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RAIL INDUSTRY SAFETY AND STANDARDS BOARD
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Digital Engineering

CODE OF PRACTICE

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Document control

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Code change procedures

The RISSB maintains the master for this document and publishes the current version on the RISSB website.
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Changes to this publication must be approved according to the procedure for developing management system documents.
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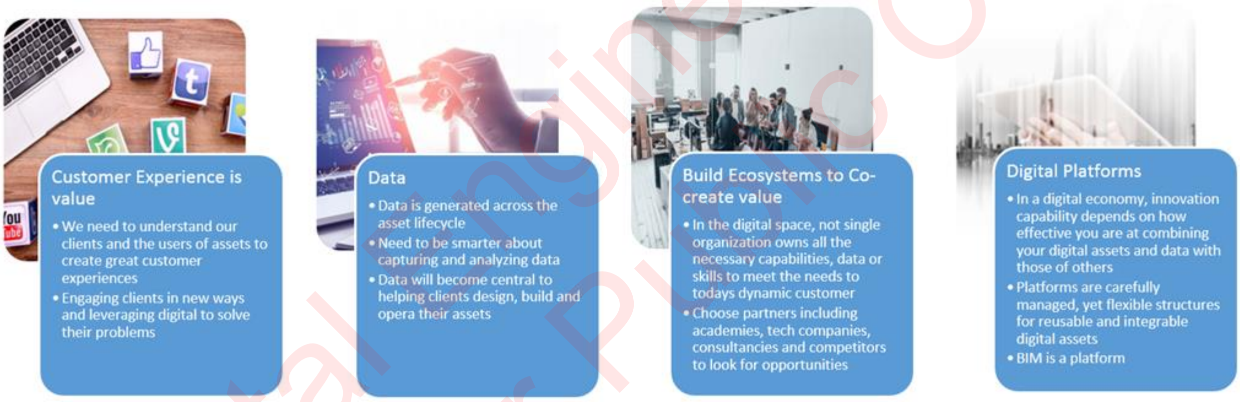
Contents

1 Vision

Why do we need to transform to digital engineering?

- Australian rail market conditions will continue with strong near-term growth.
- Our traditional markets are changing, we need to be managing infrastructure change from an asset perspective rather than discipline perspective.
- New entrants will disintermediate our traditional supply chain and steal value from existing players.
- Traditional professional service models will evolve.
- Need to manage data as an asset.
- Start with the end in mind, what information do we need for our assets and ensure the management of the asset is captured through the whole project lifecycle.
- We need to inform the long-term management of our assets within the design phase, by starting with the end in mind.
- Ensure the intelligence created in the CAPEX (capital expenditure) phase can be reused throughout OPEX (operational expenditure) to reduce the TOTEX (total expenditure).
- Digitally enabled solutions will become critical to value creation, with the 4 digital realities, key for a digital engineering approach.



2 Context

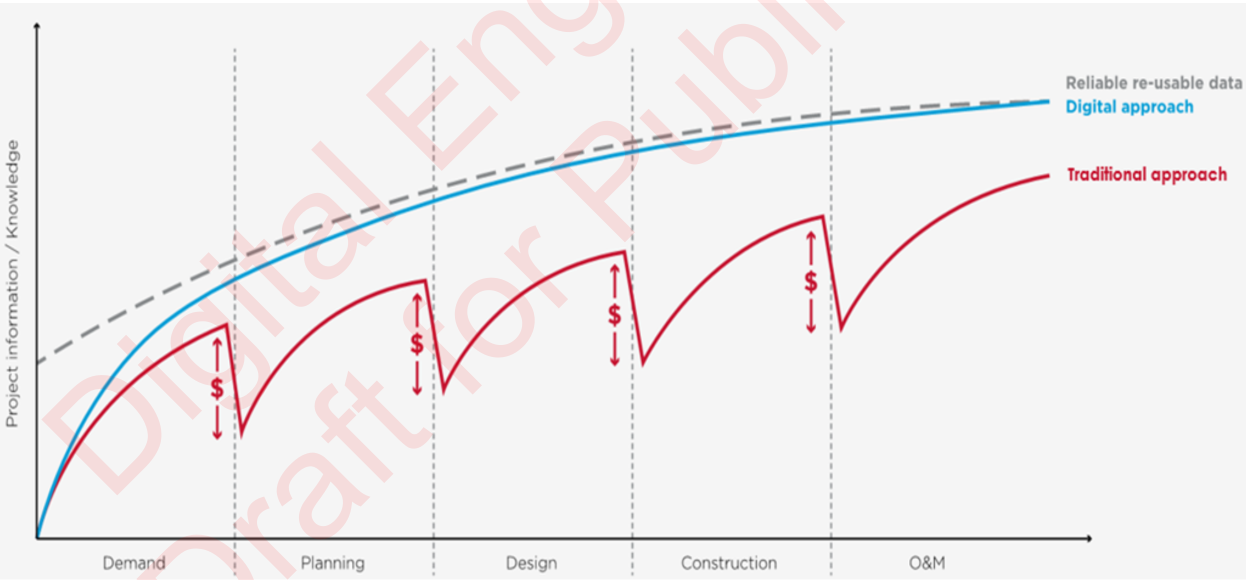
2.1 Scope

This Code of Practice is to provide the rail industry with a guide to the use of information management standards and technology which would enable the rail industry to better manage projects which are currently characterised by time delays, materials waste and cost overruns during the ongoing operations and maintenance stages of the asset lifecycle.

This document demonstrates how digital engineering (DE) is used to procure information as a structured information management process through the project lifecycle. By connecting and managing data through the common data environment, all project stakeholders including the end user will benefit by having the relevant information to make informed decision

This document will:

- provide overall understanding of digital engineering and relevance to the rail infrastructure industry;
- provide understanding of the benefits of a digital engineering approach;
- outline the use of information management standards and technology to capture, explore, and maintain consistent and coordinated planning, design, construction and operational data;
- provide direction on the provision and use of digital engineering to achieve greater project insight for cost, schedule and constructability, maintainability and safety in design;
- illustrate the steps required for an organisation to change to be ready to work in a digital engineering environment.



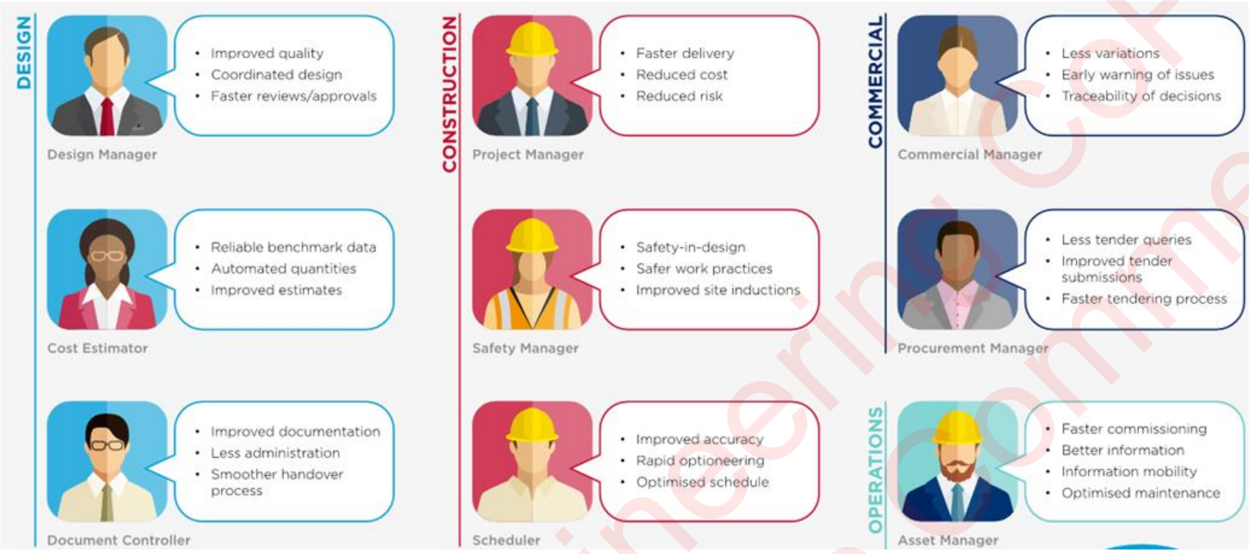
The diagram illustrates the consequences of information loss suffered at each project milestone using a tradition approach to project delivery based on a paper-based methodology. By adopting a digital engineering approach, the need to recreate information is mitigated.

The Code of Practice does not specify information technology (IT) software or systems.

2.2 Purpose

This Code of Practice promotes the use of digital engineering (DE) within the rail industry. The document caters all industry stakeholders and is intended to start DE focused conversations for all projects, thereby delivering an industry wide DE revolution within the rail industry

All stakeholders within the project will benefit from DE even though their experiences will vary as each stakeholder will have different information requirements. However, the value of finding information more easily, gaining data driven insights and making faster, more informed decisions will enhance the way we all work.



2.3 Background

People, Process and Technology are the major enablers to be working in a BIM environment. The table below illustrates minimum benchmarks to enable organisations to be aligned with future industry requirements and current industry demands.

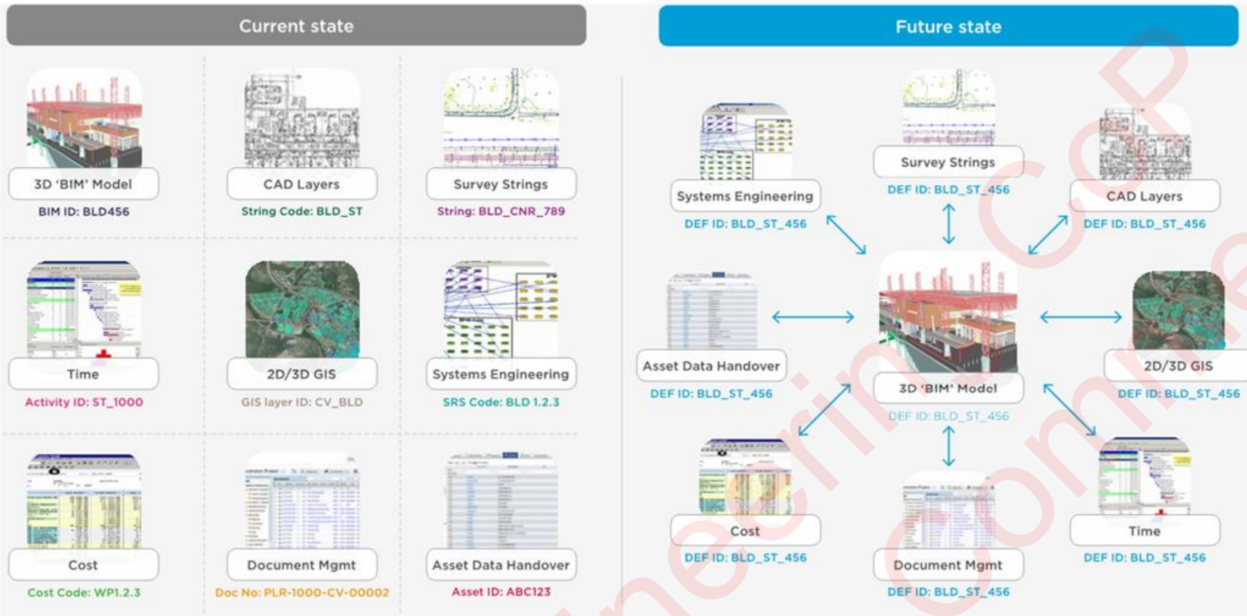
	2019	2020	2021	2022
People (Culture, Organisation)	Company wide BIM Teams through project procurement. Common BIM language throughout the business.	Monitoring, support and management of multiple BIM projects.	Continuous management of success and failures. Ability to coordinate all stakeholders. Quantity take-off and progress management using the BIM model	Digital Engineering real time project management during the whole project lifecycle. Lean construction based project management.
People (Education)	Ability to work in 3D environment, creating 3D models with defined output requirements build within template and seed files of BIM authoring tools	Ability to lead design reviews using BIM visualisation tools and processes	Ability to coordinate all stakeholders. Quantity take-off and progress management using the BIM model	Digital Engineering real time project management during the whole project lifecycle. Lean construction based project management.
Process (Policy, Infrastructure, work process)	Design coordination between limited stakeholders using BIM. Application of existing tendering and project management methods.	Increased importance of coordination between BIM models. Linking models with other forms of data for whole of project lifecycle	Increased importance of interoperability of BIM tools, version control, model synchronisation, collocated and collaborative work process. Technology assessment system.	Lean based management process, scheduling system, planning, DfMA. Tendering and management methods that can support off site and modular construction.
Technology (Software, Hardware, Information)	BIM authoring tools, BIM viewers. Working within Common Data Environment. Create a system that tracks and manages design errors.	Coordinated technology between 3D models and 3D drawing output. Use of 3D scanning for verification.	Cloud based tools, BIM servers, Field BIM tools, 3D scanning and photogrammetry for model-site synchronisation. Actual progress based 4D schedule management. A change management system	Integrated lean-based Digital Engineering Management tools for construction automation. Develop a company wide system for monitoring and managing the progress and quality of projects.
Digital Engineering Goals	Communication between managers and project participants using BIM. Understanding the use of data within BIM	Design review and coordination while managing budget. Elimination of unnecessary social cost using visual information	Coordination between all stakeholders. Total project management system for managing cost, progress and field data.	Application of mobile devices, sensors. Real time update of project construction and maintenance information. Lean based off-site modular construction.

Due to the fragmentation amongst stakeholders and the overpopulation of localised standards within the rail sector, an interconnected network cannot be achieved. The strategic map proposed above intends to initiate the effort of linking industry partners and standards to establish a cohesive market by 2022.

3 What is Digital Engineering

3.1 Digital Engineering

Digital engineering (DE) connects emerging technologies with reliable structured data. It enables more collaborative and productive methods of product delivery and management of assets through the lifecycle compared to those traditionally used.



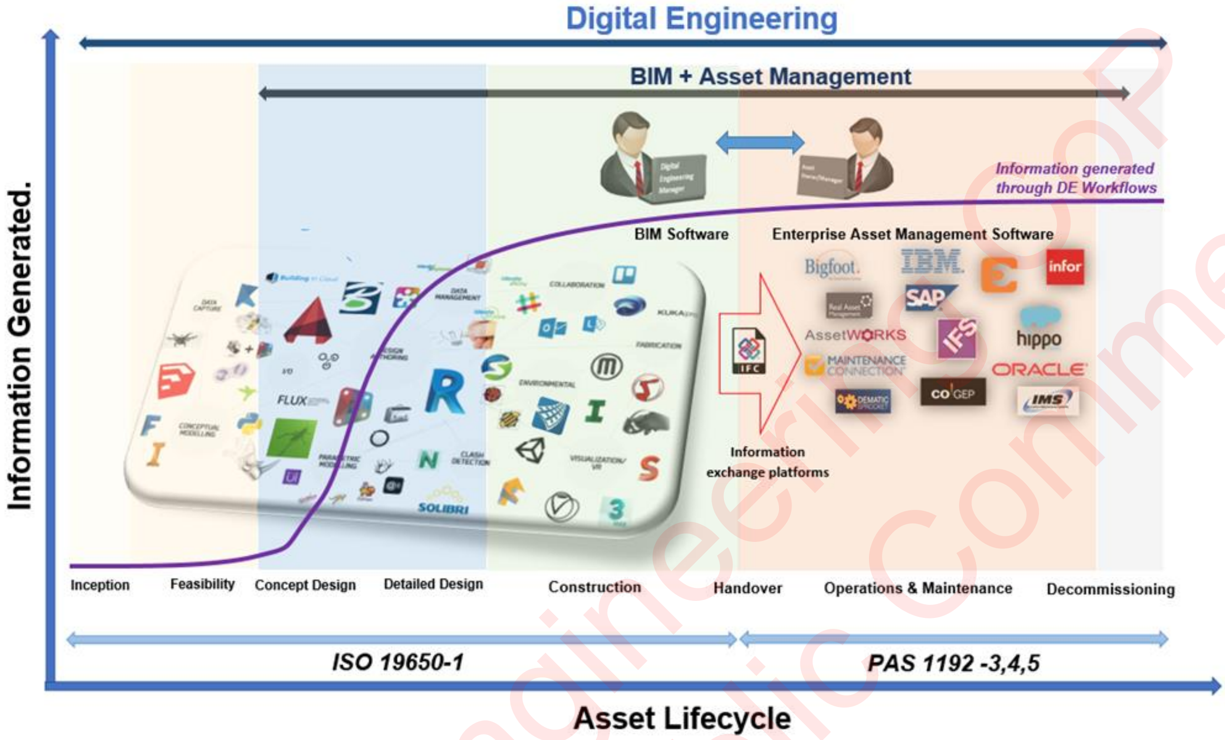
Digital engineering workflows enable information to be readily associated with the maintainable asset. When project information and asset information capture occurs in line with project progress, efficiencies are realised by removing and eliminating double handling of information, coordinating information storage for future reuse and clearly identifying asset information in preparation for handover to asset managers. With the support of DE, asset information verification and delivery can occur with fewer delays thereby improving information availability to the maintenance teams and supporting operational readiness objectives.

The information model which is a key output of the DE process acts as a digital twin which enables the realisation of two end goals of the rail industry which are strategic asset maintenance and safety management. Development of the digital twin prior to construction not only develops stakeholder engagement through advanced visualisation and a collaborative platform, it provides all stakeholders with valuable insights/ information to make key strategic decisions at an early stage of the project where it's more feasible to make changes. Cost savings are achieved through the informed decisions made during the early stages of the project which mitigates the variation work.

As essence of DE lies in connecting the structured data with emerging technologies, stakeholders who engage such workflows into their practice or project delivery are aligning/ preparing themselves to be future ready for projects. To reap the true benefits of DE, commitment from all stakeholders is required as the workflow should be treated as an ongoing process. Often the BIM model is updated through-out design and construction but however there is usually a failure to do so at operations stage. Workflows/timelines/guidelines conveyed through this COP will assist the industry in this digitisation process.

3.2 Creating a Digital Asset

When data and information is managed effectively as a “digital asset”, this creates the ability for consistent and assured information to be re-used in all stages of project delivery and allows for integration into operations and maintenance systems and processes. This will drive significant efficiencies by avoiding data-loss and minimising the need for information to be recreated and reassured at each lifecycle phase.



4 The Benefits of Digital Engineering

4.1 Project Lifecycle Benefits

Project Planning

- Ability to engage all project stakeholders at an early stage by developing a concept 3D model which will mitigate misinterpretations. Development of a concept 3D model will result in: better definition of design requirements and construction specifications;
- reduced risk project decisions;
- improved cost estimation;
- improved optioneering for faster decision making based on project constraints;
- reduced site investigation;
- improved prior knowledge;
- early visualisation.

Design

Driving the efficiency of the design phase by utilising DE software applications and processes results in:

- improved design coordination.
- clash detection.
- improved accuracy & drawings.
- more effective consultation (stakeholder engagement through all lifecycle).
- improved configuration control & requirements management.
- visualisation of constructability and operations.
- O&M into the design phase (track access).

Construction

The utilisation of design information and population of the BIM model with construction/as-built information results in:

- improved safety by visualising WMS;
- streamlined construction planning using equipment and plant simulation;
- reduced risk by better planning;
- improved cost estimating;
- reduced rework;
- off-site fabrication;
- schedule optimisation;
- improved procurement;
- information assurance.

Operation & maintenance

By collating the information generated through the entire project life cycle, asset management capabilities are improved due to:

- integrating data transition to handover;
- accelerated understanding of failures or incidents;
- more cost-effective decisions;
- more targeted, preventative maintenance;
- information mobility;
- safe access planning (site inductions);
- information assurance (3D laser scan to verify);
- relationship of information to object-based asset;
- early information availability updated through construction.

4.2 Benefits for the Rail Industry

The primary challenge faced by the rail sector is the ineffective monitoring and maintenance of infrastructure assets which occurs due to the disjointed communication between assets and the O&M team. The communication of asset information requirements to all stakeholders within the supply chain is a fundamental requirement to overcome this obstacle. DE enables the end user to manage the data and information as an asset to enable informed customer focus decision making in relation to planning, delivery and management of a safe sustainable rail system by applying the following principles:

Principle	Purpose	Impact to Rail Industry
Primary source	Ensuring service and asset data is accurate, current, reliable and not duplicated	Master data management
Collaboration	Increasing access and sharing, reducing latency for improved decision making	Sharing of information between design, construction and AM to all users
Automation	Reducing or eliminating manual work associated with creating or sharing data	Reduction in human errors and data loss. Timely transfer of information
Interoperability	Reducing or eliminating double handling or translation of data between systems	Impact is reducing the risk and cost of integrating multiple information silos
Mobility	Enabling access to and input of data from multiple locations including the field	Access to timely information to those who need it. Reduce the number of user interfaces, enhanced user experience
Visualisation	Incorporating methods to develop, coordinate and check service and asset data spatially	Coordinated multidiscipline, virtual work planning, virtual sequencing, OH&S, railway safe working, public safety, system redundancy, signal sighting.
Data governance	Comply with information management policies, including open data, data information custodianship & information security	Asset owners having an active role in Information definition and requirements
Change and configuration management	Information management through defined CDE	Sharing and reusing information though lifecycle. Benefit is confidence in the currency of the information that is informing operational and capital expenditure decisions

4.3 Safety Benefits

Principle/Issue	Digital Engineering Solution
Complexity of WHS during construction	Virtual construction staging during the design stage (4D BIM).
OHS/WHS training	Induction of staff using the BIM model by running simulations.
Site visit risks	Virtual site visits using the BIM model and drone technology. Reduces access to rail corridor.
Emergency situations	Using the BIM model to simulate crowd behaviour during an emergency to achieve a better design
Customer access issues	Up to date route maps and easier access to users
Risks imposed by resolving clashes during construction	Performing clash-detection during design to mitigate clash resolution during construction.

4.4 Quality Benefits

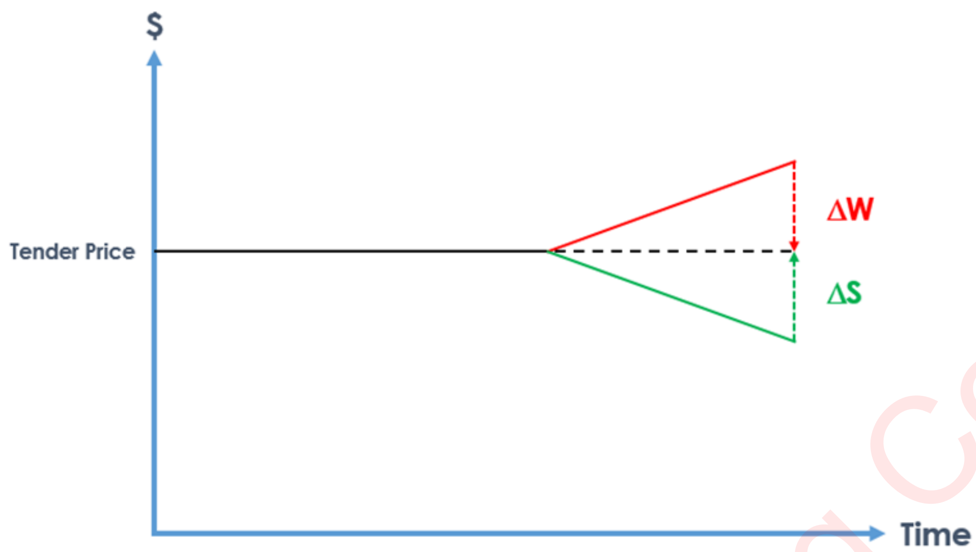
Contractors working within BIM environments report a general improvement in the quality of design data and information received for construction. Quality benefits include:

- the availability of up to date and validated information within the common data environment for decision through the project lifecycle;
- 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 maximise 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.

4.5 Indicative Cost Benefits

DE can deliver significant benefits to an Infrastructure project in the form of reduced errors and waste. Particularly as error and waste commonly result from processes which have been implemented ‘one-off’ and on-site, and which have not been tried and tested off-site (or subject to significant prototype testing).

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 could make a mistake).



The graph above illustrates continuous cost benefits which could be gained by adopting a digital approach. ΔW path is a representation of the behaviour of current projects within the industry where project costs exceed budgets through project progression. By adopting a digital approach to procure information during the project, structured data could be gathered to analyse these cost variations. These 'lessons learned' could be factored into the proceeding work-packages within the same project to shift the cost gradient to achieve savings shown in the ΔS path.

4.6 Digital Engineering Project Examples

The rail industries in many countries adopted digital engineering to obtain the accurate facility information from the BIM information, thereby increasing the accuracy of operation and maintenance information, and reducing the cost of design, construction, and maintenance.

Project name and location	MTR Project in Hong Kong
Project scope	Build a high-speed railway network and a railway station using BIM to match the demand of 4 million passengers per week.
DE benefit	Utilising the BIM model: • to check for spatial interference; • review constructability and coordination; • manage construction schedules; • reduce risk.

Project name and location	Central Railway Project in Japan
Project Scope	To rebuild railways destroyed during the great East Japan Earthquake in 2011. USD 112 billion investment.
DE Benefit	Restoration work - The BIM model was used for: • construction staging to accelerate program

	• quantity take off • cost estimation • earthquake recovery planning Asset management and operation; • 3D point clouds were created to develop terrain and architecture models • BIM models linked to the railway GIS network for maintenance and future planning work

Project name and location	Forrestfield Airport Link, Western Australia
Project scope	The project delivers 8km of twin bored tunnel under the Swan River and Perth Airport, tunnel cross passages and egress shafts, two underground stations, and an above ground station, integrated park-and-ride and bus transfer facilities
DE benefit	The scope of work includes the use of BIM and digital engineering to achieve: • engineered solutions to maintenance access, where possible eliminating the need to enter the danger zone; • engineered solutions to creating places of safety including access and egress around critical and non-critical infrastructure; • improved analysis of signal sighting distances; • provide detailed visualisation of the end product for drivers, engineers and maintainers; • delivery of clearly identified asset information; • incorporating PTAs kinematic envelopes into the 3D BIM model for clash detection and design coordination bringing greater efficiencies and reliability to the design effort; • during construction tunnel boring machine data, wriggle survey and Lidar survey results were feed back into the 3D BIM model to ensure an accurate record of the built environment was captured.

Project name and location	East London Line Project - UK
Project scope	Connecting North-South lines to the existing East London Line as part of 2012 Summer Olympics program. Developing BIM models for four stations and six bridges.
DE benefit	25% overall project time savings were achieved due to: • the presence of a collaborative work environment; • structured information communication process; • mitigating misinterpretations due to the use of advanced visualisation.

Project name and location	High Speed 2 Project - UK
Project scope	High speed rail line connecting London and Birmingham expected to be completed in 2026.
DE benefit	By gathering knowledge based on previous rail projects delivered in BIM: • a structured information process has been developed.

	• advanced modelling techniques have been implemented during design to exceed visualisation targets. • a collaborative project environment has been developed by using a common data environment. • initiatives undertaken to educate all stakeholders by utilising the BIM models developed during the process. • sustained stakeholder engagement achieved due to the use of BIM models.

Project name and location	East Perth Station Upgrade, Western Australia
Project scope	Rebuild of existing train station, upgrade to signalling and OLE infrastructure and the installation of turn back facilities.
DE benefit	3D BIM was used extensively by the design and construction teams to: • coordinate multi-disciplinary spatial requirements • ensuring existing above and below ground infrastructure would not impact construction • provide assurance to the alliance team and project management team by using 3D construction sequencing

Project name and location	Doha Metro Rail Project – Qatar
Project scope	Metro Rail developed as part of infrastructure plan for 2022 Doha World Cup.
DE benefit	With the BIM mandate imposed on railroad projects, following benefits have been achieved upon client's requirements: • Informed project and quality planning. • Space programming. • Progress management. • Record tracking and control. • Project Information modelling and management. • Value engineering.

Project name and location	New Generation Rolling Stock Facility, Wulkuraka, Queensland
Project scope	New rail maintenance facility combined with the purchase of 75 new 6 carriage trains.
DE benefit	Utilising the BIM model: • spatial conflicts between elements in an asset are detected in time, in an efficient process, and solved before manifesting during construction or operation. All disciplines engaged on a weekly basis to resolve issues within the BIM space; • advanced coordination and clash detection saving site issues at the design phase considerably and reducing costs significantly; • 4D site sequencing allowed for reduced on-site errors and enabled tracking on project activities; • allows for the opportunity for advanced quantity take off and cost estimation.

4.7 Emerging Technologies

Sensors are a critical technology piece to provide feedback to asset owners on the behaviour of infrastructure railway assets.

After successful implementation of BIM, project and maintenance information will be continuously collected by technologies such as the Internet of Things (IoT). The collected data will be processed to help project participants to make informed decisions using Big Data analysis.

Big Data is a data analysis technology that processes large sets of structured and unstructured data, such as images, online documents, and videos, beyond the capabilities of traditional database management tools. Based on this analysis capability, railway networks can be managed visually in real time through the connections to other information.

Intelligent BIM requires BIM data scientists who can collect, process, and analyse information from design, construction, facility, and asset management activities. Informed decisions will be made based on the analysis results. Additionally, AI will be able to automate the data and exchange processes.

Major technologies involved in this phase are Big Data processing and AI technologies that use data from BIM. AI will be able to automate the data and exchange processes, some design processes, as well as model quality checking. Onsite and offsite construction will be more tightly integrated and automated using IoT technologies.

Standards such as the PAS1192-5 assures the user to utilise/maximise these emerging technologies to their full potential by incorporating cyber-security principles and practices.

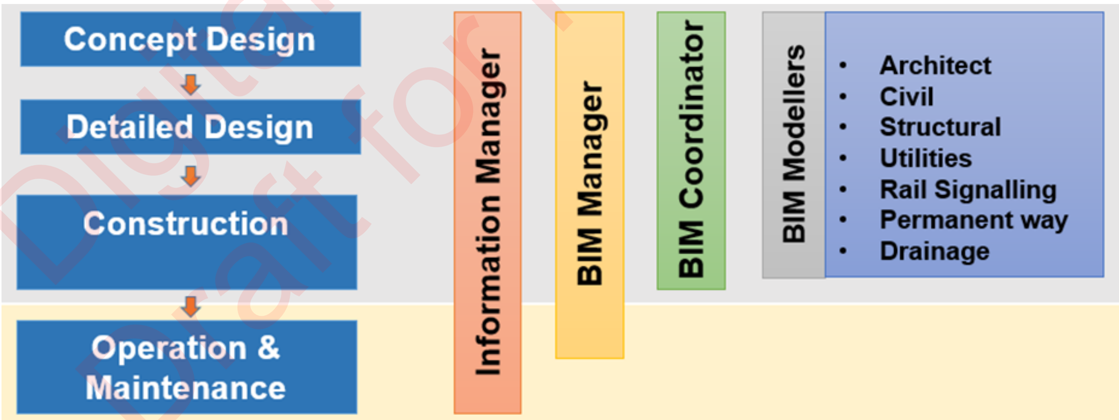
5 Journey to be Digitally Ready

5.1 Organisational Requirements

To lead a successful digital transformation within your organisation, aligning your business strategy with the outputs of digital engineering is imperative. Understanding and acting upon the 8 steps to achieve digital transformation is critical.

1	Establish a sense of urgency	Examining the current Rail Market to understand its position with the digitzation timeline. Identify crisis, potential crisis and future opportunities
2	Forming a Powerful Guiding Coalition	Assembling a team competent to understand and address the issues faced by the Rail industry using DE workflows
3	Creating a vision	Defining clear goals short term and long term to advance the organisation's position within the Rail Sector
4	Communicating a Vision	Ensuring the entire organisation is aligned with the DE Strategy and conveying the information to all clients
5	Empowering Others to Act on the Vision	Removing obstacles to change. Change systems or structures that seriously undermine the vision and encourage risk staking for new outcomes
6	Planning for and Creating Short-Term Wins	Planning for visible performance improvement and creating those improvements for project outcomes in the Rail Sector
7	Consolidating Improvements and Producing Still More Change	Hiring, promoting and developing employees who can implement the vision and reinvigorate the process with new projects
8	Institutilising New Approaches	Articulating the connections between the new behaviours and corporate success and developing the means for DE leadership within the Rail Sector

A requirement for an organisation throughout the project lifecycle are roles and responsibilities for managing, modelling and coordinating information within the digital engineering process. The diagram below illustrates the involvement of these resources through the project lifecycle



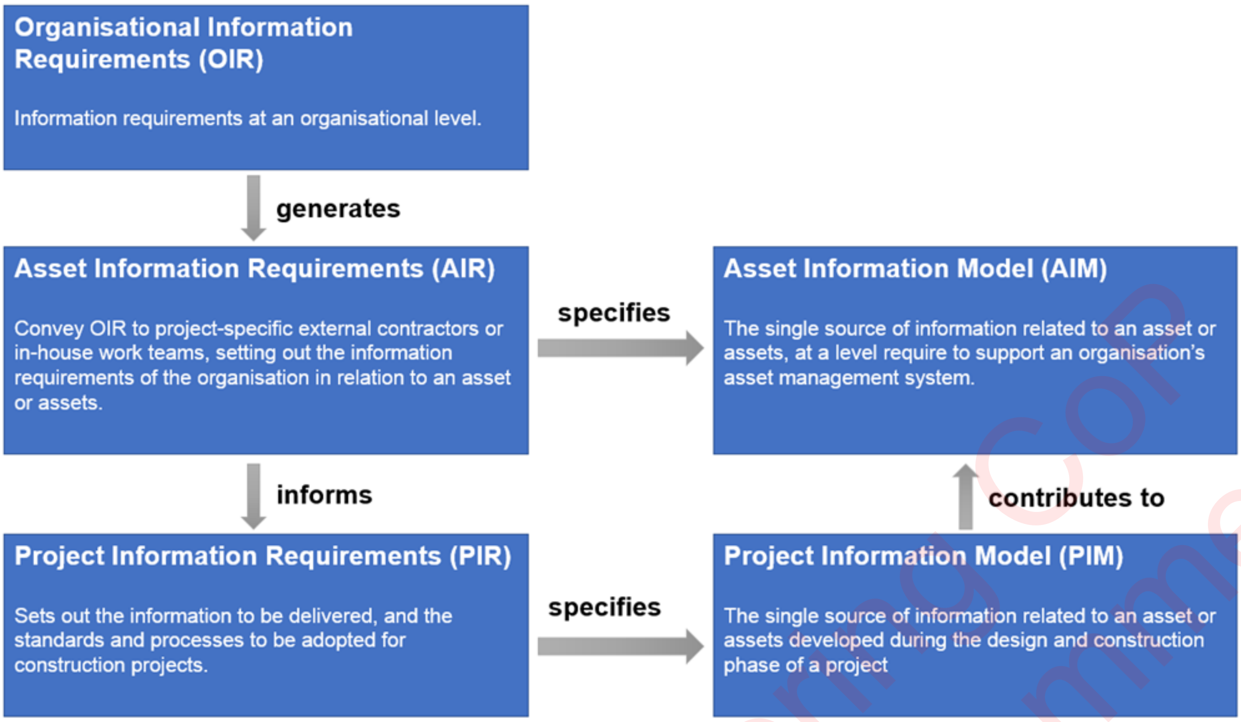
The table below briefly describes roles and responsibilities of the digital engineering resources required:

Role	Responsibility
Information manager	• Communicating project information requirements to all stakeholders • Managing the processes and procedures for information exchange • Validating information at each project milestone
BIM manager	• Responsible for addressing the project information requirements by developing the DEXP • Monitors the BIM process and act as and when it is necessary to ensure delivery is achieved in accordance with the DEXP
BIM coordinator	• Responsible for model delivery, reviewing and coordinating to ensure standards are maintained as per the DEXP • Acting as a first point of contact within the digital engineering delivery team
BIM modeller	• Responsible for model delivery and ensuring models comply to the DEXP • Responsible for populating the information model with graphical and non-graphical data

5.2 Information Modelling Concepts

Information models are a collection of geometric data (including 2D drawings and BIM models), non-geometric data (e.g. spreadsheets and databases) and any other information (e.g. email and documents) required to deliver and manage an asset throughout its lifecycle. The data and information that is to be provided throughout the asset lifecycle information requirements, are determined by the client's objectives at each stage. The data and information is used to assess performance against the client's objectives and to assist in lifecycle decision-making.

As illustrated in the figure below, this is structured around the information principles of PAS 1192-3:2014 Specification for information management for the operational phase of assets using building information modelling. This diagram has been extended by introducing the concept of organisational information model (OIM) and renaming employer information requirements to project information requirements (PIR).

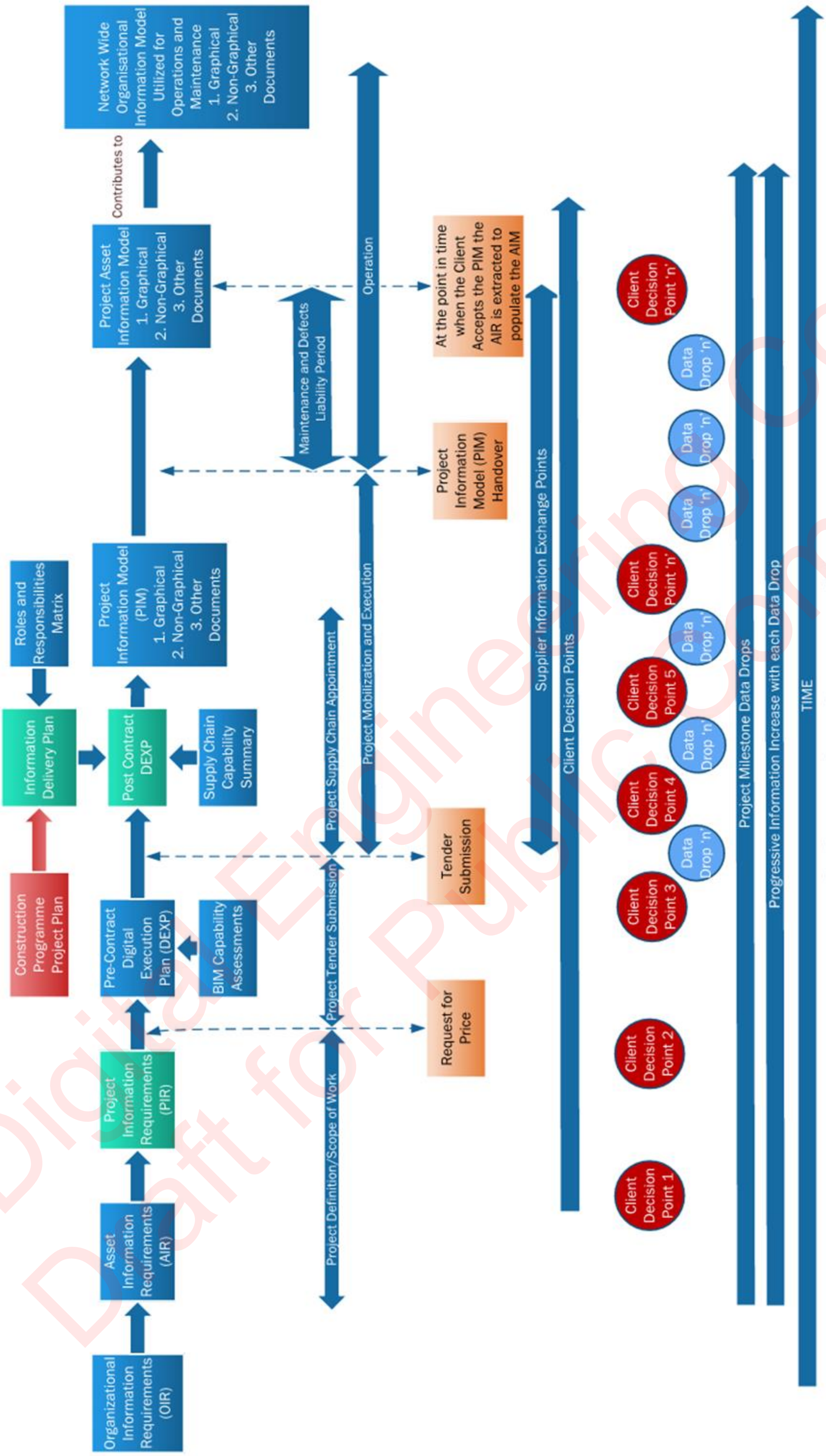


The project information created during the planning and detail design phases form the Project Information Model (PIM) and the information required to be handed over to, or generated during, the operations and maintenance phase forms the Asset Information Model (AIM). In turn, the Asset Information Model contributes to the overall Organisational Information Model (OIM). The OIM enables assessment of performance against the Organisational Information Requirements (OIR).

5.3 Organisational Information Requirements (OIR)

Organisational Information Requirements (OIR) are defined in PAS 1192-3:2014 Specification for information management for the operational phase of assets using building information modelling. OIR describe the information required by an organisation for asset management systems and other organisational functions. That is, they are organisational-level information requirements rather than asset-level or project-level information requirements. Activities that might help define Organisational Information Requirements are described in Annex A of PAS 1192-3. Where a contract is awarded for specific asset management activities, or where instructions are given to an in-house team for asset management activities, task-specific Asset Information Requirements (AIR) should be prepared. These are generated based on the Organisational Information Requirements.

Where there are significant capital works, project-specific Employer's Information Requirements (EIR) will be required, as described in PAS 1192:2 2013 Specification for information management for the capital/delivery phase of construction projects using building information modelling. In this case the Asset Information Requirements will help inform the Employer's Information Requirements and will help define the plain language questions that the employer asks at key employer's decision points to assess whether the project is developing satisfactorily.



Information Process Map

5.4 Asset Information Requirements (AIR)

The AIR are generally specified by the owner's and/or custodian's asset management objectives, which in turn are derived from the OIR, and detail all information and data that is needed to manage the asset effectively. AIR specific to the operations and maintenance (O&M) of the asset and generated as a result of O&M activities, are defined in the O&M contract. The contract specifies the mechanism, format and frequency that the O&M information needs to be provided to support business functions during service and to aid in effective asset management. A subset of information required by the AIR is generated during the delivery of a project. Where relevant, some of the AIR are specified as part of the project PIR, to ensure that the asset data and information required is captured during project delivery.

5.5 Asset Information Model (AIM)

The Asset Information Model (AIM) is the name given to all asset information deliverables produced in response to the AIR. The AIM is generated for use in the O&M phase. Information contributing to the AIM may initially be generated during the project delivery phases and handed over from the project team to the O&M party(ies) as part of a formal acceptance procedure (Initial AIM). This AIM is then built upon by the O&M team as a result of evidence generated during operation and maintenance activities (O&M AIM).

5.6 Project Information Requirements (PIR)

The Project Information Requirements (PIR) define the information that will be required by the employer from both their own internal team and from suppliers for the development of the project and for the operation of the completed built asset. Relevant extracts from the employer's information requirements are included in procurement documents for the appointment of each supplier appointed directly by the employer, which may include; advisors, consultants, contractors and so on.

Prospective suppliers respond to the employer's information requirements with a pre-contract BIM execution plan from which their proposed approach, capability and capacity can be evaluated.

Development of the employer's information requirements is likely to be an iterative process:

Initially, it might take the form of a simple information requirements process map which identifies the key decisions that will need to be made during the project to ensure the solution developed satisfies the business need and defines in very broad terms the information that will be needed to make those decisions.

It develops to identify the required material, functional and performance information about facilities, floors and spaces.

As the design progresses, it identifies more specific requirements about the proposed systems and building components to support procurement.

By the end of the project it defines the need for information to support the maintenance and operation of systems and components that are installed.

The employer's information requirements should clearly articulate the information requirements for each supplier and describe the expected information deliverables in terms of documents, model files and structured information. It should also define how and when information should be exchanged in the project lifecycle.

5.7 Project Information Model (PIM)

The Project Information Model (PIM) contains all documentation, non-geometric (data) and geometric information (engineering drawings and models) used and produced during the planning, design and construction phases of the project. The systems used to structure and store this information are referred to collectively as the Common Data Environment (CDE), refer to Section 6.2 for further discussion regarding the CDE.

The information contained within the PIM includes all deliverables identified in contract documentation including asset owners, Standards and any other information relied on or used by the contractor for the development and delivery of the project.

All project and asset information remains within the PIM until the client's project transitions into the O&M phase at asset handover. On handover of the physical asset and appropriate associated information, the PIM becomes the 'Initial AIM' that is then developed by the operator and maintainer during the O&M phase. Those sections of the PIM that are not required for the O&M phase are archived for future reference (Archived PIM).

Successful handover of information from the project delivery-phase PIM to the AIM, requires that there is an alignment/mapping of asset information metadata in the asset register to project information metadata, particularly delivery work package location and asset location.

6 Digital Engineering Project Requirements

6.1 Collaborative Working Requirements

Effective collaboration by the project teams is essential for realising the benefits of digital engineering, both between client and the contractor, and within the supply chain. The tools, mechanisms and individual responsibilities that will enable collaborative working, including how, where and when project information will be shared, shall be communicated clearly to the project team.

Collaboration between the client and the contractor shall be at regular intervals, appropriate to the project such that project objectives and expectations between the parties remain aligned. Formal collaboration to facilitate design federation, reviews and approvals by the client shall be scheduled at appropriate milestones, to ensure design deliverables are achieved as required by the client and within any constraints of the project including those discovered by the contractor during the design process.

Similarly, the contractor team, including subcontractors are recommended to engage in appropriate collaboration to:

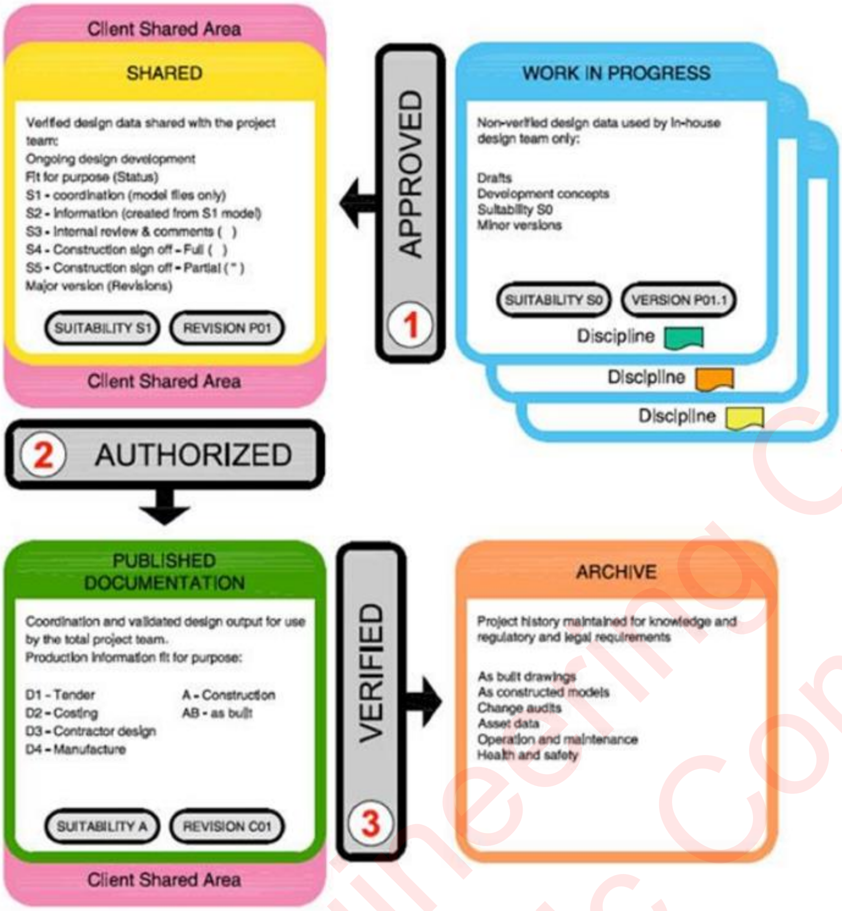
- achieve project objectives;
- early identification of design constraints;
- completion of deliverables as specified by the client;
- sharing of information and ideas;
- identification of conflict and clashes.

The timing, tools and objectives of collaboration are to be defined such that collaboration is undertaken at appropriate intervals to align with the project schedule and delivery milestones and to facilitate the completion of clear objectives/outcomes for each project phase.

6.2 Common Data Environment

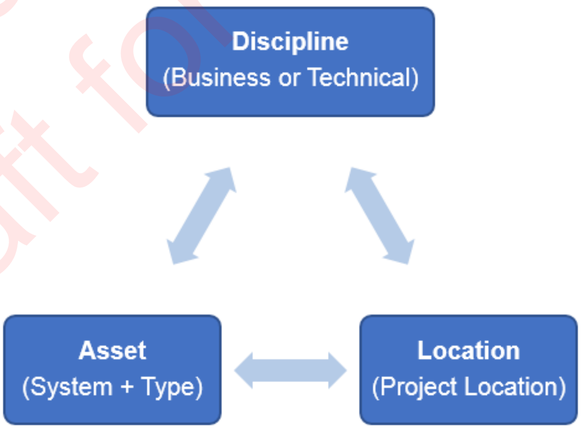
The CDE is the collection of data repositories nominated to hold the current information models. In a project delivery context, the CDE is the single source of information for any given project and is used to collect, manage and disseminate all relevant approved project documents for multi-disciplinary teams in a managed process (PAS 1192-2:2013).

As information is produced, coordinated and validated within the contractor-CDE and submitted to the clients CDE, shall flow through a sequence of defined approval states, based on the principles of BS 1192:2007 and PAS 1192.2:2013, refer below.



6.3 Project Data Classification

For DE projects, data is to be classified and referenced (named) appropriately such that it can be identified, managed, federated, stored, analysed and interpreted correctly, both within a project context, as well as an organisational context. Specific classification and referencing is to be applied to discipline, asset, and project location, with these classification relationships illustrated in figure below.



The different classifications provide analysis of information to the project and the asset owner:

- Discipline: enables assignment of responsibility or grouping for an activity, asset or document by the business/organisational or technical discipline.

- Asset: enables grouping of like assets by type and/or system.
- Project location: enables grouping of activities or assets by location.

This Code of Practice recommends the use of Uniclass 2015 as the adopted classification of assets and locations during the project lifecycle. Refer to https://www.thenbs.com/services/our-tools/introducing-uniclass-2015 for further information related to Uniclass 2015.

Another way of managing data through the operation and maintenance phase is the use of exporting COBie (Construction Operations Building Information Exchange). This is a structured facility information for the commissioning, operation and maintenance of an asset often in a neutral spread sheet format that will be used to supply data to the operator for asset management purposes from the BIM.

6.4 Management Requirements

Management requirements are specified to assist the project team in implementing appropriate control, coordination and governance during the DE process. Management tools include the DEXP, communications and document control. The full suites of project-specific management requirements are included in the Project DEXP.

The primary tool for the management of DE during the project is the DEXP. Specific requirements for inclusion of project information, in relation to DE, and the management of this information are to be defined in the contract documents and reflected in the DEXP. The DEXP is to be actively managed and updated throughout the course of the project to ensure that it is appropriate to the project scope, DE strategy, contract structure and available resources (tools/IT systems and personnel).

6.5 Technical Requirements

Provided in the following sections are the required deliverables aligned with the DE disciplines:

Survey

Digital survey techniques are increasingly used to support projects and are particularly important as part of digital engineering. Digital surveys are complementary to traditional surveying techniques and are used to establish an accurate representation of an asset and its environment. The results from surveys provide an accurate representation of existing conditions to inform project development and are also used to verify installed assets and asset elements throughout the life of the project. These verification surveys are typically done using 3D laser scan surveys and photography. The specification for these digital surveys shall be sufficient to meet the level of accuracy requirements of the relevant planning or design stages (concept, detailed etc.), and ultimately as-built records for transport infrastructure. The level of detail and structure of the information provided should also allow flexibility for more detailed modelling at a later stage and be in alignment with the requirements for the level of detail for design.

GIS

The use of GIS as an information viewing platform is justified due to the rail infrastructure existing in linear narrow project boundaries. With the compatibility offered through the recent developments made to BIM models, the link between BIM and GIS is expected to strengthen in the future.

The presentation of GIS as web portals creates a consumable platform which mitigates the need for the expenditure on specialist software by all project stakeholders. These web-portals enable easy access to the operation and maintenance team to make informed decisions based on real-time data.

The architecture behind the GIS platform enables the integration of LiDAR and laser scans to update the information model.

CAD

2D CAD drawings will remain as one of the primary deliverables of exchanging design drawn information for projects to submit at each deliverable as required by the asset owner.

The CAD standards to be adopted shall be in accordance with the asset owner/clients CAD requirements and be in accordance with the project Digital Engineering Execution Plan (DEXP).

To maintain the integrity of the information, as a minimum, the following process shall be implemented when producing 2D CAD deliverables:

For the purposes of consistency, all 2D and 3D CAD data information shall be populated from the BIM models

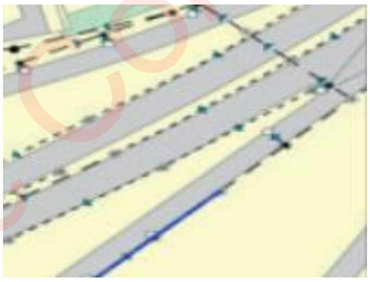
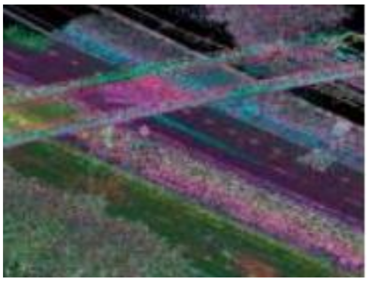
Drawings shall have reference files (Xref) package (Etransmit for AutoCAD, merged for Microstation) to form a single file per drawing.

As the industry matures, the 3D model (3D BIM) will be the required deliverable to the asset owner and used for future design and maintenance changes.

BIM

The contractor is responsible for managing the overall cross discipline BIM collaboration process. To achieve this, each design discipline is tasked to produce a level of digital data sufficient to allow an appropriate level of coordination to take place. The coordination process will be developed along the following principles:

- Use of common setting out data across all disciplines, for example the use of a master control project set out file.
- Direct referencing of design and model data from other disciplines during the creation of BIM file/s to eliminate significant clashes at source.
- BIM objects are to be classified
- BIM file/s in native format will be ‘shared’ on a frequent basis via the contractor-CDE for use within work in progress (WIP) model development.
- Industry Foundation Class (IFC) design BIM file/s will be ‘shared’ on a milestone basis (or more frequently if required by the project) via the contractor-CDE for use within the team, for verification and inclusion in the federated BIM model.
- BIM file/s in both native format and for use by a collaborative software application (e.g. Autodesk Navisworks, Bentley Navigator etc.) format are to be provided as specified in the Project DEXP
- 2D documentation sets are to be published as specified by the Project DEXP
- Use of the federated BIM model as the main focus for resolution and progress of design using a virtual design/construction review process
- Regular model coordination sessions are to be implemented appropriate to the project scope, as specified in the Project DEXP.

LOD		
100	Elements are not geometric presentations. They may be symbols or other generic representations of information that can be derived from other model elements. Any information derived from LOD 100 elements shall be considered	
200	Elements are represented graphically but are generic placeholders, e.g., volume, quantity, location, or orientation. Any information derived from LOD 200 elements shall be considered approximate	
300	Elements are graphically represented as specific systems, objects, or assemblies from which quantity, shape, size, location, and orientation can be measured directly, without having to refer to non-modelled information such as notes or dimension call-outs.	
400	Elements are modelled at sufficient detail and accuracy for fabrication of the represented component.	
500	The model element is a field verified representation in terms of size, shape, location, quantity, and orientation. Non-geometric information may also be attached to the model elements.	

Scheduling (4D)

Scheduling (4D) provides projects with the ability to better plan and execute construction activities through effectively prototyping assets in a virtual environment prior to actual construction. This is achieved through associating scheduling data to different components as the BIM models that are created. Adding scheduling data enables 3D visuals of a project's development to be created, showing how it will be constructed and how both the structures and surrounding site will appear at each phase. This is beneficial in terms of planning work in a safe and logical way that maximises efficiency on site. Project teams can effectively prototype assets in a virtual environment first and provide rapid feedback on design or methodology changes.

Cost (5D)

5D BIM is procures cost information by interconnecting the design information with construction and program schedules. The structured process generates information which assists the realisation of project financials. The information generated enables stakeholders to understand the Δ W's as described in Section 4.5, occurring during the project and to shift the curve to achieve savings as the project progresses.

Asset Data (6D)

The 6D asset data deliverables are focused around the structured asset data that is created or captured during a project and contributes to the Handover Asset Register. This information may be captured within the BIM model or in the Handover Asset Register itself. A unique project asset ID is to be used to link the information contained in the Handover Asset Register with the information for the same asset in the BIM model or other data sources.

6.6 Quality Assurance

Without limiting the quality assurance and quality control measures required elsewhere in the particular project Contract documentation, the asset owner requires contractors to establish, implement and maintain quality assurance and quality control processes, procedures and protocols for digital engineering.

The asset owner requires contractors to include, as part of their audit management program, compliance checks with digital engineering requirements included in the contract. As per the audit requirements contractors are to report on the results of internal digital engineering audits and resolve any issues or process improvements.

6.7 Project Team

All personnel in organisations delivering and managing assets for the asset owner play an important role in the production of reliable, consistent information. All project personnel shall adopt the behaviours listed in the table below to help develop an appropriate working culture to facilitate successful DE.

Project Behaviour	Description
Share, collaborate, deliver	All personnel have a responsibility to share information, and where required, coordinate and collaborate to deliver to asset owners required digital engineering outcomes.
Use common language	Use a common language so people can effectively exchange information.
Auditable assurance pathway	Resolve issues collaboratively, manage risks and track decisions to provide a traceable and auditable pathway through design development up until asset disposal.
Digital tools to support decision making	Implement effective tools and provide training so personnel are empowered to make decisions using the best available information.
A platform to support innovation	Use digital engineering tools and processes to drive innovation in the way projects are delivered.

Roles, responsibilities and levels of authority for the management, control and execution of DE activities and deliverables shall be assigned to identified personnel within the project team, on both the asset owners and the contractor sides, as agreed by the asset owners DE manager and the contractor.

The contractor will confirm the party(ies) and named person(s) who will be responsible for information modelling and DE management for the project in the DEXP, describing what activities will be performed and what authorities will be held by each individual. This includes overall responsibility and scope of appointments for both the asset owner and contractor personnel, as appropriate to the project structure.

Allocations can change depending on project scope and complexity, and all engaged personnel shall be able to demonstrate the required and appropriate experience, training and competencies.

7 Abbreviations

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
AIM	Asset information model; relating to the operational phase
AIR	Asset information requirements, relating to the operation of an asset
AM	Asset management
IFC	Industry foundation classes
BIM	Building information modelling
BEP	BIM execution plan
CAD	Computer aided design
CDE	Common data environment
COBie	Construction Operations Building Information Exchange
DEXP	Digital Engineering Execution Plan
EDMS	Electronic data management systems
FM	Facilities management
GIS	Geographic information system
LOD	Line of development
OIR	Organisational information requirements
PIM	Project information model
PIR	Project information requirements

8 References

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- Rail BIM 2030 Roadmap by Professor Ghang Lee
- BIM According to Arcadis – 0006-EUBIM-MGT-05-ARCADIS BIM White Paper
- PAS 1192-2:2013 Specification for information management for the capital/delivery phase of construction projects using building information modelling
- PAS 1192-3:2014 Specification for information management for the operational phase of assets using building information modelling
- https://www.designingbuildings.co.uk

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