our 3D design model) which can support key decisions reducing the reliance on manual validation onsite e.g. at stations
- Providing a model which can be accessed by a number of systems to enable swift and accurate comparisons of information, reducing the risk of delay misuse in the event of a problem being identified at a station, thereby reducing operational costs
- Providing a data model which can be monitored against trends in failures and repairs reducing maintenance cost through developing strategies dealing with proactive preventative measures, resulting in lower maintenance costs
- Minimising re-surveying areas before design / construction changes though the re-use of information, reducing repair, replace and new project creation costs
- Supporting maintenance activities through the use of rehearsing complex procedures, optimising temporary works designs and planning procurement of materials, equipment and manpower, reducing renewal and maintenance costs

6.2 Project Efficiency Benefits

- Improved collective understanding of design intent

  Because of BIM's ability to support 3D visualisation and its rich database of reliable

information, the collective understanding of design intent provides a high level of value because models can be used to better understand and monitor ideas that carry through the whole life of the assets e.g. Farringdon visualisation of the interaction of contract interfaces.

- Early mitigation of potential conflicts and changes during construction

  Conflicts and changes in the field are costly, affecting both budget and schedule. By using the BIM model to identify potential issues before they occur on site, users can; prevent costly mistakes, reduce Request for Information (RFI), site change requests, non-conformities and site coordination problems, e.g. clash detection within the integrated 3D model.

- Risk Reduction

  - Increased confidence in design, construction and operational costs, e.g. through 4D analysis integrating schedule with the 3D model
  - Crowd behaviour and fire modelling capability enable designs to be optimised for public safety. Asset managers can use the 3D model to enhance operational safety. Contractors can minimise construction risks by reviewing complex details or procedures before going on site

- Enables efficient project team coordination and collaboration

  All project partners, different design disciplines, the customer, contractor, specialists and suppliers use a single, shared 3D model, cultivating collaborative working relationships. This ensures everyone is focused on achieving best value, from project inception to eventual decommissioning

- Makes project delivery efficient and economical by leveraging the latest computing technology e.g. data mobility, apps, etc.

- Reduced information loss throughout the whole life of the asset including between project phases

- Delivering quality training to staff by using the BIM model to deliver interactive learning applications and animated 3D simulations

Based on the fact that we already work within a BIM environment the improvement potential will be less than that evidenced in other public works. In Crossrail a further efficiency improvement of 1% on a construction base of £8bn would generate indicative benefits to the value of £80 million.

6.3 Safety Benefits

- Understanding what is proposed during construction

  Because of BIM's ability to support 3D visualisation and its rich database of reliable information, the collective understanding of design intent provides a high level of value because models can be used to better understand and monitor ideas that carry through the whole life of the asset and enables non-technical staff to readily

understand processes and relationships.

- Demonstrating “Readiness to Dig”

  Using simple 4D models as visual validation that the contractor and site teams understand what is to be built and when, and the key steps to opening up and commencing the groundwork.

- Eliminating mistakes with the potential to cause harm

  Documentation and briefing materials is improved as objects are only modelled once in BIM, meaning that drawings automatically derived from that model are more consistent and accurate, and avoid clashes that may otherwise occur.

  Most of the Central Section stations have between £10-25m identified as risk contingency for contract interface risks. At Farringdon a BIM 4D analysis identified that their interface risk could have a potential reduction of at least £8m (at a cost of some £100k in staff time). The BIM 4D work contributes to the decision-making process – how the benefit can be realised in practice is for others to determine.

6.4 Quality Benefits

Contractors working within BIM environments report a general improvement in the quality of design data and information received for construction. Quality benefits include:

- High quality, single source of truth in data and information for decision making ensures only one version of each document is kept
- Provides up-to-date reliable and trusted information, with the integrity for both client and supply chain
- Utilising 4D data in a BIM Model provides the tools to maximize the efficient coordination of Manpower on site
- Utilising 5D data in a BIM model can provide instant access to material and cost information. This functionality helps phase a project by determining more accurately when to, for example, open a section of a remodelled building or close a corridor to allow work to proceed
- Requests for Information (RFIs), change requests and non-conformities will be significantly reduced during field construction due to the enhanced coordination and conflict reduction with the use of 3D
- Accurate as-built drawings are available immediately at the close of construction with the use of BIM and a 3D model. The 3D model, as it is updated throughout the project duration, represents in electronic format the virtual design of the physical asset

Design errors, typically through clashes and spatial interfacing conflicts can typically account for some 2% of cost increases in civil engineering works. Assuming a base of say £4bn, additional costs of some £80M will be avoided.

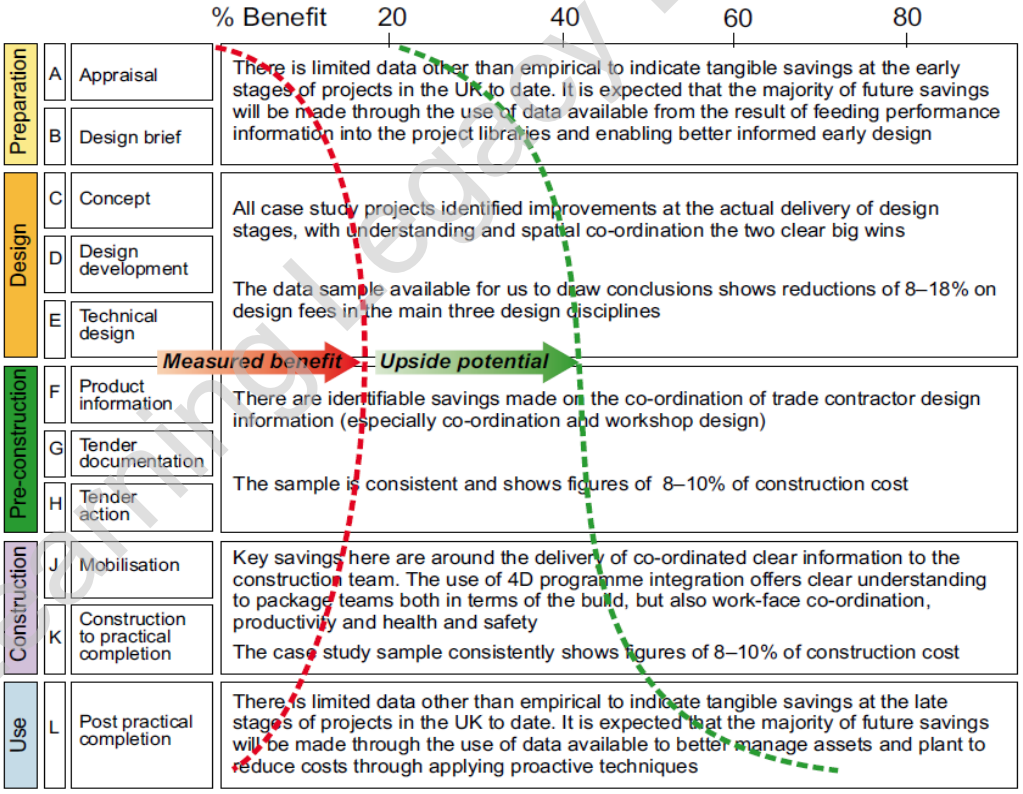
6.5 Indicative Cost Benefits

Many of the benefits that arise from BIM are reductions in waste and errors that occur in infrastructure projects. Often this happens where the assembly process on site is a "one-off" and not tried and tested off-site (or where significant prototype testing is undertaken as in the automotive industry).

A business case based on the reduction of errors only illustrates the potential to reduce underlying risk (it is hard to build a convincing case based on the fact you may make a mistake).

Studies in the US have indicated that net savings in using BIM (off-setting start-up costs) to be approximately 5% on the construction of new-build projects. The ROI for BIM systems has also been estimated at being greater than 60% based on a survey of US users, and helps account for the interest in development of BIM is the US.

In the UK, data published by the Government, based on published UK commercial data, illustrate there is a consistent reduction of 8-10% of costs associated with RIBA construction Stages F-K. (See red line in the figure below).



6.6 Costs to BIM Activity

While BIM is expected to deliver important benefits to Crossrail, it is clear that as we continue to develop our delivery methodologies and improvements there will be costs, including:

- Education and Training

  Adequate training is a barrier to the adoption of BIM technology, as only a limited number of users are adequately trained. Education and training costs have two broad elements:

  - Ensuring a company has the required personnel (either by hiring new staff or by retraining existing staff) to establish and integrate BIM technology into a company's operations
  - Retraining the majority of existing staff to support the behavioural and organisational change required to fully adopt BIM technology within our business model

- Systems Start-up

  The implementation of BIM technology requires specialised software and data storage, and may initially represent a significant cost to a company. Not all applications are interoperable. Ensuring interoperability requires significant start-up costs. This is particularly problematic when individual project teams involved in the design, construction and operation phases have based their business model around pre-existing technology, much of which represents a capital investment.

  The manageability of a complex BIM project is a major information management challenge. In particular, the size and complexity of the files created by use of BIM technology continue to be unwieldy. The current approach to MDM which requires us to take out the older "stand-alone" applications to ensure better data integration does have start-up costs but these will easily pay for themselves through effectiveness and waste improvements.

- Transition and Behavioural

  The support of senior management is essential to the widespread adoption of BIM technology, as senior managers are more likely to be required to justify the costs and efforts associated with bringing BIM into practice.

  Furthermore, there may be disinterest among more experienced veterans of the industry, who have been operating in a certain way for many years.

  Importantly, the levels of design activity (and associated fees) increase as the project nears and enters the construction phase. However, changes during the construction phase of a project are relatively costly.

  BIM technology would help to mitigate such costs by drawing all parties together in the project at an earlier stage, and facilitating information sharing.

Although these costs are common to the adoption of many new technologies BIM is expected to deliver many benefits to industry at costs that are not materially higher than traditional or alternative management approaches we would be expected to adopt.

7 Where are we with BIM in CRL?

To understand how to take BIM further forward, we need to understand how far we have progressed developing our BIM environment in respect to the Government framework.

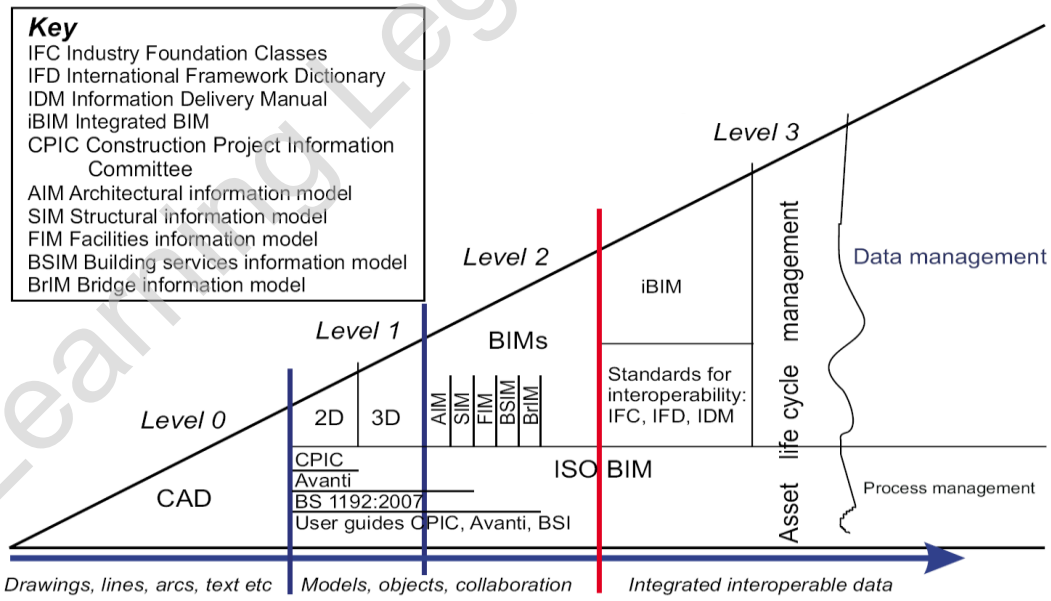
7.1 Government BIM Framework

The Government Construction Strategy (May 2012) has a series of objectives including the need to deliver a structured sector capability to increase BIM take-up over a five year horizon as part of a joined up plan to improve the performance of the government estate in terms of its cost, value and carbon performance. Rather than define BIM it sets out a hypothesis and a number of tests to guide and validate the proposed strategy focussed on the outputs of BIM.

The hypothesis is:

> *"Government as a client can derive significant improvements in cost value and carbon performance through the use of open shareable asset information."*

Government has defined the competence and delivery required from a BIM world. This provides a useful framework to assess where we are and to where we could potentially move Crossrail if this provided measurable benefit. It illustrates the framework with the 'wedge' diagram (below, courtesy of Bew-Richards) that has become the industry standard to take out the ambiguity associated with the term 'BIM'.



Definition of BIM Levels

- Level 0

  Unmanaged CAD data with paper as the most likely data exchange mechanism.

- Level 1

  Managed CAD in 2D or 3D format using BS1192; with a collaboration tool providing a common data environment, possibly some standard structures and formats. Commercial data managed by standalone finance and cost management packages with no integration.

- Level 2

  Managed 3D environment held in separate discipline 'BIM' tools with attached data. Commercial data managed by an ERP (Enterprise Resource Planning software). Integration on the basis of proprietary interfaces or bespoke middleware could be regarded as 'pBIM' (proprietary). The approach may utilise 4D programme data and 5D cost elements as well as feed operational systems.

- Level 3

  Fully open process and data integration enabled by 'Web Services' compliant with the emerging IFC / IFD standards, managed by a collaborative model server. Could be regarded as iBIM or integrated BIM potentially employing concurrent engineering processes.

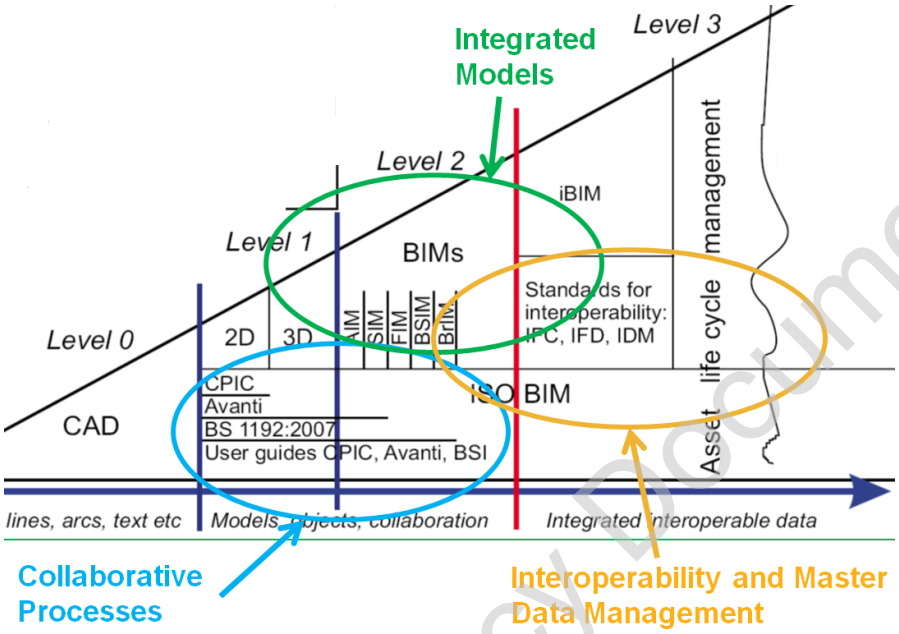
7.2 Crossrail's Current BIM Level

In line with the BIM maturity model (below), Crossrail has progressed from Level 1 BIM into BIM Level 2 across many of the separate contract packages and making strides into parts of what is emerging as Level 3, evidenced by:

- Usage of integrated and collaborative processes enabled by 'web services' and compliant with emerging Industry Foundation Class (IFC) standards. Utilisation of 4D construction sequencing.
- Adopted topographical surveying in 3D in the mid 1990's, well in advance of normal practice
- Required our Framework Design Consultants to work in a collaborative 3D environment and create object-orientated design models when they were appointed in 2009 (for robust integrated spatial and geometric planning)
- Developed workflows and CAD Standards in accordance with BS1192 (that sets out the basis for collaborative working with 3D models etc.)
- Bringing into use a connector between the 3D models (in ProjectWise) and our main EDMS database (eB) and building in the concept of 'Intelligent Objects' into our data
- Utilising 4D programme data, with the capability for utilising 5D
- Through the IT Directorate, developed a strategy for Master Data Management which we have begun to implement (actually Level 3 BIM – see figure below)
- Have an agreed development plan to ensure asset data we collect will migrate seamlessly to the IM's
- Documents (in our EDMS called 'eB') can be directly linked to 3D models and drawings (in 'ProjectWise' software)
- Documents can be directly linked to our spatial GIS data in Oracle

- On-going development of standards for 'Data Interoperability' supporting the migration to the IM's and Master Data Management, Crossrail will be able to demonstrate adoption of some characteristics of Level 3 BIM

The extract of the 'BIM Wedge' below indicates where Crossrail are currently working in a BIM environment.



8 CRL Strategy

8.1 Objectives

The Crossrail BIM objective has been stated as:

CRL BIM Objective

To set a world-class standard in creating and managing data for constructing, operating and maintaining railways by:

- **Exploiting the use of BIM by CRL, contractors and suppliers**
- **Adoption of CRL information into future IM & operator systems**

The measure of achievement will be assessed as follows:

- Migration of asset information into Infrastructure Maintainer and Operator's IM systems
- Use of new technologies and processes to deliver construction

Crossrail have aspirations to use elements of BIM Level 3 as reasonably practicable, particularly through the use of Master Data Management and ensuring data interoperability across systems.

8.2 Developing BIM Further in Crossrail

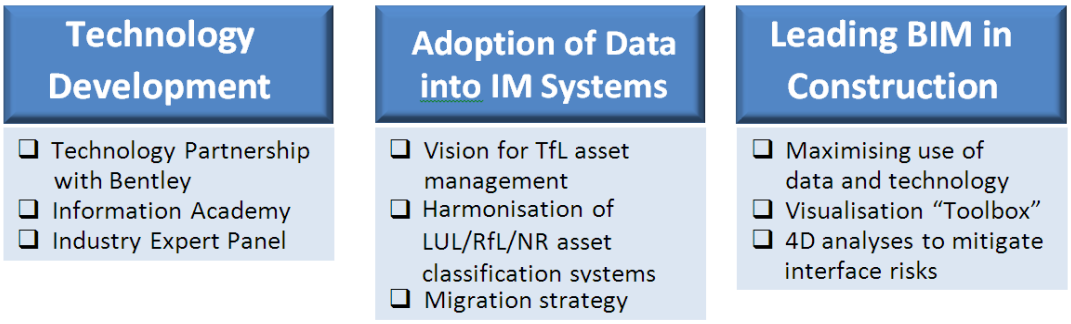
Much of the activity and process already in Crossrail is structured towards achieving or supporting our BIM objectives. Improvement processes such as data architecture in master data management are being done not because of any specific BIM strategy, but because they make sound business sense that improves our project delivery – and reflect the changes that Government wish to encourage through use of developing technologies.

In Crossrail we also recognise the major infrastructure civils works have been designed and effectively completed (to some 80%) within an integrated 3D model. There is no significant opportunity for developing the rules and standards for this area of work.

However, considerable opportunity does exist for us to use BIM principles and methodologies within the major areas of work that remain, namely:

- MEP design, recognising this must fit into our existing standards etc.
- Construction activity and supporting processes
- Asset information collection and management for the IM's
- Creating future business benefits from the potential for GIS

The future development and implementation of BIM within Crossrail will therefore be structured across three inter-dependent workstreams, see overleaf:



We recognise our asset data for the Central Section will eventually be handed over and adopted by RfL and LU. As discussed in Section 9.1, the current approach to managing and maintaining rail assets in London is legacy-based with different systems across different parts of the rail network.

Crossrail gives TfL the unique opportunity to create new world-class standards in the management of data for operating and maintaining railways that would unify systems across both Network Rail and TfL. Our approach to harmonise classification and develop a new asset management system with RfL and LU will enable us to realise our overall objective.

8.3 Current Infrastructure Maintainer Requirements for Crossrail Data

A key driver of the Government's BIM strategy is to ensure that appropriate data will be migrated across from construction through to maintenance and operations.

An approach for the development of appropriate asset information is in place (Reference: 'Asset Information Management Plan' CRL1-XRL-Z3-STP-CR001-50002). This plan sets out the creation and handover of asset information and data to the IM's, based upon expected and agreed requirements, and agreed through CAG.

Current data requirements for asset information are generally based on documentation set down within the Crossrail Standards Baseline. The IM's within TfL currently use three asset management systems to maintain their railways:

- SAP-AMIS (London Overground, DLR)
- Ellipse (legacy Metronet network)
- Maximo (legacy Tube Lines network)

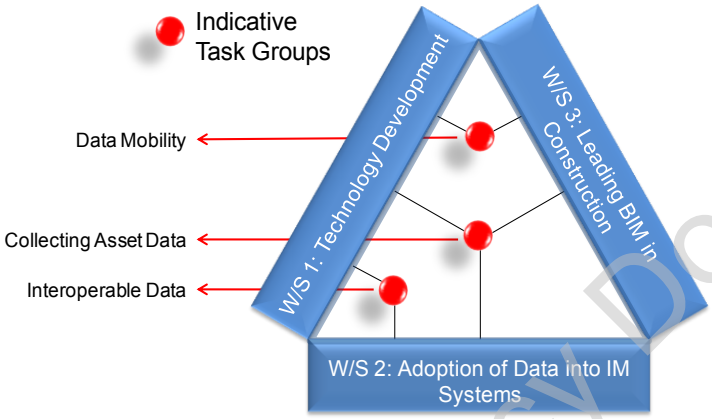
The IM systems have developed over the years with legacy data and often a degree of uncertainty about many of the assets. Data between these three systems is not interchangeable. TfL has set up an Engineering Information Systems Forum to identify the impact of BIM to their IM estate. TfL are currently undertaking initiatives to consider the requirements for a new modern asset management system across the TfL rail systems.

We therefore appreciate the IM's are not yet in a position to give us their specific requirements for the future 2018-19 integrated modern asset management system. Hence Crossrail are adopting an approach to develop a rich integrated store of information, based on latest BIM practice wherever possible, which can potentially be accessed by a number of different asset management systems.

8.4 Workstreams

Three workstreams are outlined in further detail below, all of which are an extension to Crossrail 'business as usual' activities.

Workstream activities are inter-related as shown below, for example Task Groups set up with contractors will advise the Technology Development teams and IT of requirements for implementation of new processes, applications etc.



A governance group for the three workstreams is to be established. Working papers and briefing notes created will be circulated around all workstreams.

Workstream 1 - CRL Technology Development

Lead: Crossrail IT

Objective

- A complete suite of BIM solutions and systems to align with technical strategy by end of 2013, incorporating asset information and maintenance interoperability provisions as part of the handover programme.

Key Activities

- Continue to develop our relationship with Bentley as a CRL “Technology Partner” to help us achieve our BIM objectives. Key initiatives include:
- Evolve the ‘Crossrail Information Academy’ with Bentley as an awareness centre into a richer, more immersive environment for learning future systems.
- Create a ‘Sharing Knowledge’ and ‘Best Practice’ environment for lessons learned and technology development from other sectors such as oil & gas, nuclear etc.
- Formally articulate all aspects of technical information handover by end Q3 2013.
- Develop the industry/academic Expert Panel to drive advancement of adoption of specialist BIM-related technologies, methodologies and other issues (in progress through Technical Directorate).
- Implement plan for GIS interoperability of data within the BIM environment including upscaling of GIS functionality, mobility applications and 3D capability harnessing ESRI technology.
- Ensure contractor accessibility into our data sources and 3D model, and assist in their use of data for off-site production, modular construction etc. (on-going)
- Tap into the various international deployments of BIM currently in progress and share across work streams (on-going).
- Establish the Bentley Enterprise Licence Scheme across Tier 1 contractors (completed).
- Articulate the standards and rules for collaboration and data interoperability (completed).

Success will be evidenced by:

- ‘Crossrail Information Academy’ seen as a source of contractor training and best practice
- Contractor use of CRL 3D models for planning, design, off-site fabrication (including robotic techniques etc.)

- Using the Academy as a laboratory to develop and showcase applications of innovative technologies within the construction sector (e.g. mobile applications for data creation or collection, cloud-tools etc.)

Workstream 2 - Adoption of data into IM systems

Lead: [redacted] (Head of Technical Information)

Objective

- To establish and maintain a single source of reliable assets and related asset information & models and migration of this to the Infrastructure Maintainers

Key Activities

The activities of this team fall under the existing work undertaken in the Technical Directorate within the Asset Information Team. An Asset Information Management Plan has been developed and is implementing the Asset Information Management System (AIMS).

The Asset Information Team is responsible for:

- The population, management and administration of AIMS
- Ensuring the requirements for asset information is based on Crossrail Standards Baseline and consistent with the asset information templates and asset document requirements utilised by the IM's
- Creation of asset hierarchies and the asset data dictionary that describes the asset classifications (using Uniclass) etc.
- Work with other teams in Crossrail and the IM's to develop a vision to assist TfL create a long term model for managing future railway information
- Collaborate and share knowledge with RfL, LUL and Network Rail on asset information etc.
- Continue develop our information migration strategy by assisting RfL to choose their asset maintenance system. Refine asset data collection / hardware development strategy to ensure future-proofing

Success will be evidenced by:

- An agreed vision with RfL and LUL for the use of asset information for managing Crossrail data and information, evidenced by requirements for handover are in place by Q3 2014
- An asset classification model agreed between Crossrail, RfL, LUL, and Network Rail.
- Authorised set of AD4 and ADD Asset Classification in place for all asset disciplines.

- Creation of 125,000 named assets by the end Q2 2014

- Use of AIMS by the MEP designers, so that asset information is directly tagged to 3D models

Workstream 3 - Leading BIM in Construction (Delivery)

Leads: [redacted] (Information Applications Manager) and [redacted] (Project Information Senior SME)

Objective

- To ensure, through Crossrail as an enabler, the use, exploitation and adoption of appropriate technical information tools during the construction phase

Key Activities:

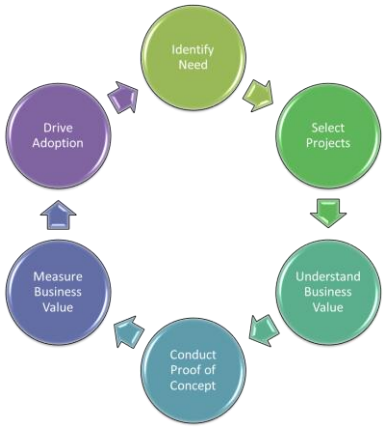
- Three Task Groups have been set up which focus on implementing BIM innovations onto Crossrail that drive real business benefits. Current active task groups are:
    - Mobility Task Group - Research, develop, trial, adopt and promote appropriate mobility tools, applications, and communication technologies. To equip site based personnel with adequate information to make informed, accurate and timely decisions.
    - Modelling Task Group – Maximise the use of appropriate modelling tools to assist with the management of construction works on site.
    - As Built Task Group – To ensure appropriate as-built data is incorporated into the Crossrail BIM model and organised in a way that supports operational and asset maintenance activities.

- Acting as an enabler between Crossrail, Contractors and the wider industry to promote the adoption of BIM related technologies and processes on Crossrail.

- Conduct proof of concept projects on Crossrail sites that identify and measure business value. Publish findings from Task Group projects and drive wider adoption across the project. (see image overleaf). Current projects include:
    - Tablet based forms based technology to enable site based personnel to complete form digitally and send data back to central Crossrail systems.
    - Field Supervisor app which allows access to current documents (e.g. drawings, ITPs, specifications) on a tablet device on site.
    - Augmented Reality app which brings the 3D model onto a tablet device in context of the live camera view at a site location.
    - 4D Modelling. Developing process for automating the creation of 4D models that link the 3D model to the P6 schedule.
    - 3D Model Review. Developing a world class solution for undertaking 3D model reviews for clash detection and discipline coordination.

- Electronic Redlining and As-Builts to allow approved changes to design to be captured electronically.
- Laser Scanning. Being evaluated for application on project by Crossrail and Contractors.

- Ensure the appropriate transition to the management of the asset through close collaboration with the 'BIM for Operator and Infrastructure Maintainers' Working Group.



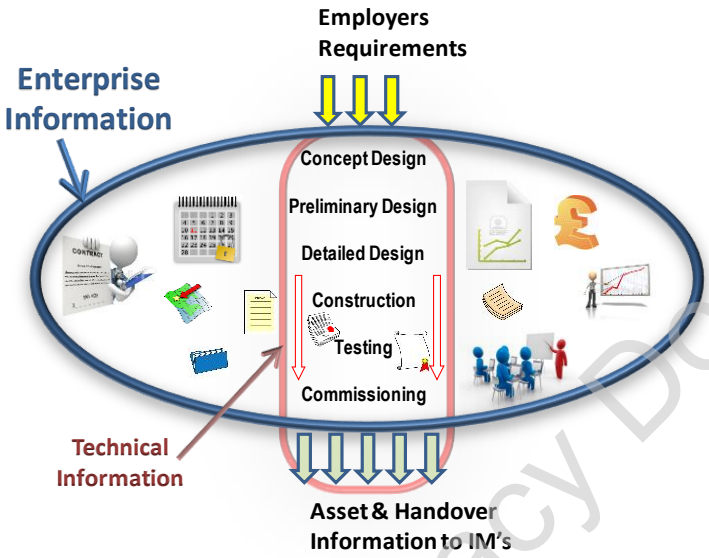
Each task group follow a standard model for project identification, delivery and close-out, as is shown below. Each task group is focused on delivering targeted technology enabled business solutions that drive measurable benefits to the Crossrail project. (See adjacent diagram)

Success will be evidenced by:

- Undertaking the proof of concept projects that identify real business value through safety, cost, schedule or risk.
- Establishing through the Works Information the contractual requirements for BIM to support Delivery.
- Implementing BIM technologies and work processes across the Crossrail project.
- Collecting metrics on the amount of use and business benefit of the implemented projects by Crossrail and Contractor personnel
- Understanding and articulating the current issues with 2-4D visualisation tools, developing and implementing a plan for extending their use consistently across contracts
- Establish through the Works Information the contractual requirements for BIM to support Delivery
- Establish protocols to support Crossrail processes and procedures for design assurance and certification (completed)
- Contractor use of CRL 3D models for planning, design, off-site fabrication including robotic techniques etc (completed)

9 Use of BIM in Crossrail

Crossrail creates and manages different types of 'enterprise information' dependent on the stage of the project, which cuts across many functions; Programme Controls, Finance, IT, Commercial, HR, Training & Development etc. The BIM environment tends to focus on the project "technical information" which, in terms of Crossrail begins as the Employers Requirements which take shape in the form of outline designs, developing granularity through design evolution and resulting in assets and associated data that will be handed over to the IM's.



The efficient and effective management of enterprise data is therefore a critical determinant to the effectiveness of BIM in Crossrail. This can be characterised by the way in which contracts are procured and contractors are engaged, how data is shared and how a collaborative environment is encouraged.

By the nature of its client role, Crossrail is "an enabler" of BIM, i.e. setting the standards and requirements within which others collaborate and play their part in the making of the project.

Using a variety of processes, a range of outputs and associations to develop and exploit our understanding: Our BIM environment can be explained in the upcoming sections:

- Information and Data Management
- Document and Data Control
- Computer Aided Design (CAD)
- Information Applications
- Geographical Information Systems (GIS)
- Asset Information and Configuration Management

9.1 Information and Data Management

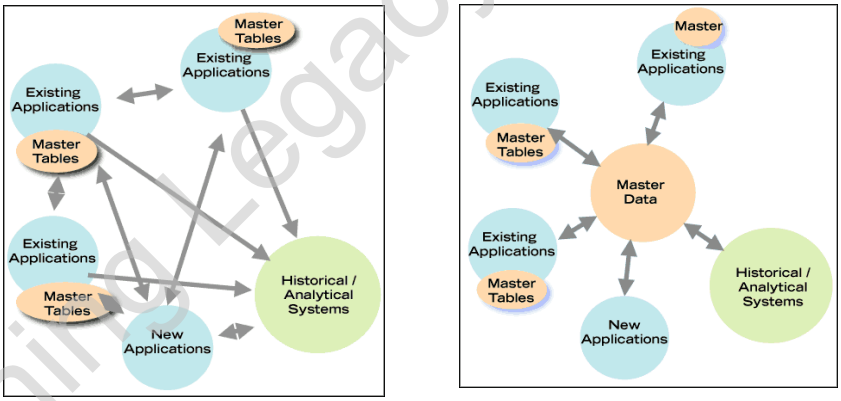
Master Data Management

Across the construction industry, some estimates show as much as 80 per cent of vital business information is currently stored in unmanaged repositories, making its efficient and effective use a near impossibility.

The organisational needs for data and information in large infrastructure programmes such as Crossrail change and develop throughout the various phases of the project life cycles. Traditionally this evolves with new systems and applications being brought into use alongside the old as and when they are required. This may ultimately result in processes and data sets that are not ideally balanced or structured because of simple incompatibility or ownership reasons.

The arrangement of applications and data types may then require duplication or additional processes to enable this data to be used across the project. In Crossrail this was the situation in 2010 with the use of a legacy EDMS and other stand-alone applications.

In a BIM world where data is centralised the concept of Master Data Management (MDM) is critical. MDM seeks to ensure that we do not use multiple (and potentially inconsistent) versions of the same master data. We seek to create and maintain an authoritative, reliable, sustainable, accurate and secure data environment that represents a single and holistic version of the truth is imperative.



This overcomes traditional issues with the quality of data, ownership, consistent classification or identification of data, and data-reconciliation issues. This is what we are seeking to achieve in Crossrail.

BIM is process-driven and does not rely on a single piece of software. Interconnected models and databases of reliable information needs a high level of interoperability between software packages and need to be capable of integrating data from a number of disparate software systems. This enables participants to use, re-use and exchange information for decision-making or design purposes in a coordinated and efficient manner.

An important aspect within BIM technology is the dynamic ability to explore the structure of objects and their relationships to each other. The processes and tools used in a BIM environment are the key to this new shift in project delivery. For example, 3D modelling is nothing new, but in BIM, schedules, databases, budgeting and other data

are embedded and can interact together with the 3D models, so that information such as quantities, estimates and schedules can be easily extracted or linked.

MDM Architecture

The concept of MDM does require additional work at the initial stages to deliver scalable systems to accommodate future growth; this investment is marginal in comparison to the reduction of risk of inconsistent data, data reconciliation, duplication of effort etc.

A key component of delivering the value of MDM is the establishment of key architecture principles. Part of those principles is a well composed MDM architecture addressing a variety of data management concerns that defines components responsible for the following functions:

- Creation and managements of the core data stores
- Management of processes that implement data governance and data quality
- Metadata management
- Extraction, translation and loading of data from source to target(s)
- Backup and recovery
- Analytics
- Security and visibility
- Synchronisation of data changes
- Entity matching and generation of unique identifiers

Utilising ‘Service-oriented Architecture’ (SOA), information can be invoked by different applications for different purposes through a variety of platform independent service interfaces.

An effective MDM solution should be constructed as a metadata-driven SOA platform, consuming services that allow the resolution of master entities and relationships and move from traditional account-centric legacy systems to a new entity-centric model.

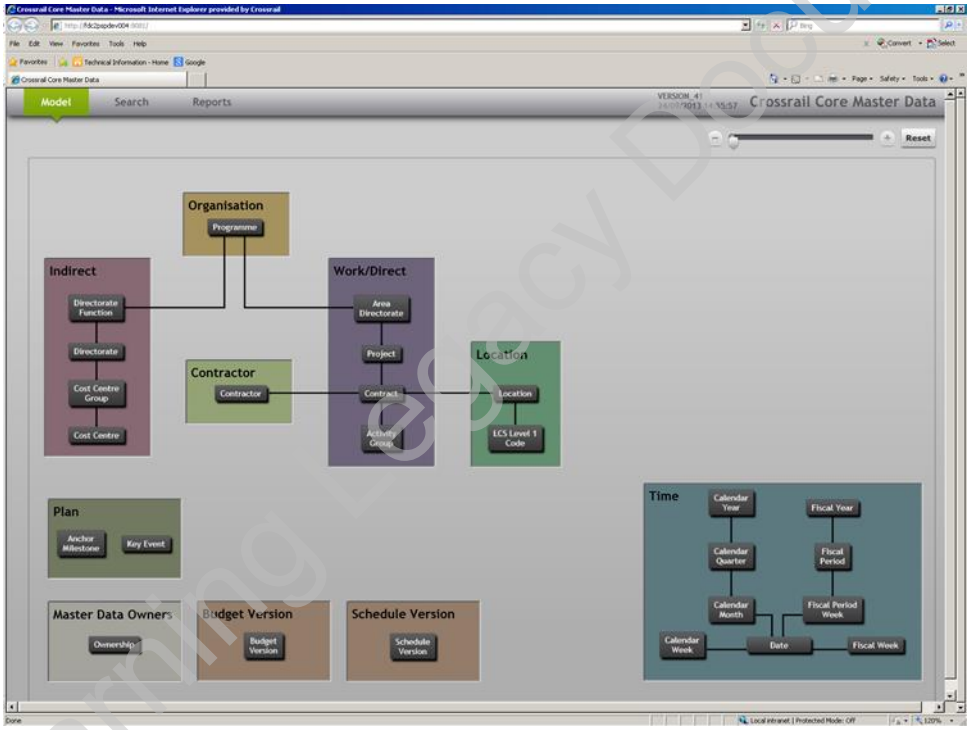
Key aspects of information architecture, in context to BIM are the following:

- De-coupling information from applications and processes to enable it as a standalone, interoperable asset.
- Support the concept the information shall be captured once and validated at sources, breeding a right first time culture.
- Enable measurements, assessments and management of data quality in accordance with information quality standards established by Crossrail and articulated to the rest of the organisation.

- Ensure data security.
- Provide effective platforms and training for standardising content, definitions, structures and formatting at source.
- Promote metadata driven definition for all data.
- Preserve a well-supported and well defined data governance policy.

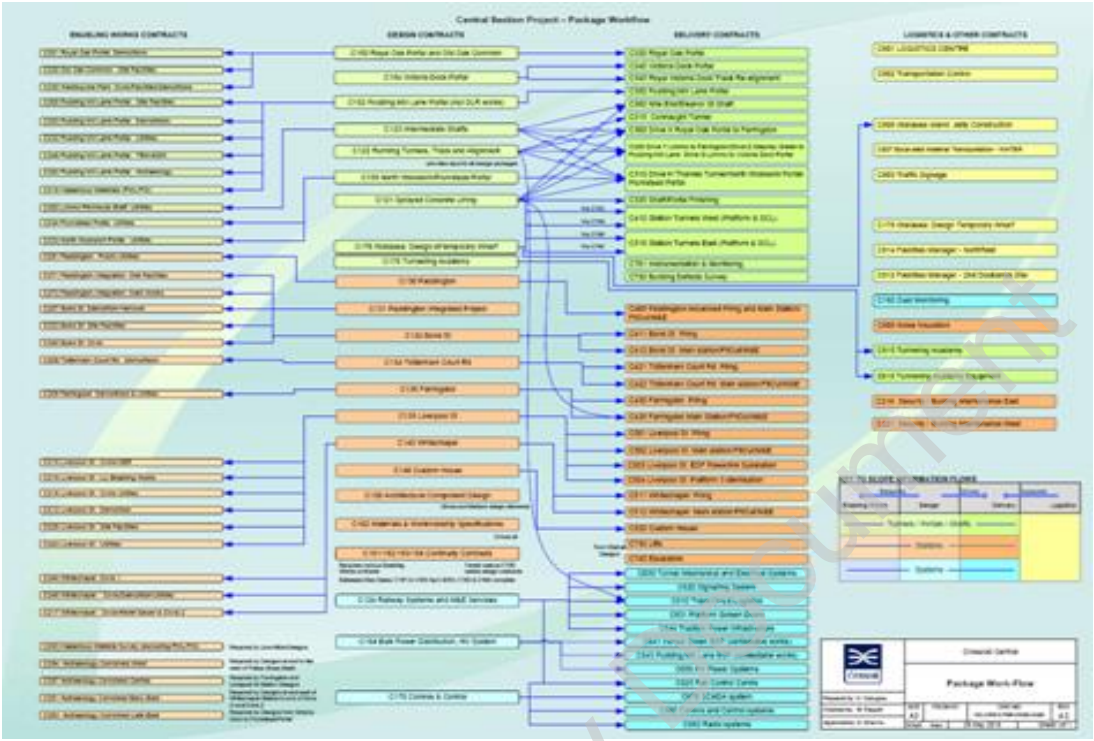
Crossrail's MDM implementation looks to involve people, processes and technology as critical factors to the successful delivery of an information architecture that enables the organisation to become agile, operate effectively, consistently and accurately.

The screen-shot below shows the Master Data Model and the different areas it covers. The model is made up from entities where each entity is made up of a list of values called members and each member can have number of data attributes attached to them.



Any request that may impact the data model structure and/or relationships is sent to the Programme Change Control Manager. They then contact all relevant parties for approval before sending the request to the Head of Business Systems.

Contractual Complexity



The complexity of Crossrail can be visualised in the contractual arrangements required to deliver the systems and infrastructure. With over 25 design contracts, 30 advanced works and 60 construction and logistics contracts (often with multiple interfaces), the potential for error is significant. The complexity is caused not just by the scale of Crossrail but by the diversity and interdependency of activities and disciplines both at station locations and along the route.

Working on the principle that *"everything should be made as simple as possible, but not simpler",* Crossrail have chosen to implement a Master Data Management system where all lists of Master Data are managed, and eliminating multiple (potentially inconsistent) data usage.

An important characteristic of Crossrail's approach to Information Management is that software is always "out-of-the-box" without customisation, to minimise support issues etc.

Best Practice

Best Practice refers to a standardised and consistent way of working based on a framework of policies, procedures processes, guidance and instructions which must be adopted to engender a culture of continuous improvement

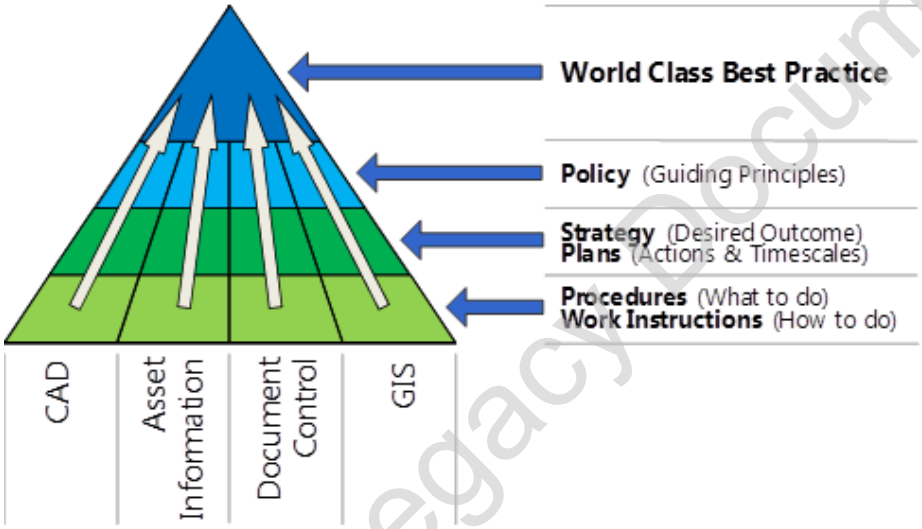
The best practices initiative within Technical Information is a direct response to requests from the business for guidance on

- Compliant information and records management practices
- Continual program improvement ideas

- Government regulations that impact records and information management

We benefit from best Practice through

- Increased Productivity
- Reduced costs
- Increased customer satisfaction
- Improved communications
- Minimised risk



Collaboration Platforms

Utilising Microsoft SharePoint and eB (Enterprise Bridge by Bentley Systems) technology, Crossrail has evolved from the utilisation of network storage drives to operating with highly sophisticated electronic document managements and content management systems.

SharePoint

Microsoft SharePoint is a content management system designed to organise Crossrail's information into a simple, centralized location. It is a server managed repository, that's web enabled for users to organise, manage, search and collaborate.

This is depicted in the adjacent SharePoint wheel:

By default, SharePoint has a Microsoft Office-like interface, and it is closely integrated with the Office suite. The web tools allow non-technical users to provide intranet

portals, document & file management, collaboration, social networks, extranets, websites, enterprise search, and business intelligence.

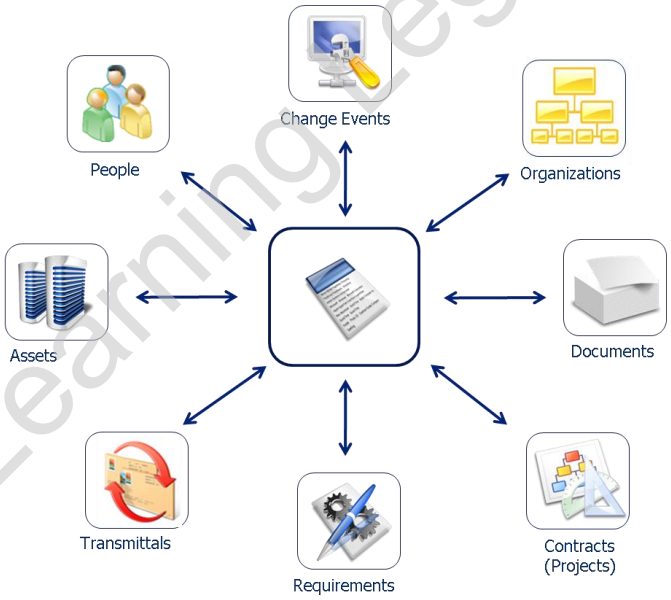
A key initiative within Crossrail is the creation of individual SharePoint teamsites. The teamsites provides central storage and collaboration space for documents, information, and ideas for a team as opposed to working in uncontrolled network drive environments.

The SharePoint sites helps groups exchange information and work together. Members of the site can contribute their own ideas and content as well as comment or contribute to other people's. SharePoint is found in real world applications within Crossrail such as:

- Coordinating projects, calendars, and schedules.
- Discussing ideas and reviewing documents or proposals.
- Sharing information.

eB – Enterprise Bridge

eB is a an object-orientated relational database. This product was first introduced into Crossrail in 2009 for its configuration management capability, and is now the key component of our common data environment. It is being used by all the Crossrail contractors as the EDMS for contract administration, document management, asset data etc. and is the main repository of information for Crossrail. As a relational database it has the capability of forming relationships between different types of information as shown below,



It is therefore critical that a standardised procedures and metadata rules are used consistently by everyone. Data can then be sifted and sorted in many different ways. For example a pump may be viewed by: (i) location, (ii) classification, (iii) function.

Each record kept in Crossrail is accessed utilising eB Web using a standard web browser and can generate and distribute reports, manage publishing packages and crucially, interface with SharePoint documents.

Crossrail use the workflow functionality for many of the basic transactions required in the management and administration of the contract. The metadata in these transactions ensures the details (of letters, instructions, requests etc.) are immediately stored in the database.

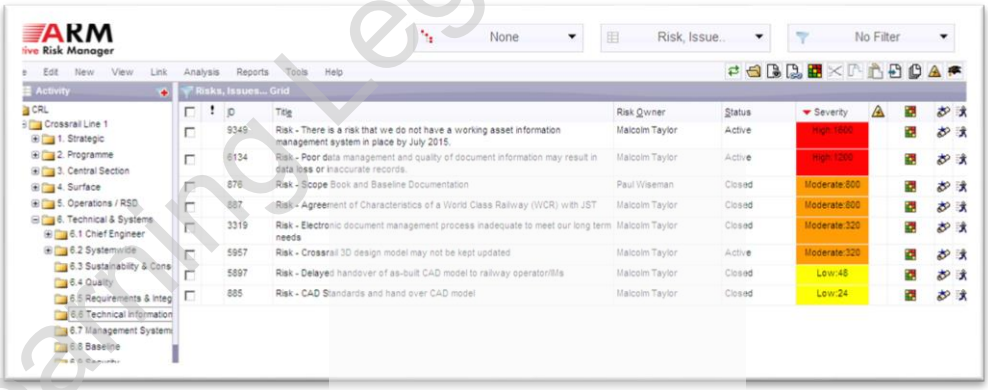
Risk Management

The nature of risk to information within Crossrail is multi-faceted and features common risk constituents such as:

- Poor data and information practice
- 'Local' information risk:
    - Lateness
    - Inadequacy
    - Checking / governance
    - Correctly structured
- Server downtime
- Communication link failure
- Information corruption
- Viruses
- Hacking

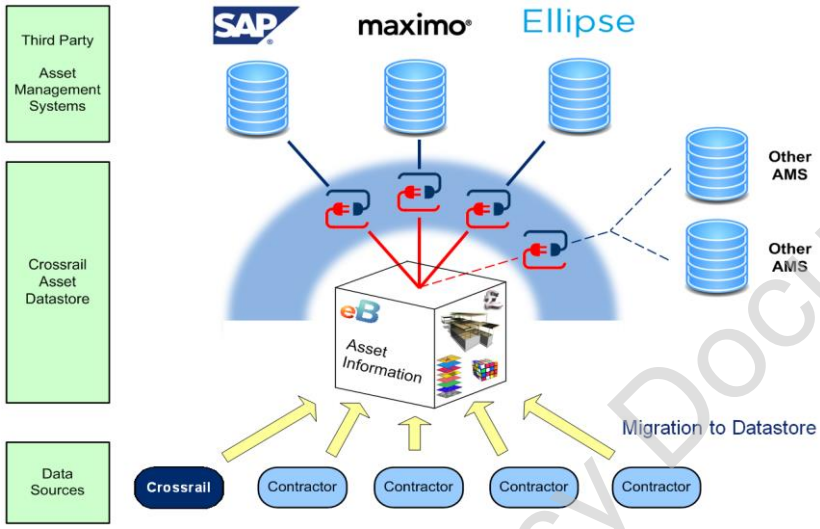
In order to mitigate for these risks, Crossrail employs the use of a web based Risk Management program, ARM, to identify, allocate ownership, assess impact, score and plan for the mitigation and prevention of risk actualisation.

Following normal practice, the risk register is reviewed at regular intervals.



9.2 Crossrail Aspirations for Data Migration

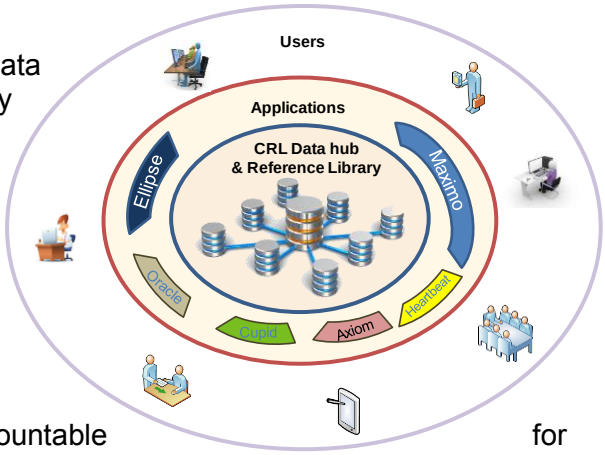
Crossrail is obligated to hand over all the technical data, associated information and records needs to ensure that the railway can be operated and maintained by the IM's. As noted in Section 8.3 the railway lines operated within TfL use a number of specific and separate management systems. Our current approach will be to create asset information that will be interoperable across whatever third-part system may be required, as illustrated indicatively below:



Crossrail seeks to ensure we migrate data over to the IM's such that it will facilitate the creation of world class best practice in rail asset management.

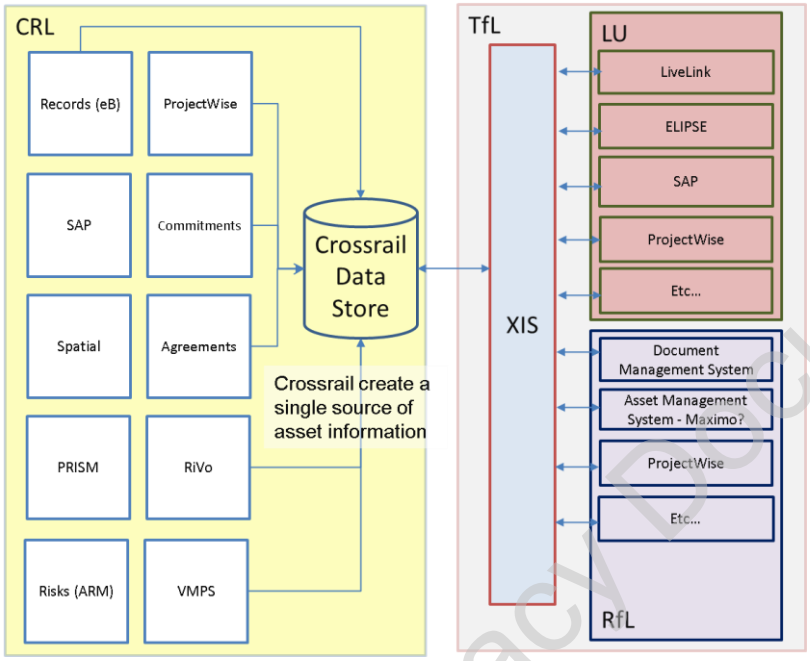
To ensure this takes place, CRL are advising and working with TfL, RfL & LUL to define the data characteristics and requirements that would enable and support a world class asset management system.

The CRL strategy is to create a complete data store of information and reference library hub. This would comprise all the required documentation needed for acceptance of the railway by the IM's, plus all the relevant background digital reference and supporting data used to create the railway. CRL is using the TfL Pathway framework for structuring and organising the required IM information.



Crossrail is currently responsible and accountable for the information building up in the data hub. Most of the record data is within eB, the GIS data in Oracle and 3D model data in ProjectWise. At present this data is located within CRL's own IT systems, but it is expected that within the next 2-3 years TfL will provide CRL's IT support services and the data will sit within TfL hardware. Handover of the digital data to the IM's will then occur by transferring responsibility of the data hub over to the IM's. Future governance and rules of stewardship and change control of data in the hub will be developed before then.

An indicative interpretation of how the data store could be represented in terms of IT systems and applications is shown below. The box identified as XIS is TfL's data integration solution - this is not yet a mature solution but has begun use in TfL. Implementation planning will need to take account of the level of maturity/usage at the time that data transfer will start to take place

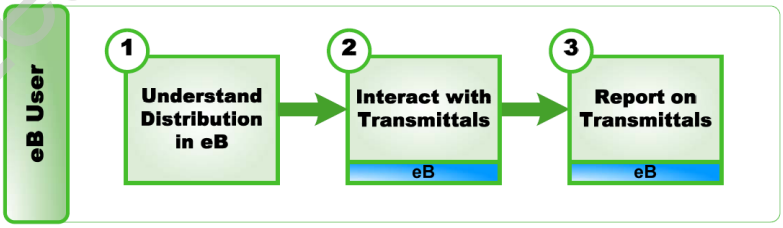


9.3 Document and Data Control

Document and data control is all undertaken within eB. All contractors are required to work within this application. The typical workflows that are used in the database to manage our documentation environment include:

- Transmittals

A formal method of distributing information to people within CRL and External Parties that includes a 'Reason of Issue' e.g. Issued for Review, For Acceptance



- Work Orders (Review and Acceptance, Distribution)

  Distributing information via a controlled Workflow e.g. Review and Acceptance, Distributing Correspondence

A Work Order contains a defined set of tasks for a specific business process and provides users with visibility of tasks that are:

- Forthcoming
- Awaiting Action
- In Progress
- Completed
- Rejected
- Delegated
- Require Re-assignment

Each Work Order is:

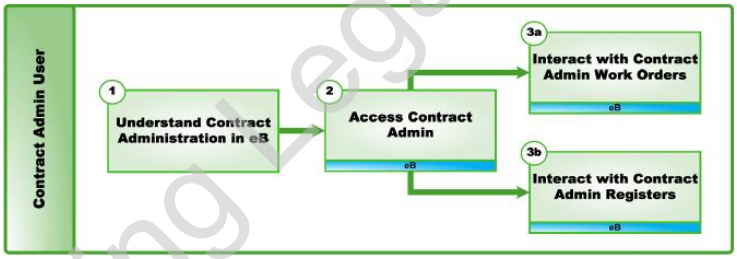
- Composed of one or many tasks which are assigned to different recipients
- Each task has specific instructions of what actions are required

Contract Administration

- Contract Admin Work Orders

  The Contract Administration section within eB allows you to initiate and manage key processes such as 'Early Warning Notification' and other communications, to help highlight and manage project risks. eB maintains a record of these processes which form part of the audit trail.

  Contract Administration Work Orders can be initiated whenever a business need arises. For example, an 'Early Warning Notification' can be raised to highlight project risks.



Document and Data Compliance

Data Compliance ensures that the right people are able to retrieve the right information throughout the project's lifecycle.

Crossrail's technology platform is continuously developing and since the implementation of eB and SharePoint, a set of clear guidelines must be available to users to know which solution to use and where to store their documentation.

Crossrail create a large volume of documentation. In support of planning, designing and constructing the programme, a substantial amount of documentation requires strict control to deliver each project. The Data Compliance Strategy is built around three key areas, as follows:

- Understanding of current Document Control policy and responsibility landscape in order to provide a baseline against which compliance can be measured;

- Review and understand the existing tools for measuring compliance. Identification of additional compliance tools and metrics relies upon the findings from part i;

- Additional areas of importance for Document Control Compliance. These include reviewing roles & responsibilities, security and confidentiality, communities of practice, site liaisons, closing contracts and so forth.

Benefits and Risks

Compliance is important to ensure that the quality of the virtual world is as good as the quality of the physical world. Poor document management can delay the Programme and hinder progress in both worlds. The aims of the compliance team are to achieve the construction and post-occupancy benefits by adopting BIM recommended standards.

Other benefits include protecting the confidentiality, integrity and availability of corporate information from unauthorised disclosure, modification or destruction. Through frequent identification of high-risk processes and procedures, reputational damage and raising an NCR can be avoided.

Additionally, compliance can improve three key business areas, as follows:

- Security and control - Crossrail's EDMS security features are superior to email communication, allowing for an audit trail and safe exchange of sensitive project documentation. Furthermore, the system can control what every employee has access to and in the event of a mistake, documents and data can be retrieved;

- Collaboration and sharing of information – correct usage of EDMS system ensures that the most up-to-date revision is being worked on, creating a single source of truth, thereby eliminating inefficiencies such as duplication of work or lost information;

- Overall business practices – provided that users assign correct document metadata, EDMS enables efficient search function and serves as a reliable storage facility, eliminating unstructured shared drives.

Management and mitigation of risks

The results from Compliance Reviews are used to identify areas of non-compliance. Based on the results and feedback, the Document and Data Compliance team can concentrate on the high-risk issues. Data Compliance Programme will help the team with planning and delivering the most effective compliance tools.

Key compliance components of Document Control

Based on the above policies, procedures and responsibilities, four key components need to be considered in order to effectively assess compliance:

- Creation of documents – appropriate document control upon creation or receipt;

- Security and confidentiality – appropriate classification is assigned to relevant documentation and it is being stored in the appropriate system with the correct security levels;
- Storage of documents – appropriate and secure storage is being used;
- Archiving, disposal and destruction of documents – documents are being archived, destroyed or disposed of in accordance with the archiving procedure (also documents that are legally eligible for destruction are being routinely destroyed).

Document Control Compliance Baseline

The baseline for document and data compliance is the Document Control Policy. The key objectives of this policy are as follows:

- Ensure that all documents are approved at the appropriate level for adequacy prior to release;
- Ensure that only the correct and approved versions of documents are released, and that the latest versions are readily identifiable as such;
- Ensure that documents are quickly and easily accessible to authorised users;
- Provide a secure and flexible repository for the storage and retention of all formally released documentation;
- Optimise efficient access and retrieval of documents through appropriate numbering, indexing, grouping and use of content and attribute-based search facilities;
- Implement effective revision (change) control by use of document versioning and a single document numbering system;
- Manage the number of controlled paper copies of documents in circulation, and eliminate the circulation of uncontrolled paper copies;
- Support CRL business and project processes by automating workflow where beneficial

Management and Acceptance of Field Documentation

There are a number of processes associated with the Crossrail Delivery Teams management, receipt, identification and distribution of design documentation to and from the Contractor and the receipt, distribution, review and acceptance of Contractor documentation by the delivery teams and others which support the Quality and Assurance requirements.

Documentation is stored and managed using the CRL eB system through the use of:

- eB Work Orders
- Structures aligned to the Master Deliverables List

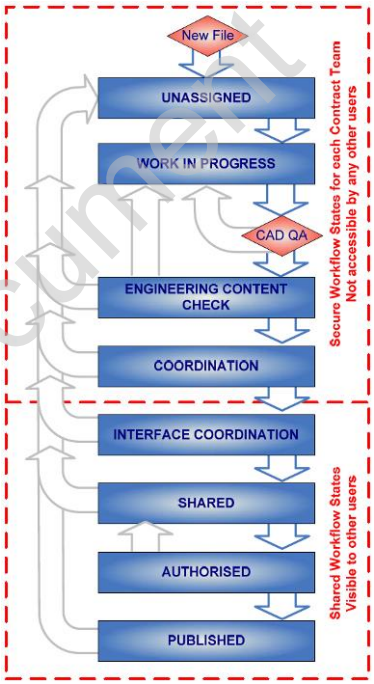
9.4 CAD (Models and Drawings)

The CAD Team is responsible for ensuring that all CAD data used on the Crossrail project has been created in accordance with the appropriate standards and is fit for purpose. It is essential for the safe and efficient construction of the Crossrail project that all drawings and models produced are accurate, consistent and approved before being issued for design or construction purposes.

All CAD data at Crossrail is produced and stored in the CAD Management System (ProjectWise). This system controls access to the appropriate information based on a user's role as well as providing the mechanism for the checking, approval and acceptance of CAD Drawings and Models. The system also automatically produces PDF renditions of CAD drawings and submits them to the Document Management System (eB).

In the ProjectWise system there are two workflows for CAD Models and Drawings which have been developed based on the BS1192:2007 code of Practice.

The workflow supports a number of workflow states:



- Unassigned

  Used as an initial holding state when files have been created or revised prior to be modified

- Work In Progress (WIP)

  The only Workflow state where files can be modified

  When files are 'Approved' they must pass through an automated CAD QA check to validate the file's compliance with the CAD standards.

- Engineering Content Check

  The content of the file is checked to ensure that the scope of work has been completed and that the file has been compiled correctly in accordance with the CAD Standards.

  A 'Check' PDF is produced when the file reaches this workflow state and is placed in the 'Unapproved PDF' area in ProjectWise.

- Coordination

  Used for contract inter-discipline coordination or internal contract reviews

- Interface Coordination

  Used for multi-contract discipline or interface coordination or client contract reviews

- Shared

  This is the final state for contract team approvals. At this state the file is identified as being checked and approved by the contract and is ready to be issued to Crossrail for authorisation

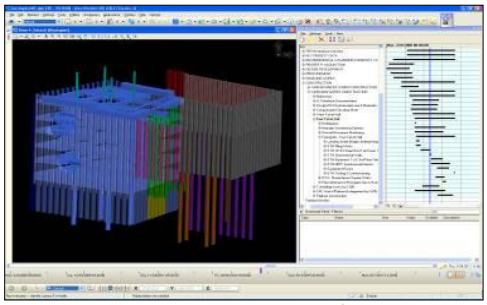
- Authorisation

  A holding state for files issued from the Contract to Crossrail.

  Prior to approval the Authoriser must select the reason for the authorisation from a pre-defined attribute list in ProjectWise. The approval at this state is deemed to be a contractual authorisation that the file is suitable for the purpose of issue (Suitability)

- Published

The final state for all CAD data and any CAD file that has reached this state can only be revised after following the appropriate change control procedure



3D PDFs - In order to enhance the decision making processes and aid visualisation, Crossrail has created a series of PDF documents with embedded, interactive 3D models.

Within the PDF a user is enabled with the ability to rotate, zoom and explore the model with a variety of tools and views.

Bond Street Station interactive 3D PDF

Key outputs for CAD within Crossrail are:

- Integrated data
    - Using the Crossrail CAD EDMS 'ProjectWise' system to identify and locate models which enable users to link to 'Street Scene' data to provide visual information of associated utility data
- Modelling
    - 2D Sequencing Drawings are being used at a number of sites to effectively communicate current and planned construction progress
    - 3D object orientated modelling is our normal BIM environment

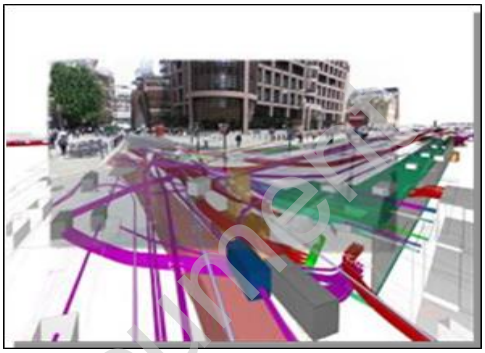
9.5 Information Applications (4D)

Key outputs

- 4D to link schedule with 3D models to give a visual validation of where a proposed construction sequence is acceptable

Wider Modelling Concepts

- Crossrail have created rules and standards to ensure current models are 5D capable
- Utilising models to maximise the potential opportunities associated with the prefabrication of larger, more complex parts of the project and offsite manufacture
- Virtual reality – we will be developing a 3D station model to create a computer-simulated environment that can be investigated and explored
- Augmented reality – we will be investigating the ability to use visualisations to expose in a hidden asset data within stations e.g. services buried in solid walls



BiDWG - BiDWG is the BIM in Delivery Working Group

BiDWG consists of Crossrail and Contractor individuals working collaboratively to solve business problems through the deployment of BIM technologies.

BiDWG gathers best practice use of technical information within the wider industry and works towards driving adoption on Crossrail. BiDWG collaborates with a number of industry bodies to identify this industry best practice.

Field Supervisor

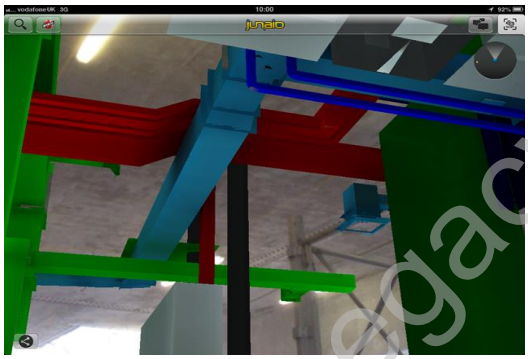
The activities of the BiDWG include:

- Development of a 30 minute training module being delivered as part of the syllabus for the Crossrail Technical Academy. All Crossrail and Contractor personnel are encouraged to attend the Crossrail Technical Academy to learn more about BiDWG and Crossrail's approach to technical information.
- In response to the strong demand for mobile based technologies at site the BiDWG Mobility Task Group and Crossrail IT are developing a Mobility White Papers to capture Crossrail's mobility requirements and progress with mobility application testing and implementation.
- Current progress from the active BiDWG task groups includes the Field Supervisor Application. The app has been launched and is available for iPad via the Apple AppStore. Crossrail is currently installing a server to allow the app to connect to the eB data-store. Testing has commenced and selected stations followed by roll-out across the project.

- The Mobile Forms App is intended to integrate with the Field Supervisor App so that a field engineer can retrieve drawings/documents and populate mobile forms from within one environment

  Testing using the Formotus app commenced at Whitechapel station in June 2013 with an extended trial at Bond Street station in early July 2013. The next phase of this project is to work collaboratively with Bentley Systems to develop a generic backend forms solution and mobile app. The Mobility task group have developed an end user requirements and scenarios document which outlines how this app will work.

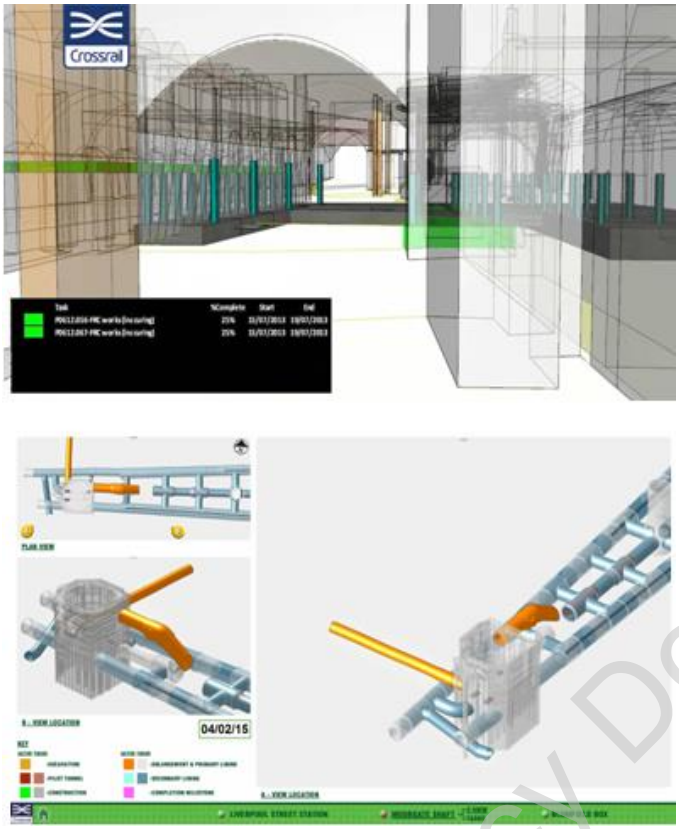
- Augmented Reality is a constantly developing initiative which will enable Crossrail to investigate the ability to use visualisations to expose in a hidden asset data within stations e.g. services buried in solid walls



- 3D laser scanning is being assessed as a stable methodology to rapidly capture accurate 3D point clouds of Crossrail assets. Potential use cases include the validation of as-builts, spatial coordination and clash detection.

- To enable collaborative real-time drawing annotation and RFI tracking, the BiDWG are conducting a touch based plan review. Potential use cases included engineering drawing review, redlining and punch listing.

- 3D Model in the field is an initiative to provide access to the current approved 3D design model on mobile devices. Currently being tested by CSJV on Paddington and under investigation for wider implementation by BiDWG as of July 2013.



9.6 Geographical Information Systems

A key focus of BIM is to support much more efficient planning, design, fabrication, construction and maintenance of new facilities. Software products are now becoming optimised to facilitate and allow multiple users with unique disciplines to interoperate and perform complimentary functions.

In contrast, GIS has a much less defined role, and at present there is no rigorous common underlying GIS data structure similar to the CAD world. The relationship between GIS and BIM within Crossrail is primarily focused around the integration and adoption of data, procedures and standards to ensure that GIS can act as a contextual tool for the visualisation, analysis and reporting of project information. It relies on the interoperability of data between systems to 'draw down' information into a centralised data model which can enable 2, 3 and even 4D views to be created for users to consume.

Key outputs

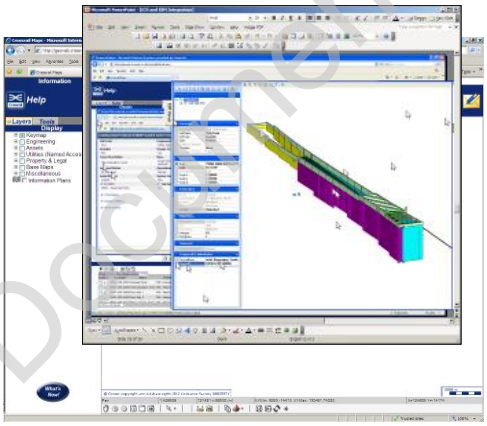
- Accessing documents through spatial queries of our GIS system 'Crossrail Maps' e.g. linking contract documents to a specific area on a map

- Utilising mapping data to identify and locate drawings and models which can be further interrogated to view tags and their associated asset information

A fundamental tenet of GIS, particularly in the context of the enterprise database environment, is that a single source of data can be used to create dynamic outputs, allowing both standard geographic views of spatial data as well as linearly referenced or graph database (network topology) derivatives. The use of open data sources also allows data to be consumed by a variety of systems and applications that are accessible on multiple platforms, from desktop, web and mobile sources, without the need to recreate data

By the time Crossrail asset information is migrated to the IM's we can foresee this position changing and so we need to ensure our strategies going forward will enable us to create the potential for significant additional "business outcomes" using GIS.

We have used 'Crossrail Maps' in planning and design, and this is now being made available to all contracts to facilitate access to utility data. However, GIS offers many advantages to the future operation and maintenance of Crossrail including:



- Overlay analysis (how things intersect and interface)
- Proximity analysis
- Surface analysis
- Statistical and time-based analysis

GIS data has begun to be used by facilities managers to help operate facilities across wide geographical areas to answer typical questions that involve location, time and tabular data.

Currently we are able to create polygon shapes within the GIS system and pull out all associated documents to that area. From a station operations perspective, this could be refined to identify "how many fire extinguishers do we have to inspect at a station next month and where are they?", or "how many leased spaces do we have available in the next six months to support a coffee shop outlet?".

Major asset owners such as British Airports Authority now use GIS as the first interface into accessing their asset data. The current development of mobile computing devices with cloud-based tools will make information even more accessible.

The convergence and interoperability of GIS, BIM models and specific facilities management technologies (enterprise asset management; computerised maintenance management systems; computer-aided facilities management etc.) mean that the concepts identified for "Smart Buildings" must be captured and used and developed by Crossrail.

Mobile GIS (Crossrail Maps Mobile)

Crossrail Maps Mobile is a lightweight GIS app for the visualisation and interrogation of geospatial data for the Crossrail Project.

It uses ESRI's ArcGIS Online cloud technology to enable the GIS Team to create and distribute maps to named users and groups for specific purposes according to the needs of the project.

This currently includes information pertaining to assets, structures and utilities, as well as links to external information such as information plan drawings held within Enterprise Document Management Systems.

Users can choose from a variety of base map layers, geo-locate according to their current position, use a global search tool and interrogate geospatial information from the map layers that are available.

In addition the user can measure distances and area, bookmark locations for easy navigation and even add their own point features with attached photographs and videos.

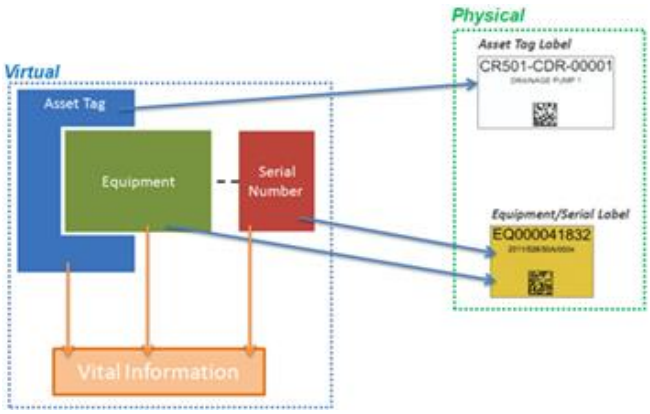
Additional functionality that has come with the ArcGIS Online subscription includes integration of mapping within SharePoint and Office Products, as well as traditional website mapping capability including SDK for custom mapping services.

9.7 Asset Information and Configuration Management

Crossrail rely on asset information and asset knowledge as key enablers in undertaking both strategic asset management and operational activities.

The Asset Information Team, are responsible for the management and population of the Asset Information Management System (AIMS) and the processes used to ensure that asset information is obtained to the required quality and timescales.

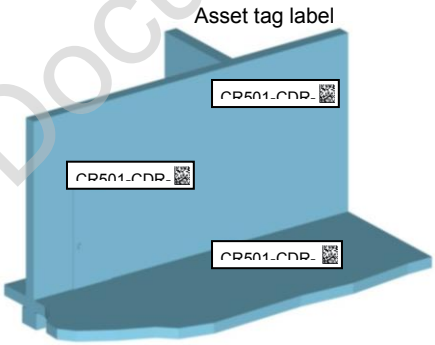
Asset details, such as function, location, type, size etc. are captured centrally to agreed standards.

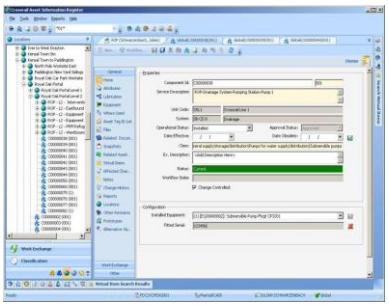


The provision of high quality asset information is an essential deliverable of any railway project to enable long term management of the assets provided.

Asset information is a key input to a number of Crossrail processes and systems:

- Asset information is a key enabler for long term asset management approaches by the Infrastructure Managers and should be provided in formats that support these objectives
- The provision of asset information is a process that runs throughout the duration of an engineering project.
- Asset information, if not gathered at the appropriate point in a project, will be expensive and difficult to retrospectively obtain.
- Information provision processes shall be managed, assured processes with progress and issues visible to relevant stakeholders.





Asset Information Management System

Configuration Management is a process for establishing and maintaining the consistency and integrity of configuration items (vital information) and the relationships between these items.

The Configuration Management team is establishing configuration items to a level of granularity consistent with its required visibility / control.

Current status is maintained by consistent application of change control, status accounting and audit of these items.

An asset information classification system has been developed, based on Uniclass and described in the CRL 'Asset Identification Standard', this standard also sets out the processes to be used in the identifying, labelling & marking of assets and collecting of asset information.

An outline schedule for the migration of data to the IM's has been developed. Government is looking to use a method called COBie across the construction industry for transmitting the data during migration. Crossrail will be compliant to COBie, assuming it will be able to achieve the level of detail required for rail station asset management or for linear infrastructure assets.

Crossrail asset information data will be collected and put into our EDMS relational database, which will ultimately be used for migration of data over to the IM's. We recognise the length of time it will take to collect the data but also to develop the appropriate asset information management system and implement a migration strategy.

9.8 Associations

To ensure Crossrail can keep up-to-date with issues, trends, developments in BIM activity, and help shape that direction, we continue to develop links and associations with outside organisations and academic bodies.

- Bentley – a Technology Partnership and an Information Academy
- Industry Expert Panel being set up to include representation from:
    - Cambridge University
    - Imperial College
    - Bechtel
    - Specialist world class expertise in technology and asset management
- Reading University, particularly their Design Innovation Group
- BIM4RailUK

10 Relevant Documents

Crossrail Documents

CRL1-XRL-O6-STD-CR001-00014	CAD Standard (CR-STD-005)
CRL1-XRL-Z3-GPD-CR001-50001	Document Management Procedure
CRL1-XRL-Z3-GPD-CR001-50002	Correspondence Procedure
CRL1-XRL-Z3-GPS-CR001-50001	Document Control Process (Review and Acceptance of Documents for Construction Issue)
CRL1-XRL-Z3-STP-CR001-50002	Asset Information Management Plan
CRL1-XRL-O6-STD-CR001-00031	Asset Identification Standard
CRL1-XRL-V3-XWI-CR001-50035	Works Information Volume 2B: Section 13.5
CRL1-XRL-O8-XTC-CR001-00004	CRL Maintenance Strategy
CRL1-XRL-N2-GPD-CR001-00003	Whole Life Cost Principles

External Documents

Report to the Government Construction Clients Board on Building Information Modelling and Management	http://www.bis.gov.uk/policies/business-sectors/construction/research-and-innovation/working-group-on-bimm This report provides Government Clients with a suggested roadmap and strategy to enable the progressive use of BIM on Government building programmes as well as providing a framework for procurement and delivery standards
BS 1192:2007	This Standard establishes the methodology for managing the production, distribution and quality of construction information, using a disciplined process for collaboration and a specified naming policy
Constructing Excellence: Never Waste a Good Crisis	www.constructingexcellence.org.uk A report from Constructing Excellence authored by Andrew Wolstenholme. The report looks to determine the level of industry progress since Rethinking Construction and define the improvement agenda for the next decade
Constructing Excellence: Whole Life Costing	www.constructingexcellence.org.uk This fact sheet introduces the principles of whole life costing for organisations that are new to the subject or in the early stages of working with whole life costing
Uniclass	http://www.ribabookshops.com Unified Classification for the Construction Industry published by the RIBA