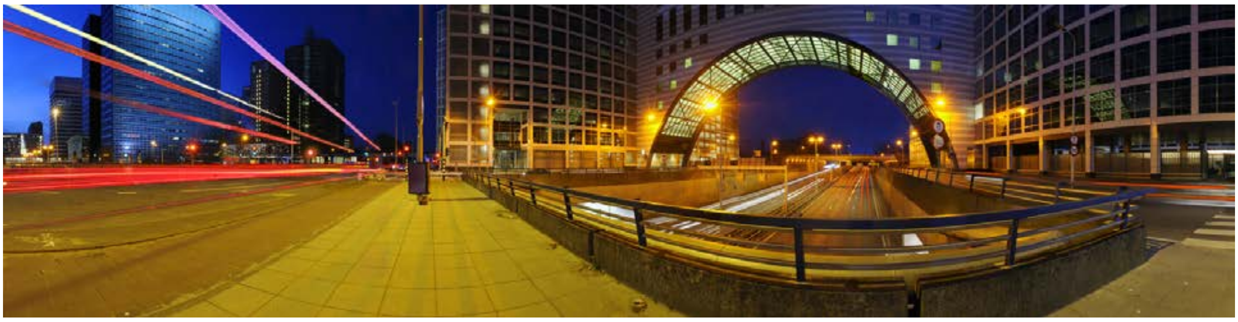
buildingSMART International
Infrastructure Asset Managers BIM Requirements Technical Report



Infrastructure Asset Managers BIM Requirements

Technical Report No. TR 1010

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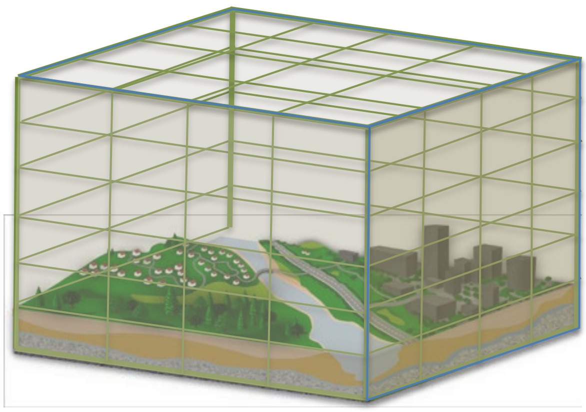
Delivering the information 'Asset Managers' need and can trust using openBIM™



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1 Executive Summary

This report is the result of a review commissioned by the buildingSMART International InfraRoom to understand and outline the specific requirements of infrastructure asset managers from Building Information Modelling (BIM) as distinct from those of designers and constructors. It reports on a number of interviews with asset owners and private conversations across the infrastructure field including roads, railways, airports, water and environment.

It reports its findings as a set of information requirement principles that span across the lifecycle of infrastructure assets plus a set of recommendations on the process of collection and content required. It does not look at detailed asset by asset attribute requirements but rather attempts to set the principles for types and content of information captured and how these are collected and managed stage by stage. It sets these findings in the context of an 'Open' approach to information in particular how the standards of buildingSMART can be used and adapted to create value and quality in the data lifecycle.

Not surprisingly it finds that most current asset management practice relies retrospective asset information collected and interpreted after design and construction and from a large existing asset base. It highlights that as BIM has matured it now offers significant savings in cost, effort and improved content quality and relevance if information can be acquired as an integration of BIM and Asset Information Management disciplines.

A significant trend amongst asset owners is to apply an overall framework to the discipline of asset management which recognises that the delivery service and minimisation of risk is critical. Replacing the maintenance and repair of individual assets towards a more holistic organisational value approach incorporating total asset expenditure rather than isolated operational and capital expenditure. In doing so it applies the discipline of asset management from the early planning of a new or upgraded asset through its design and construction rather than after construction. In other words, an asset starts life at its planning stage not when it completed.

It reports on how organisations are adopting those principles and their maturity in doing so.

Finally it sets out a roadmap of potential research, development and application could support the implementation of the findings.

2 Introduction

2.1 Background

This report was commissioned by buildingSMART International (bSI) InfraRoom and is designed to assess and define the information needs of infrastructure asset managers in receiving and keeping pertinent and accurate information regarding the assets as they are planned, delivered, operated and maintained.

The infrastructure construction industry is slowly evolving from recording information using documents and drawings, which are paper-based, to adoption of computer technologies and a shift from electronic documents and drawings (file-based) through to digital data. Increasingly technologies such as Building Information Modelling (BIM) are used to deliver structured and unstructured data and information collected over the entire life of assets, including geospatial, survey, condition monitoring, operational, maintenance, condition, performance and utilization of assets. BIM is therefore triggering a digital transformation of the infrastructure sector, with development and management of the virtual world becoming as important as the physical. This embraces not only the built but also the natural world, including our interaction with the overall physical environment which we inhabit, and which the construction industry works to support.

In this context, the manager of assets has a vital interest in receiving complete, accurate, validated and verified information and in maintaining that information during an asset operational lifespan. This makes the Asset Manager a key stakeholder for digital information providing a clear requirement driver for information standards. The demand for this Asset Manager Information is now being recognized as a key deliverable from projects and hence an important factor in delivery using BIM both for new assets and existing ones that are being updated and maintained. However, standards for delivery of that information are often overlooked in the development of openBIM and other standards. Many of those standards have been heavily biased towards the design stage of the life cycle and concentrated on the geometric representation of BIM components.

This report aims to bring the requirements from asset managers into view to inform the commissioning and development of future bSI Infra standards including IFC, Data Dictionaries and Object Libraries. This is done by analyzing the requirements and reporting them systematically against existing and projected standards to provide a recommended roadmap for future standards development including potential benefits and business case.

The report goals can be summarized as: -

- Discovering, clarifying and making explicit the requirements for delivery of asset information from the perspective of organisation and their asset managers.
- Understanding the asset managers' requirements for BIM information in the strategic and operational management of assets.
- Translating the requirements into openBIM Standards requirements.
- Providing a Roadmap of steps responding to the requirements.
- Disseminating the results both to buildingSMART and to international publications and conferences.

2.2 Scope

For the purposes of this report 'Infrastructure' refers to the fundamental facilities and systems serving a country/state, region, city or area, including the services and facilities necessary for its economy to function. It covers, amongst others, civil engineering, environmental engineering, road, rail, metro, waterways, airports, ports, bridges, tunnels, campuses, water supply, sewers, electrical grids, telecommunications, landscaping, flood protection, and coastal protection.

3 Definitions

3.1 Defining openBIM in Infrastructure Asset Management Context

BIM (Building Information Modelling) - a BIM Model can be defined as a digital representation of physical characteristics and functional characteristics of a facility or asset. The term ‘Building’ here refers to the act of building and the built environment result and not just a building. A model, although often perceived as a 3D representation of an asset, in the context of this project is a data model including a full range of attributes about an object (perhaps better referred to as a ‘thing’) which may include geometric information but also include many other attributes including function, performance, condition, and other parameters. The critical term in BIM is therefore ‘Information’ and how it is modelled and managed which applies across the many domains that are included in infrastructure. In asset management geometry and location is relevant but, the broader information attributes assume an increased criticality and importance.

There are many software tools that create and edit 3D object models of the built environment and many others that view, analyse, update and report on the ‘things’ that are being modelled. Most of these have proprietary formats which work well within the limited domain of the software. However, most technical and managerial domains wish to communicate and exchange and information between themselves and others to deliver the full benefit of BIM.

For the purposes of this report the term BIM is inclusive of all information about assets which includes those usually attributed to Geographic Information Systems (GIS) which after all is just information about things within a geographic spatial location or boundary.

In order to facilitate that exchange and create a common base buildingSMART has developed IFCs (International Foundation Classes http://buildingsmart.org/ifc/) for data sharing amongst the many software and domains involved in the built environment. Those IFCs have been developed and matured over a number of years. More recently the specific requirements of infrastructure asset have been recognised and IFCs are being developed for roads, rail, bridges with others to follow.

Supporting the IFCs buildingSMART have introduced other standards Information Delivery Manuals (IDM) that which describe information requirements for a specific function, Model View Definitions (MVDs) which provide detailed IFC subsets for particular domain information exchange tasks and a data dictionary (bSDD) that describes objects in common terms and vocabularies.

3.2 Defining Assets

The term asset is used across many ownership fields from financial resources to personal items. In the context of this report an infrastructure asset is an identifiable object in the natural and built environment that has value to an owning or stakeholder organisation.

3.2.1 Some Basic Definitions

Subject	Definition	Notes
Asset Definition	An asset is an identifiable object that can be real/physical or virtual that has value to the owning or managing organisation.	It follows that an asset can be a representation of a physical managed thing but also can include data and information, a set of functional requirements, a service level need.
Asset Management	The systematic process of deploying, operating, maintaining, upgrading and disposing of assets efficiently and effectively.	Encompasses but goes beyond managing individual or collections of assets.
Asset Management Framework	A framework that provides a basis for the whole asset management needs, setting out the principles for governing asset management in an organisation.	In respect of this report the frameworks set out in the ISO 55000 series of standards together with the Institute of Asset Management (IAM) Anatomy
Asset Life Cycle Information	Information following the life cycle of an asset from strategic assessment through concept design, detail design, and delivery to operation and maintenance.	Whilst, to date, BIM has provided detail mostly in the design stage of an asset the owner and manager of an asset requires information that meets their needs throughout the life cycle from concept to replacement and demolition.
Organisational Asset Information	Information that supports the management of the organisation including its whole asset portfolio	Supports Organisational Objectives & supports portfolio return on investment, compliance and sustainability
Operational Asset Information	Information that supports the operation and maintenance of the asset	Typical FM and AM function that looks at maintaining the asset in good serviceable repair.
Service Level Asset Information	Information that defines and supports the required service to be provided by the asset	Understands relationship between assets and the service capacity and performance

Capital Project Asset Delivery Information	Information that supports the delivery of the asset during construction, modification or repair	BIM to date has been restricted to this area of 3D modelling collaboration, construction and procurement sequencing and costs of delivery. Further requirements in life cycle BIM add functional requirements and technical requirements.

3.2.2 Infrastructure Assets Features

Infrastructure assets typically have features that set them apart from those in other industries:

- The asset is the core of the business rather than just providing a space or platform for a business.
- The majority are effectively ‘prototypes’ when constructed in that they are one-offs, even if some of their components are mass produced (e.g. precast concrete elements in modular construction)
- Most infrastructure assets are designed for a relatively long life. Indeed, few are decommissioned at the end of a predetermined lifetime. They may be replaced for reasons of safety, capacity, or function, but typically not on a widespread basis.
- Many of the assets are publicly owned and have critical external dependencies, driven by economic function of a city, state or country. For instance, flooding may be the result of a failure in environment assets that will impact many other infrastructure facilities.
- Assets are not only the result of multidisciplinary collaboration but are themselves part of larger systems and programmes. Hence they include sub-assets such as electro-mechanical and information technology systems. A bridge for example, is of little practical use without the rest of the transport network of which it forms an integral part. Most equipment sub-assets will have several and different replacement cycles within the lifecycle of the overall asset.
- Experts from many different disciplines are therefore required for the effective management of such assets as well as crosscutting expertise in generic skills and processes such as system thinking, finance, procurement, operational risk, materials science, organisational performance, and change management.
- An infrastructure asset failure can have catastrophic consequences on the surrounding environment and the wider asset base for instance an embankment slip closing a road or a flood overwhelming a bund and causing damage to the adjacent property.
- Failure of infrastructure assets such as earthworks, pavement, foundations, planting, and drainage or long-life assets such as bearings

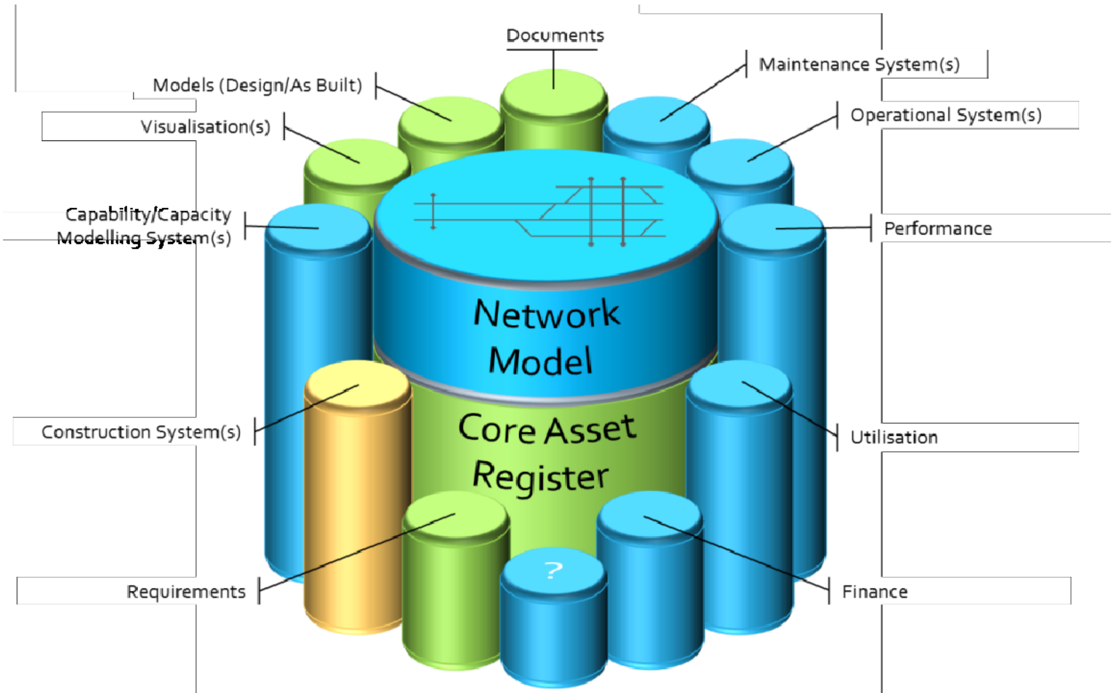
and culverts are not always solved by going to a spares cabinet and selecting a replacement with a known installation process.

- Assets procurement in most infrastructure client organisations is continuous, adding to an existing portfolio with many cross dependencies.
- During its lifecycle, an asset may be reassigned to a purpose that is very different from its original design.

3.4 Defining Asset Information

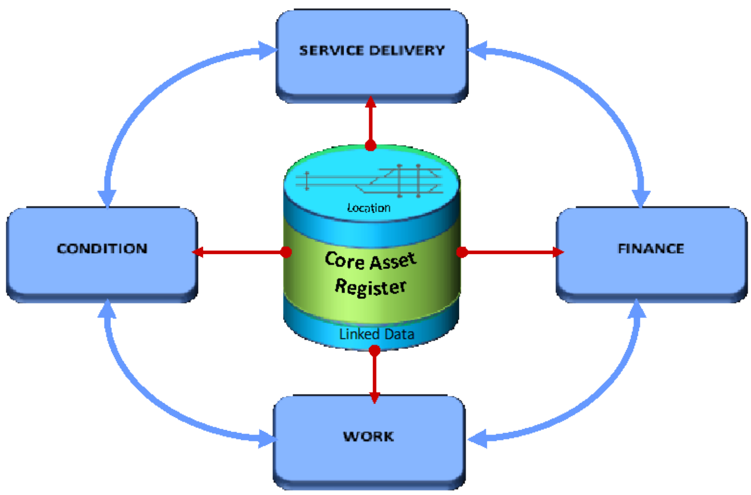
The term asset information is a generic term covering a range of information and data types. These data may or may not sit in a core asset register, but are associated or linked with an asset.

This is illustrated diagrammatically in the following illustration for a railway asset:



With acknowledgement to Douglas Young Asset Manager for the UK High Speed 2 Project

Asset Information is at the heart of Asset Management providing the information and context to support the management functions of delivering an effective service, recording and maintaining asset condition, carrying out work on assets, and effectively managing the finance required.



With acknowledgement to Douglas Young, Asset Information Manager, UK High Speed 2 Project.

It is within this context that we have to examine the information requirements for Asset Managers and how BIM can support and facilitate its capture and delivery.

4 Research Approach and Methods

To gain an insight into current and emerging practice the following approaches were used in carrying out the study: -

- Literature review – a review existing and emerging standards and practice guides for asset management.
- Carry out structured interviews with selected asset owner organisations.
- Interview and discussions with institutional bodies involved in asset management.
- Discussions with other asset manager related projects notably CEDR Interlink Project.
- Analyse results of interviews and summarise current practice and emerging trends.

4.1 Literature Review

A review of existing standards and codes of practice was undertaken to provide a framework for the project.

The table below sets out the most significant of these.

Many further documents and local standards emerged during the project, however, most organisations were at least aware of these standards and practices and most were found to be incorporating them into their strategies for asset management. Hence they are used as the basis for developing a framework for this report.

Publication	Publisher	Notes
PAS 55:2008 Asset Management Parts 1 & 2	BSI Standards	An early publicly available specification setting out the basics of asset management. Having gained international recognition, it has now been developed into the ISO 55000 series of standards.
ISO 55000:2014 Asset management - Overview, principles and terminology	ISO International Organization for Standards	Provides an overview of asset management, its principles and terminology and expected benefits from adopting asset management.
ISO 55001:2014 Asset management - Management systems - Requirements	ISO International Organization for Standards	Specifies requirements for an asset management system within the context of an organisation.
ISO 55002:2014 Asset management - Management systems - Guidelines for application of ISO 55001	ISO International Organization for Standards	Provides guidance for the application of an asset management system in accordance with the requirements of ISO 55001
Asset Management - an anatomy V3 2015	The Institute of Asset Management	The Anatomy provides an entry point for people seeking to understand asset management. It has wide international acceptance and provides a good foundation for the principles of asset management and its practice.

4.2 Discovery Session Interviews

Interviews were carried out over a protracted period, starting in May 2016 and finishing in December 2016. This period was influenced by the availability of interviewees and ensuring that the range of interviews covered as much as possible of the scope of infrastructure.

The interviewees were selected to cover the range of infrastructure projects and included water utilities, airports, defence establishments, road authorities, rail authorities and environment agencies. Those were chosen to encompass a significant part of the infrastructure spectrum including networks, earthworks, structures, bridges, tunnels, drainage, environmental features, pavement, road, rail, water supply and treatment and utilities.

As far as possible interviews were carried out face to face and local to the interviewees organisation. Those interviews were held as discovery discussions following a previously distributed briefing document (attached as Appendix A of this report) Whilst the discovery sessions had some structure inevitably the conversations covered a wide range of subjects, depending on the maturity and interests of the interviewees. Hence the results picked up trends in thinking as much as current practice detail. Most organisations were looking to a future that incorporated the life cycle of asset information.

Interviews with organisations that were more difficult to reach physically were carried out by telephone conference call. Inevitably these did not cover the depth of the face to face discovery sessions but gathered the direction and intention of travel for those organisations.

In all cases the interviews were welcomed by the participants and the subject recognised as being important to the development of their ongoing asset management strategies.

4.2.1 Interview Summaries

The table below identifies each of the discovery session organisation together with a summary of their current tasks and notes on application. A more detailed summary of each discussion is attached as Appendix B to this report.

Organization	Responsibilities	Notes
Anglian Water (UK)	Provision of water supply, water recycling and waste water for a UK region serving six million domestic and business customers in the east of England. Managing existing assets provision of new assets	Manage and procure a wide variation of assets from treatment plants, distribution networks to drainage systems and reservoirs. Asset Management where appropriate use ISO55001 and PAS55 to outline asset management best practice, detailing a standard against which they can measure their asset management function whilst challenging and continually improving what they do.
AustRoads (Australia) **http://www.austroads.com.au**	Austroads is the peak organisation of Australasian road transport and traffic agencies. Austroads members are collectively responsible for the management of over 900,000 kilometres of roads valued at more than $200 billion representing the single largest community asset in Australia and New Zealand. Austroads' purpose is to support its member organisations to deliver an improved Australasian road transport network. One that meets the future needs of the community, industry and economy. A road network that is safer for all users and provides vital and reliable connections to place and people. A network that uses resources wisely and is mindful of its impact on the environment.	Develops & sets policies and procedures but does not manage assets themselves. Has produced a number of forward thinking documents on asset life cycle.
Australian Government Department of Defence	Operational assets including buildings and infrastructure. Own 360 life cycle of assets	Manage wide variety of assets from buildings to airports and campuses and their supporting infrastructure.
Brisbane Airport (Australia)	Asset and FM management of airport estate. Provision of new assets	Assets cover buildings, real estate, runways, taxiways, roads airside and landside, lighting, signage and much more - akin to a city environment than just airport buildings and their Facility Management.

Organization	Responsibilities	Notes
Crossrail (UK)	Delivery of new rail across London including all assets for future management	Creating a new asset that will be handed to operator. Has a service based philosophy for delivery. Assets include rail, road, tunnels, bridges station buildings and mechanical & electrical services. Using BIM as a delivery mechanism following BS 1192 process. Has created its own asset management system to collect asset information based on a series of Asset Data Dictionary Definitions. Incorporates both physical asset definition plus the required function of the assets through the project delivery.
Danish Roads Authority (Trafikstyrelsen) specifically Danish Roads Directorate section of the Transport Authority	Managing lifecycle of Danish Highways Assets - The Danish Road Directorate are responsible for the national road network, which comprises motorways, a number of main roads and many of the country's bridges – a total of about 4,000 kilometres. To ensure a cohesive and well-designed infrastructure, the Danish Road Directorate cooperates with a large number of authorities, and in particular with the rest of the Danish road sector, as well as local authorities. Works in three main areas: Planning and design, Road and bridge construction, Operation and maintenance.	Developing strategies for BIM delivery direct from contracts. Although recognising ISO 55000 and adopting some of its principles maturity is not significant. Planning stage new asset management systems and collaborating with other Scandinavian authorities in doing so.

Organization	Responsibilities	Notes
Environment Agency (UK)	Managing both public and private assets impacting the environment, flood prevention, pollution, & waterways.	Manages a wide range of assets from earthworks, waterways, drainage, systems, flood prevention systems, and mechanical systems. Deals with not only their own assets but assets owned by others. Provides us with a wider understanding of infrastructure that stretches beyond the component led assets found in buildings. Failure of assets can lead to catastrophic consequences. Leads the UK in delivering Level 2 BIM for Infrastructure. Is building an asset library for BIM delivery to match their asset management systems.
Ferrovial (International)	International Corporate involved in design construction, facility and asset management. Owner and manager of Heathrow Airport	Included as they not only manage Heathrow Airport but are involved in a number of Design Build and Operate Road Projects plus they have a dedicated FM division. Have conducted research in direct BIM to asset handover.
Finnish Transport Agency (Liikennevirasto)	Managing lifecycle of Finnish Highways Assets. The Finnish Transport Agency enables smooth, efficient and safe travel and transport. They are responsible for Finland's roads, railways and waterways and for the development of Finland's transport system.	Have developed OpenInfra Standards for project information collection particularly Spatial and 3D model based. Incorporating collaboration process with contractor auditing. Have concentrated on models less on information. Asset management based on broad range of systems.

Organization	Responsibilities	Notes
New Zealand Roads Department	Service Delivery for NZ Highways	Views Asset management as service driven. Adopting ISO 55000 strategies and policies. Treats data as an asset. Moving towards electronic handover but at present this is a manual bulk upload process. Committed to Open Data.
Rijkswaterstaat (RWS) (Netherlands) National Road Authority	Managing lifecycle of Netherlands including the main highways network, the main waterways network and water systems.	Heavily committed to openBIM Standards. Have developed a Object Type Library based on National Object Type Library (OTL). Handover of information is carried out throughout the life cycle of project delivery and operational management based on this OTL they have a container mandated information handover - COINS. Founded on Linked Data principles.
Trafikverket Swedish Nation Road and Rail Authority _ Specifically the Road Authority for Interview.	Responsible for long term infrastructure planning for transport road, rail, shipping and aviation. The department interviewed had specific responsibilities for Road Transportation.	Committed to openBIM delivery standards and developing those for infrastructure. Developing new asset management systems alongside national classification standards. Life cycle driven with plans in place to carry out direct information transfer through the process. Working with other transport authorities to sponsor and develop openBIM standards.
Transport for New South Wales (Australia	Rail and Road transport asset life cycle in NSW	Responsible for setting policies and developing service led systems approach across a cluster of transport related assets including roads, trains etc. A number of assets management approaches are currently being used across the cluster. Have future asset management strategy that brings standards together across their responsibilities. Developing processes and standards for a lifecycle information approach

4.3 Supplementary Interviews

These discovery sessions were supplemented by further conversations with individuals and organisations that have an interest in or influence within the asset management community. In particular, those who have been involved in developing international asset management standards. These are listed in summary in the table below: -

Organization	Responsibilities	Notes
Institute of Asset Management (IAM)	The IAM is the professional body for those involved in acquisition, operation and care of physical assets – especially critical infrastructure. The Institute is for professionals worldwide who are dedicated to furthering their knowledge and understanding of Asset Management.	Members of the IAM were interviewed. Julian Schwarzenbach of DP Advantage (also involved in Crossrail Asset Strategy development) and Nevill Shetty of Atkins who is lead consultant and involved in UK HS2 project
Institution of Civil Engineers Information Systems Panel	The Information Systems panel is an expert panel of the ICE works alongside academia and special interest groups to foster and influence best practice in using information systems. They are currently producing Asset Management Lifecycle Guidance notes	Several private discussions with members and experts on the development of asset management practice.

4.4 Private Conversations

A number of private conversations held with colleagues and referred professionals. Most notably Douglas Young, who is working with the UK High Speed 2 project on asset information.

4.5 Collaboration with CEDR Interlink Project

Finally, the project collaborated with a parallel project known as Interlink being undertaken by CEDR (Conference of European Directors of Roads) involving a consortium of European National Roads Authorities (NRAs). Interlink has the specific aim of launching a new pan European project to provide NRAs and their supply chain with information management standards using Linked Data as a European Road Object Type Library (OTL). Whilst this project only examines Road Assets many of these assets are very like assets encountered in the wider infrastructure context. Hence the conclusions of that project are pertinent to these wider infrastructure asset manager's requirements and can add valuable contextual and practical guidance. In particular the introduction of the concept of Linked Data and Object Type Libraries.

4.6 Summary of Interviews & Current Practices

As might be expected the interviews discovered a wide range of maturities in the use of BIM and Asset Management practices. Whilst each interview started out with a semi-structured form of questions most ended up as discussions of current practice and intended strategic direction. All the interviews proved to be too short in time to cover such a complex subject despite most taking place over a day or even longer.

All interviews provoked wide ranging discussions on what might be described as digital life cycle engineering and the opportunities this will facilitate across the industry: the potential of a more holistic view of information and the entry of new tools and analytical methods including the Internet of Things (IoT) and Big Data Analytics.

Despite the interview series including a wide range of domains of interests within infrastructure the foreseeable needs of each domain in asset management have much in common.

There is considerable interest in what design and construction use of BIM can offer asset managers in terms of quality information at the start of operation of assets. However, a there is a wide difference in understanding of what BIM represents and can offer. These range from BIM being thought of as just 3D design models that improve the asset procurement process to it supporting a complete set of handover information about assets that have been procured and offering information to plan and brief new projects.

Itemising specific answers is quite difficult to achieve as are providing a statistical analysis of findings. All interviewees recognised the need for a more life cycle view of information and for the need to pass information through that life cycle to inform the asset management process. In most cases capital expenditure on new assets and operational asset management was handled under different budgets and by different management teams.

The following tables set out a summary of findings: -

Topic	Summary
Organizations responsibilities	Most organizations interviewed were owner operators and held responsibilities for planning and delivering new assets and operating existing assets effectively to meet the organizations operational needs. In a couple of cases, the interviewed organization were responsible for developing new assets ready for handover for operational use, and therefore required to consider long term asset management aspirations.
Definition of an asset	Across all organizations there is reasonable agreement that an asset is an identifiable object that has value to the owning organization. An asset is not necessarily coincident with a design or construction component, but can be represented by a part of or a collection or a derivative of such components. There is growing recognition that such assets can be physical or virtual and that information in and of itself should be treated as an asset.
Asset management framework	Most organizations recognize the contribution of ISO 55000 Asset management standards and are either building their strategy around those or are moving towards a framework that follows similar principles step by step.
Capital/Operation Organization	Most organizations have a strict divide of management and budgets between new capital projects and operational management. Accounting practice does not encourage a total life cycle view across an organization. Hence, inefficiencies are built in to the practice. Current assets and assets built prior to current systems are not all recorded in a consistent form (if at all). In general, therefore information and management of that information is siloed by budget. Developing life cycle information requirements and joining the life cycle up is proving a challenge. Consequently, defining what information might be delivered by a BIM process is only more recently being realized. In some organizations, the value of a more holistic approach is being recognized and proof of that value is emerging.
Operational management process	Operational management processes vary across the industry and across different types of asset. At the very least the process carries out maintenance as a replace on failure, but may range through predictive and routine intervention. Organisations in the vanguard have adopted a process based on service level and managing risk. In most cases, the owning organization contract out operational management to third party contractors, relying on these to carry out day to day operational management and to collect and manage information regarding those assets. Information collected during operational management often remains with the third-party contractors. However, most organizations are now realizing the value that information holds for them as asset owners and are specifying a requirement for delivering asset information during operational contracts.

Topic	Summary
Current Asset Management Systems	Most organizations have a complex landscape of siloes and bespoke systems for managing their assets. Some of these are very specialized and relate to linear condition monitoring (for example road pavement management systems and rail track condition systems) collecting analogue and time related data. Others relate to major assets such as bridges. Most, to date, concentrate on maintenance work planning rather than a holistic maintenance strategy. Several organizations are embarking on or already on route to developing and implementing systems that incorporate asset information across the asset life cycle.
Asset data dictionaries	Most organizations have some form of asset data dictionary that defines types of assets and the information required against those. The content and required detail varies considerably. It is apparent that, despite there being a desire, there is no universal data dictionary that covers all domains and interests. Recognizing those different domains and their varying naming strategies and information requirements is perhaps the key to delivering infrastructure information. Organizations like Anglian Water have developed comprehensive asset data object requirements and built them into their financial and procurement management systems thus permitting a financial view as well as an asset view of their performance. Others are developing data dictionaries or object type libraries that sit at the core of their asset management process.
Level of granularity	The level of information granularity is not consistent across organizations or within organizations with some domains recorded at a higher level than others. This is mostly founded in historic practices and the sophistication of the systems managing those domains.
Classification	Most organizations use a classification system to index assets however the depth and use that these specify vary considerably. In some cases, classification is little more than a list of asset types (sort of a data catalogue without parameters) Others use the full power of a multi-faceted classification based on ISO 12006. Scandinavian organizations are developing new classifications based on these standards evolving from previous classifications. UK based organizations are basing their interpretation of ISO 12006 on Uniclass 2015. Other organizations are using the USA based Omniclass system.

Future plans	Most organizations have future plans to take a more life cycle view of asset information and are developing strategies and processes to do so. These plans vary from evolution of current systems into a single source of truth to developing new single asset management systems or linked systems that provide a flexible view of information across the enterprise.

Topic	Summary
Data collection process and timing	Most organizations collect data at the point of project completion usually consuming as-built information from documents. This information is then reviewed, in some cases re-surveyed or audited and then entered into asset management systems. Most agreed that such a process was not only expensive but also lost a good deal of important information en-route. The practice of collecting data through an assets life cycle from design and construction is being adopted by the Netherlands and in public clients in the UK. Both use a container based approach for information delivery; the UK relying on COBie; the Netherlands on a local system known as COINS. Both rely on declaration of information requirements within contracts for delivery. Others, notably Sweden and other Scandinavian authorities are intending to follow these practices. Several organizations are basing their current or future data collection process on Systems Engineering principles ensuring life cycle information capture against requirements with step by step validation and verification. Indeed, Anglian Water approach does not mention BIM but frames their process around PLM (Product Life Cycle Management)
Physical attributes	Recording of physical attributes varies from organization to organization. In general, most organizations record some sort of asset identification and perhaps installation dates and serial numbers if the asset is a manufactured product. In most cases, physical attributes are captured via drawings and documents which are referenced in the relevant asset management systems. Anglian Water capture attributes for new assets as part of their systems engineering approach completing details required by their SAP asset dictionary. Crossrail are capturing asset attributes as part of their delivery process in accordance with their Asset Data Dictionary Requirements. Similarly, RWS are collecting attributes required by their Object Type Library via their COINS process.
Dimensional attributes	Dimensional attributes are not normally recorded except perhaps as extents or a reference to drawings. Definitions of what required dimensions mean should be set out in data dictionaries and will vary depending on the asset.
Geographic location	Most organizations record asset geographic placement information in Eastings and Northings (XY) coordinates. Exactly how they are recorded varies, usually they give a general insertion point for the asset however some organisations record geographic extents of the asset. These are often used by GIS tools as a front end to information access giving the asset managers location context.

Network location	Many, not all, infrastructure assets exist and support a wider network connection of assets. For example, roads, railways and utilities. Most of the Road and Rail Authorities record location of critical assets relative to the elements in their networks.

Topic	Summary
Linear location	Similarly, information location along a linear asset is critical not only for finding an asset, but also for being able to overlay information from multiple sources. For instance, pavement condition against material records or video condition capture. All the organizations who manage linear assets record and use this information. Not all use consistent standards or adhere to the OGC developed standards or ISO 19101.
Functional asset attributes	Functional attributes of assets are being recorded in those organizations that are adopting a systems approach to asset information, providing the purpose that the recorded asset fulfils and sufficient data to ascertain performance and capacity against relevant criteria. In most organizations, however this is not carried out systematically.
Technical specification attributes	Again, technical specifications are being recorded in those organizations that take a systems approach, giving specific technical details that satisfy functional requirements and informing designers and constructors.
Condition	Asset condition is rarely recorded at the end of a project even though it is critical to operational management. During operation condition becomes an important attribute and hence its recording is essential. There are many forms of condition attribute ranging from visual inspection records to behavioural performance.
Spatial & 3D capture from BIM	Spatial attributes and 3D geometry is generally not captured specifically from BIM. Some organisations, notably those in Scandinavian organisations, the UK and in the Netherlands, are requiring spatial and 3D modelling information to be captured and handed over at operational stage. How this information is handed over varies substantially but usually includes native formats from models or CAD or via IFCs where these exist to define the asset. Finland have a number of 3D model handover standards which are mandated by contract. These include IFC (they have an IFC bridge data delivery requirement) or in their interpretation of Land Infra based on LandXML which both comprehensive and well documented.
Attribute capture from BIM	Attributes captured from BIM are generally not captured those organizations adopting Systems Engineering approach and those following UK Level 2 BIM are doing so. Notably RWS have defined (via their Object Type Library) the information attributes they wish to capture at each life cycle stage. This is exchanged using their COINS container concept that transfers data defined for delivery at a given project stage on a regular basis. The UK Level 2 requirement is to deliver information at each life cycle stage in COBie format to meet the defined information requirements laid out in contracts.
Master data management Information Change Control	Change control on asset information takes a number of forms. Rigorous master data management is not carried out through asset lifecycle in most organisations.

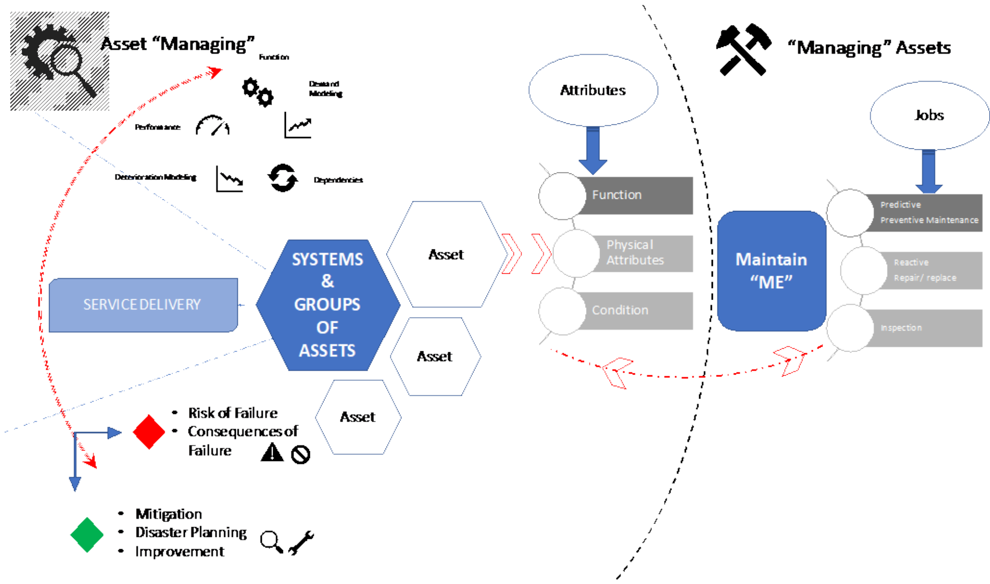
5 Asset Management

In order to develop the information requirements of asset managers it is worth exploring first the underlying principles of asset management and its goals.

5.1 Managing Assets or Asset Management

There is a distinct difference between managing assets and asset management.

- Managing assets (things you do to assets) encompasses day to day maintenance, repair and replacement of an asset: keeping in good condition; enhancing and extending its usefulness. Oiling the hinges and carrying out preventative maintenance. It is focussed on: -
    - Lifecycle activities and asset care – availability, reliability, dependability and safety.
    - Asset location, condition, life extension and interventions.
    - Asset databases, systems and performance.
- Asset management is more about managing the service that a set of assets support. It focusses on:
    - Purpose of organisation – what assets does it need and why.
    - Value purpose and long-term outcomes.
    - Risk and context e.g. regulation, climate, sustainability.
    - A joined-up view of funding streams e.g. Capital Expenditure (CAPEX) and Operating Expenditure (TOTEX) viewed as Total Expenditure (TOTEX).
    - Collaborative behaviours breaking down internal and external silos.
    - How assets contribute to organisational value.



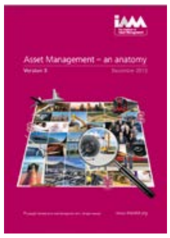
The ISO/TC 251 Asset Management Group (responsible for the ISO 55000 series of standards) has the following list of activities that asset management encompasses.

- Improve Asset Performance
- Improve Asset Value
- Effectively Manage Risk
- Enhance Business Growth and Improvement
- Reliable Decision Making
- Grow Stakeholder Confidence and Reputation.

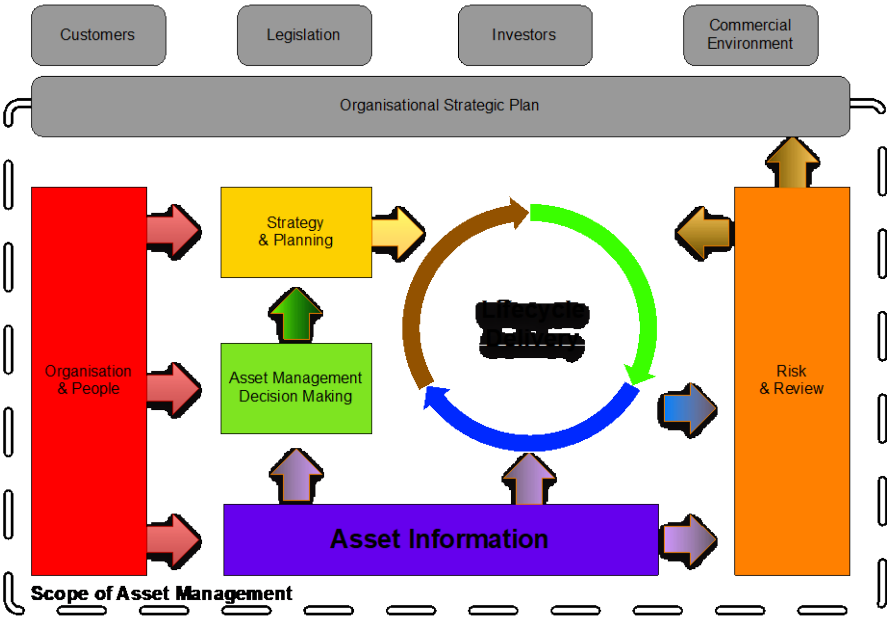
Of course, when considering information requirements both aspects matter and managing assets must be an integral part of carrying out the overall asset management tasks. However, to achieve asset management successfully, the information collected via BIM (or any other process) must be more than a list of products or components with their immediate attributes but encompass the function of the complete asset set. We are not just collecting a list of installed things and a cabinet of spares or a set of maintenance instructions for those but a rather more holistic set of information that describes performance, capacity, function, risk and interdependency.

5.2 An Asset Management Information Framework

This report sets out to understand what information asset managers require as a delivery from a BIM led project. To provide a framework for that information and what information is required it is suggested that we refer to the ISO 55000 series standards, which overview asset management and asset management systems, together with the Institute of Asset Managers (IAM) anatomy of asset management. Together these documents give a basis for evolving and maturing asset management and judging by the project interview results are recognised as being the foundation of most future strategies.



The IAM publish a conceptual asset management mode which sets out the major asset management subject groups and their inter-relationships. A simplified version of that concept model diagram is shown here reproduced with their permission.



The IAM Conceptual Asset Management model - Copyright 2014 Institute of Asset Management

Of course, it covers the whole of the asset management activities, process, standards and strategies, in our case it clearly helps in understanding what asset information is required and what activities and outcomes it supports. Centred around the life cycle of an asset from acquisition through operation maintenance and disposal information is required to support: -

- Strategic planning for whole asset portfolios
- Asset management decision making.
- Operational management.

- Service delivery and use management.
- Maintenance.
- Risk management.

6 Summaries of Information Requirements and Good Practice

Drawing conclusions from our interviews we can assemble what can be called emerging good practice and ensure that the requirements developed not only match that but recognise future trends.

This chapter summarises and tabulates findings and information requirements.

Following chapters discusses how these have been developed and explores some of the issues surrounding achieving the goals that these requirements set.

6.1 Initial Critical Discoveries

Some critical general discoveries were made during the process. There are notable exceptions to these conclusions, but the following summary list gives an indication of the state of the art: -

Significant Quotes from Ferrovial (*Private Report*)

---delivered savings of between three and seven percent over the anticipated lifecycle

“Over the lifecycle of a major infrastructure project, a three percent saving is a significant benefit— potentially reducing the total cost of ownership by tens of millions of dollars. However, independently of the figures, the most important lesson learnt is that by using this collaborative approach, it is possible to reduce cost in CAPEX and OPEX during the lifecycle of infrastructures.”

The value of the new approach is particularly evident at specific points in the lifecycle, such as handovers. By eliminating the need to populate an asset management system manually with thousands of asset records, integrating BIM and asset management from the design stage onwards could save hundreds of hours of work over many months. And more generally, having a seamless end-to-end flow of asset information enables smarter decision making at every stage.

- The existing asset base accounts for over 95% of asset information knowledge.
- Most current asset management practice is governed by what has developed around existing assets and information that has been captured after construction by survey and local knowledge.
- Consequently, information held in most asset management systems is limited to retrospective knowledge, incomplete and not information that could be captured through a rigorous BIM delivery process for new assets.
- Currently asset managers hold information in many domain-centric systems most of which are bespoke and not linked in any way.
- Most Asset Managers are acutely aware that information about their current assets is incomplete and not necessarily current or fit for purpose. Much of it needs transformation to digital information.
- Current asset management information is a mixture of documents, databases, GIS and multisource analogue data.
- Many asset management systems are built around work planning and routine maintenance rather than the assets themselves.
- In general asset managers view BIM as a 3D modelling tool useful in design and construction and not a process for capturing asset information or for viewing and accessing information in context.

- Explicit declaration of what information is required during asset management is not often given at planning, design and construction stages of an assets life cycle.
- Handover and recording of new asset information is most often carried out from delivery of as-built drawings and documents which are interpreted and put into management systems.
- This late handover of information is both wasteful (much critical information is lost) and costly. Conservative estimates discovered during interviews, suggest that some 3% to 7% of total life cycle costs could be saved by a more systematic handover of data.
- Even in the more advanced organisations much data is still handed over as drawings and documents associated with or linked to asset objects. Thus, important information is still hidden from analytical view.
- Critical asset information occurs at each stage of an assets lifecycle and not just at a single stage such as the end of construction, repair or upgrade.
- Systematic information capture is a life cycle issue not just an end of construction issue.
- BIM to date has been focussed on design and construction in its approach and there is a need to make it more asset centric. This has implications to design and construction modelling approaches. It is notoriously difficult to get designers to model for the construction phase and operational phase of an assets life cycle however this requirement suggests a fundamental change in approach.
- Asset managers require asset centric information and less so component/product information.
- To date openBIM standards have concentrated on ‘Use Cases’ that are concerned with geometry and design or construction components and not with delivered assets.
- Building Smart’s IFC’s are hence considered by asset managers as design and construction 3D and 4D modelling tools rather than those that contribute to final asset information.
- Most asset managers desire access to 3D representations of their assets to view them in context and to understand relationships. However, 3D models without at least connection to data/information about the asset are have limited value.
- Geospatial location is a critical asset attribute. It is required not just to see where an asset can be found but also shows it in context and relationship with other assets.
    - Information on how to find, reach and access an asset needs be available.
    - How it might impact other assets nearby or connected.

- Network and linear location is critical in asset management to locate and overlay the many linear features used to assess condition of roads, track, pipe networks and others.

The following lists summarise what is emerging good practice: -

- An asset starts life and recording information at conception and not when constructed
- An information requirements driven delivery process is essential.
- A systems engineering approach to delivering information is desirable.
- Verification and validation of information against requirements at each asset life cycle stage.
- A progressive delivery of information at appropriate stages of an assets life cycle.
- An asset centric view of information delivery as paramount.
- A design and construction information model that not only meets design, cost and construction needs but can be rolled up to an asset model.
- Asset and asset information is the core delivery of a BIM process not components and manufactured products.
- A service and risk driven asset management process necessitating information that supports this.
- Recording of functional requirements against an asset as it is designed– why it’s there and what it is supposed to do.
- Recording of technical specification against an asset as it is designed – what technical performance is required of the asset verified against functional requirement.
- Recording of as built installation of assets.
- Recording of the commissioning information against each asset verifying it against functional and technical requirements and the condition of the asset at handover.

6.2 Overview of Level Information Requirements

In this report, information requirements are treated as sets of principles and indicators as to why and what types of information are required rather than an explicit list of detailed dictionaries and attributes. They provide; therefore, indicators of how detailed information requirements can be developed and what information types for the many domains that infrastructure covers.

Specific IFC schema extensions are avoided as are specific data types and dictionary additions.

6.3 Detailed Requirements Summary Tables

The following tables indicate summaries of findings during research. They show principles and indicate where in the report to find the more detailed discussion on the topics.

6.3.1 High Level Requirements

In broad terms the asset manager's information requirements can be defined as:

Asset Stage by Stage Information (Appropriate to each stage of delivery)
Information for a decision on:
Business requirements fulfilment
Function, performance and capacity requirement fulfilment
Information for delivery and continuity on:
Technical specification requirement
Topology
Geometry
Links to supporting information
Physical Attributes
Information for assurance, provenance and quality of data
Proof of coordination and trustworthiness
Validation against outcome requirements
Verification against technical requirements

6.3.2 MoSCoW Requirements Basics

The following table gives summary guidance to the basic information requirements for any given asset. It is designed as a list that gives headers of information attributes required and to be fulfilled by detailed against detailed object descriptions. It uses the MoSCoW rating system for priorities specifically: -
M – Must have information
S – Should have information
C - Could have information
W – would have eventually information if time and money available

Subject	MoSCoW Rating	Notes
Asset Inception and Life Cycle	Must begin life as it is conceived not when it has been built and handed over after or during construction.	To satisfy life cycle information requirements, the development and collection of data about an asset must instantiated at conception and be progressively managed and added to through its life cycle
An Asset	Must have a unique identification and a reference to type of object. Managed revision identifier	As an asset is conceived in the planning & design process it should be uniquely referenced and from that point on version controlled.
	Should have information related to its: - Currency Suitability for information use Functional. Technical performance specification.	Date of information currency Suitability of use of information including quality and accuracy. The function the asset performs. The technical performance specification for the asset
	Could have: - A location – Geospatial, Linear & Space A topological relationship and location. Geometric construction Dimensions Relationship to other assets and groupings such as Network, Entities, Facilities, Systems, and Assemblies.	Geometry and topology are not essential attribute requirements. This breaks with IFC tradition which currently mostly relies upon construction geometric components and use cases. However, these will generally be required attributes for locational and context purposes.
	Further Could haves: - Reference to Work Breakdown Structure Material Energy embedded	An extendable list which will be dependent on type of asset being described and captured.

	Energy of installation Volume or other quantification measure related to a method of measurement Manufacturer Installation date and time Performance criteria of installed product.	
	Operational & Maintenance Could haves: - Inspection frequency Condition Criticality Risk	Information that gives support to day to day operation and maintenance of the asset.
	Won’t have Will depend on life cycle stage	

6.3.3 Information Life Cycle and Systems Engineering Approach

Topic	Requirement	Detailed Discussion
Life Cycle Information	Asset information follows its life cycle from existing state through planning, design, construction, use and operation	7.1
Asset Instantiation	A new asset should be identified and instantiated at point of planning not at construction.	7.1
Requirements Led Information	Asset owner's information requirements for each asset should be declared at project start.	7.2.1
Asset Centric information	Information collected should be asset centric	7.6.2
Progressive Information	Asset information should be progressively captured and matured through its life cycle stages.	7.2.1
Information Continuity	Each stage of an assets development should inherit information from the previous stage.	7.2.2
Decision Led Information	Information captured supports decision making at operational stage.	7.2.3
Systems Engineering	A systematic delivery of information through the life cycle is probably the best approach to information delivery	7.2
Systematic Validation and Verification	Each stage of life cycle verifies its satisfaction of requirements and when built and commissioned its meeting the functional and technical requirements of design.	7.3.1

Life Cycle Actors	During life cycle actors will have their own information requirements however they should be systematically collecting and delivering asset information at each stage.	7.3.2
Information Ownership	Asset managers should assume ownership of asset information from its inception.	7.4
	Supply chain should recognise and deliver approved asset owners information stage by stage and not at end of construction.	7.4.1
Design and Construction Information Roll up to Asset.	Information requirements should recognise local actors' information requirements but must recognise the need to roll up information to asset level.	7.4.1
	Planners, designers and constructors should be required to model to suit these requirements	

6.3.4 Information Delivery

Topic	Requirement	Detailed Discussion
Objectifying Assets	Infrastructure assets need object definition to suit continuous and spatial boundaries.	7.5.1
Object Hierarchy	Object hierarchy needs to take into account required information inheritance	7.5.2
	Object groups should include Network asset, Parent Complex (sometimes called campus that's limiting) Facility or System.	
	Assets can be broken down into simple primary assets, elements and components.	
	This breakdown can be nested and recursive.	
Level of Definition Breakdown and Granulation	Level of definition should describe the geometrical detail required plus the detailed attribute content	7.5.3
	This will vary depending on life cycle stage and type of asset.	
Information Accuracy, Utility and Purpose	For each asset information delivery, the accuracy of data delivered plus what its purpose is that is what can it be safely used for.	7.5.4

6.3.5 Object Type, Classification and Data Dictionaries

Topic	Requirement	Detailed Discussion
Object Type	An object type is not necessarily a physical product.	7.5.5
	An object type describes an asset which can be: - a conceptual object, a dependency network, a representation of something described within a parameterised boundary such as a flood catchment area, something within a physical boundary such as a land plot, or a physical asset.	
	An object type defines an unambiguous description of assets and asset groupings at a conceptual level.	
	Each domain can and may need to describe an object type in a different way or use a local vocabulary.	
	Across the built environment there are many common types which need to be defined.	
	These common types can further be broken down into building and infrastructure common types.	
	Object Type Libraries provide a good foundation for linked information	
	IFC Type may need to be extended to fit the overall requirement.	
Type and Classification	An object type can have multiple classifications.	7.5.5
	Classification is not a list of object types but rather an index of uses of types.	

	Types can be therefore linked to multiple classification systems.	
Data Dictionaries	Support Object Types	7.5.5.2
	Object Libraries may reference more than one data dictionary.	
	Data dictionaries need to extend beyond product definition.	

6.3.6 Information Content

Topic	Requirement	Detailed Discussion
Asset Information Hierarchy	Organisational information to support organisational goals and key performances	7.6.1
	Asset portfolio management information for capital and sustainability planning	
	Asset management information to support service, performance and risk optimisation.	7.7.4
	Operational management of assets, preventative maintenance, repair and replacement.	
Asset Centric	Information that relates to an asset function, demand, capacity, performance and sustainability.	7.6.2
	Information seen as a whole and not isolated by discipline, domain, system or life cycle stage.	7.7
Service Level	Information to manage risk	7.7.4
	Information to relate to customers experience and relationship.	
	Information to plan and mitigate against risk scenarios including planning and recovery plans.	
	Information to support operational maintenance.	

6.3.7 Attributes, Parameters and Metadata

Topic	Requirement	Detailed Discussion
Geometry v Alphanumeric attributes	Both of equal importance and mutually supportive.	7.8.1
3D models	Not necessarily full BIM models	7.8.2
	Support location, access, augmented reality.	
	Referential linking to support information such as manuals, videos and photographs.	
	Referential linking to all object attributes.	
Dimensions	Extents of asset, access restraints, openings, space requirements.	7.8.3
	Should be explicitly described and terms such as height, breadth explained in relation to this object type.	
Location	Absolute geospatial coordinates.	7.8.4
	Map and grid projections.	
	Where on a network or what route required to access.	
	Connected location.	
	Within what zones or defined spaces	
	Linear location local, referential and general.	
Functional attributes	Information that describe the performance requirements of the asset appropriate to the stage of life cycle development and object hierarchy level.	7.8.5
Technical Specification Attributes	Technical specification for the asset to built to.	7.8.6
Commissioning Attributes	Attributes that describe the tests and results carried out at commissioning.	7.8.7

As built attributes	Attributes that describe the final as built solution, characteristics and materials used.	
	Could be a manufactured product or an in situ construction.	
Condition attributes	Attributes that describe the condition of the asset at handover.	7.8.8

6.3.8 Information Delivery Packaging

Topic	Requirement	Detailed Discussion
Information package content	Network models	7.8.9
	Design models	
	Capability and capacity models	
	Functional and technical specification	
	Construction and as built models	
	Object attributes not held in models.	
	Documents supporting objects such as sketches, detail drawings, manuals, photographs, instructional videos and safety instructions.	
Information package	A packaging system to support above content delivery and exchange.	
Linked and Semantic Data	Capability of web based delivery of semantically linked information.	7.8.10
	Capability to control ownership of information and access control.	
	Flexibility to reference different classifications,	

	domain vocabularies and international standards.	

6.3.9 Information Delivery Process

Topic	Requirement	Detailed Discussion
Common Data Environment	A controlled data production and delivery environment that supports collaborative object development.	7.9
	A process similar to that defined in the BS 1192 suite of software (ISO 19650 when it arrives)	
Contractual Delivery Process	A process defined in contract for information delivery.	
Process Verification	Proof of information trustworthiness.	
	Verification against information requirements	
	Information provenance	
	Information suitability for purpose	
	Information completeness.	

6.4 Implications for buildingSMART Standards

Name	Standard	Asset Requirements Implication Notes
IDM Information Delivery Manual	ISO 29481 – 1 ISO 29481 – 2	Recognition and addition of the processes that meet asset managers requirements beyond product data.
IFC Industry Foundation Class	ISO 16739	Addition of infrastructure asset types Alignment with Object type libraries Introduce use cases that capture asset information
BCF BIM Collaboration Format	Coordination messaging to manage change	Investigation on supporting an ISO 19650 delivery process.
IFD International Framework for Dictionaries	ISO 12006 – 3 buildingSmart Data Dictionary	Currently data dictionary is focussed on objects that reflect products rather than asset object types. Research on incorporation of Object Type Libraries and Semantic Linking and Ontologies to provide better national and domain language flexibility.
MVD Model View Definitions	buildingSmart MVD	Recognition of the information exchange requirements of asset managers at each life cycle stage.

6.5 Roadmap Development Recommendations

The following is a summary of future work guidelines that is recommended to facilitate asset information managers requirements implementation in openBIM

Topic	Recommendation
Systems Engineering	Adoption of systematic delivery of asset information through life cycle – introduce as update to Information Delivery Manual.
	Incorporate information inheritance into delivery process rather than software data exchange principles.
	Incorporate asset information requirements into Use Cases – a move from geometric use cases.
	Add attributes of validation and verification of information at each stage.
	Develop MVDs to suit continuous systematic delivery of asset information.
Object Type Libraries	Develop infrastructure object type libraries that recognise asset view rather than product view. Use RWS, Crossrail and Swedish CO Class Standards as a foundation but work with other organisations to establish rules and principles for each domain to build on.
	Incorporate types into infrastructure IFC development.
	Adopt semantic linking to link to multiple data dictionaries and classifications.
	Accelerate IFC OWL development to accommodate linking.
Information Content	Add asset centric information attributes beyond product of design and construction.
	Break down barriers between GIS:BIM:AIM by closer working and common concepts.
	Understand asset managers 3D geometry requirements and itemise deliveries required for each object type.
	Add infrastructure location types (Map coordinates spatial and linear) not force fitting building location but make more generic working with OGC
	Ensure that functional requirements are delivered during planning and design stages.

	Ensure technical design specification attributes are added at design stage.
	Add commissioning testing attributes
	Add delivery condition attributes.
Semantically Linked Data	Adopt Linked Data approach to information relationships.
	Package information delivery using linked data
Information Delivery Process	Incorporate principles of ISO 19650 into the information delivery process.
	Expand buildingSMART BCF messaging services to incorporate ISO 19650 processes.

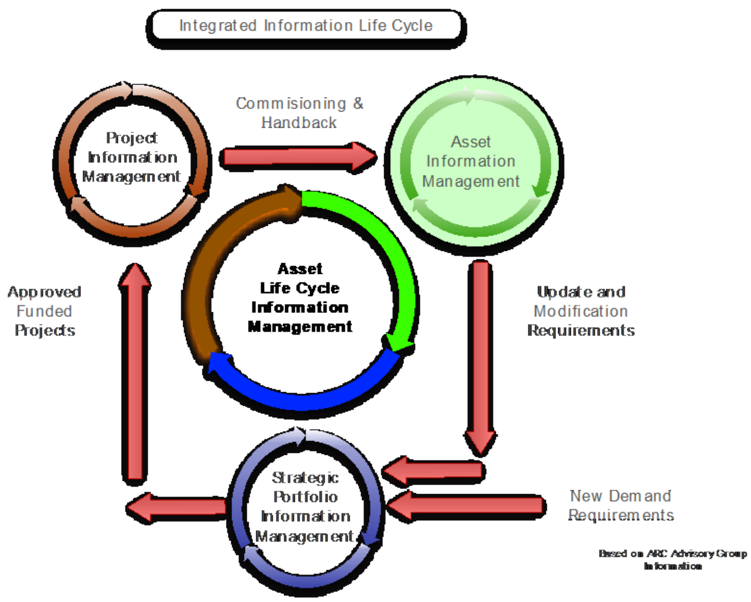
7 Developing Information Requirements

This chapter discusses in more depth the findings set out in the summaries above.

7.1 Asset Information Life Cycle

Typically, 80% of an assets costs are incurred during the operation and maintenance stage of its lifecycle. However, about 80% of lifecycle costs are ‘locked in’ at the design stage. It is therefore important to explore the whole life cycle of information requirements to ascertain the information that needs to be delivered by BIM. That information not only will support operational management and maintenance but also provide information for new projects and flag any asset changes that are planned.

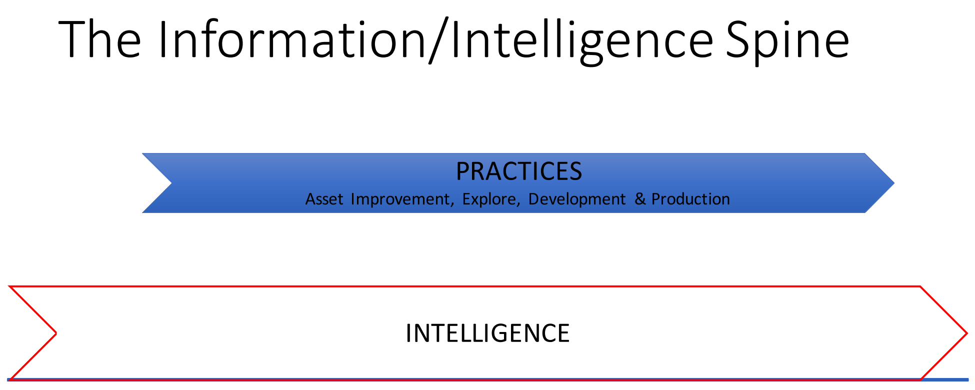
In most BIM delivered projects information concentrates on that which describes the project and its procurement supporting collaboration and virtual design and construction. Viewed in the overall assets lifecycle this represents a small proportion of the information necessary to effectively manage it through its life and often omits important attributes and content. Idealised the lifecycle of information can be viewed as being made of three distinct sets as shown in the diagram here: -



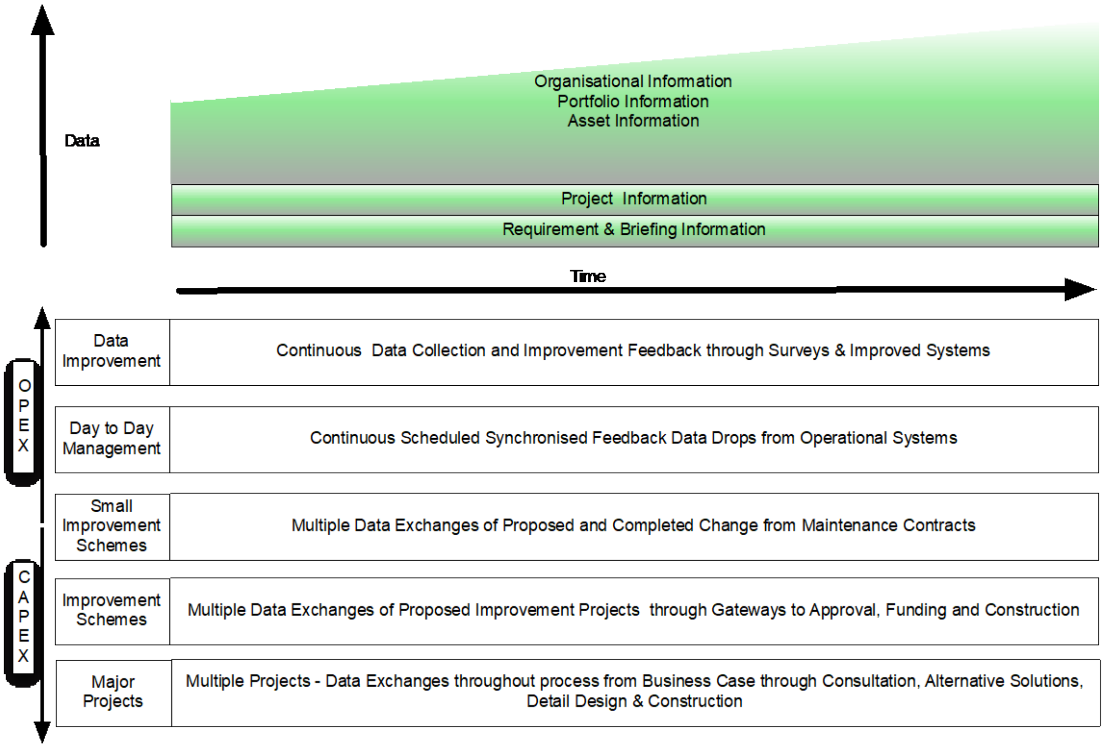
The asset information cycle is continuous often starting from an existing asset or set of assets.

- Day to day operational management updates and manages the asset information.
- Operational management may result in issues that might be resolved by modification or re-purposing.
- Asset usage information including service delivery, working with intelligent transport systems, traffic control and management, signalling, timetabling, switching, sensor interoperation and communication devices each of which require asset performance and simulation information.
- The operating environment will in response to corporate requirements, external events and political demands require perhaps increased capacity or other new demands to be placed on an asset which can be answered by investment.
- The owner/manager needs to manage their whole portfolio strategically based on information held against the asset and the whole asset estate and balance cost risk and investment.
- Once a new project is approved then the project delivery cycle can begin drawing on existing asset information and the briefing requirements from the strategic process.

That life cycle can be looked upon as a continuous intelligent information spine that supports and interacts with all the asset managing practices including delivery of asset improvements, new projects and operational



management. Aligned with performance information for project delivery, service delivery, and managing risk.



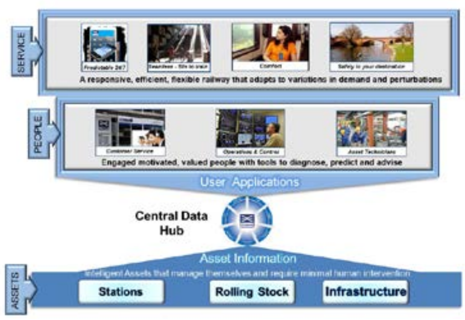
The above diagram illustrates the characteristic of infrastructure assets in that they are part of a continuous investment process with many new projects being additions to existing infrastructure and occasionally single new major assets.

As an example Anglian Water follow a process based on a Total Expenditure Delivery Workflow throughout the life cycle of an asset.

Their process for delivery is designed to create digital assets and they view this as continuous Digital Asset Creation (DAC) not one based on CAD.

A full Life Cycle PLM (Product Life Cycle Management) approach.

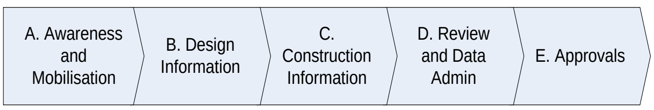
A further example is the approach taken by the London Crossrail project where Asset information is defined as information that supports the running of Crossrail as a Service facilitating resources that are engaged in running that service.



Asset information is developed and captured during planning, design, construction, testing and adoption is designed to support that service. It takes into account that many assets will be intelligent and self-managing. Fully incorporating sensors, internet of things reporting aligning to the function and location of each asset.

Asset management information creation, capture and management is an integral part of the delivery process for the project. The approach is designed to provide information for project delivery and for future operational management of the assets.

As such it follows the life cycle of and asset through its planning, design, delivery, testing and handover.



It defines that procedure in defined stages:

Stage A - Awareness and mobilisation

The objective of this stage is to initiate the process of capturing asset information.

Stage B – Design Information

The objective of this stage is to allocate Asset Tags Placeholders to relevant design objects recording their names and asset IDs in the Asset Data Collection Spreadsheets. During this stage Asset Information will be compiled progressively and complete by each contractor no later than four weeks prior to the final design gate 3, this is a gate requirement.

Stage C - Construction Information

The objective of this stage is to record Equipment IDs and associated serial/batch IDs which have been installed to fulfil the requirements of the Asset Tag placeholders plus related attribute data. During this stage Asset Information will be compiled progressively and complete by each contractor no later than four weeks after the relevant asset has been installed, assets will also have been labelled by this point.

Stage D – Review and Data Administration

The objective of this stage is to review the supplied information to ensure that it meets quality requirements, delete any surplus assets in AIMS and change the status of correct assets.

Stage E Approvals

The objective of this stage is to confirm that the Asset Information in AIMS is correct and complete and can be approved.

Eventual handover of information may be adopted by multiple users including Transport for London and National Railways.

Information collected has therefore to be capable of handover into multiple systems.

7.2 Systems Approach to Information

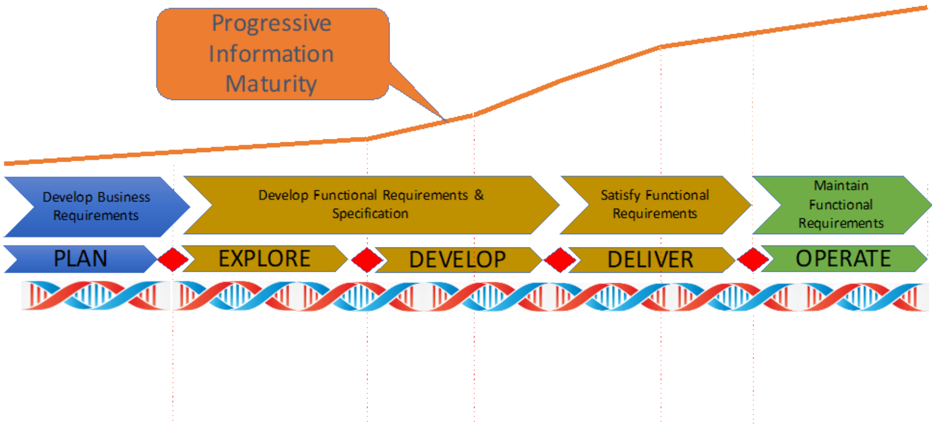
Outcomes from the interviews indicate that the majority of organisations are, either explicitly or implicitly, beginning to adopting a ‘Systems Engineering’ approach to delivering and managing assets. Some are doing this as a strategic policy others by adopting the broad principles of a systems approach. Borrowing from the software industry and from Product Life Cycle Management (PLM) used in mechanical engineering organisations. Perhaps more appropriately named Asset Lifecycle Management (ALM) in the case of infrastructure.

Systems Engineering is an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem outcome. Systems Engineering integrates all the disciplines and specialty groups into a team effort forming a structured development process that proceeds from concept to production to operation. Systems Engineering considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs.

Systems Engineering sees the whole delivery process as being requirements led and developed through life cycle stages and information being verified at each step. In some cases, the use of a systems approach is explicitly stated for instance Anglian Water’s delivery process, similarly the delivery process in RWS in the Netherlands it is a requirement and in Transport for New South Wales it is included in their future asset management strategy. In other cases, the approach is implied for instance in London Crossrail and in the UK Level 2 BIM strategy which deliver against Employers Information Requirements at each project stage

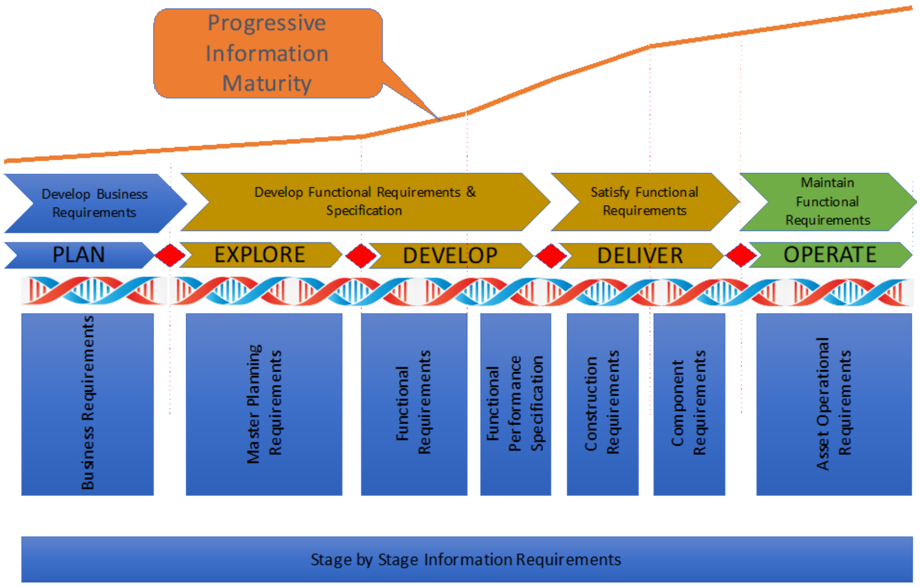
7.2.1 Requirements Led Progressive Information

Essentially a systems approach focusses on defining customer needs and the required functionality early in the development cycle, recording requirements, proceeding with design and construction validating all the systems as it progresses. It enables the integration of all the disciplines and speciality domains into a combined effort forming a structured development process that proceeds from concept to construction and operation. It is therefore a requirement led progressive development of information delivery and validation.



The progressive information delivery satisfies requirements at each stage of the life cycle and acts much like the DNA of the delivered asset. At any one stage the asset owner can look back through the information DNA chain to discover the reason and purpose of the asset. It is therefore important that the delivery stage information not only describes how the asset is constructed but can provide critical information for those who will manage and operate the asset.

It follows that information delivery must have continuity and be built on the information requirements in the previous stage of delivery.



7.2.2 Inherited information

Each stage of delivery asset information adds to information created in the previous stage inheriting the information recorded in previous stages.

It should be noted that this is not an information change process, that is, existing information is not edited or modified unless it goes through a change referral process.

So, for instance, in the master planning stage of a new road or railway business requirements are interpreted into a cell/block/object of information that describe the characteristics of the required road in capacity and performance terms which might have some geographic extents and linear length. It will inherit the business requirements from the previous phase but not edit or change them (that's a wider change control requirement) In the next phase then a concept alignment might be developed with basic road geometries. It will inherit the capacity and performance requirements from the previous phase but not change or edit them. And so on as each phase of detail is produced as ever increasingly detailed cells of geometry and information.

This not only provides rigour but also ensures that clarity of ownership of information is maintained.

From an asset managers point of view it essential that they can look back through that inherited information to understand why an asset exists, what its capacity is, what function it performs, what technical specification does it satisfy and how it was constructed. During interviews a number of examples for this requirement were given. These include: -

- A change in demand or capacity for an asset might be part of a strategic planning exercise. Being able to understand not only what physical component was assembled at construction but know its detailed DNA/history would enable a more effective analysis and save time and cost.
- A point of failure caused by a flood or a track failure having available critical information as to function and relationship within a network would facilitate not only repair but also in developing mitigation measures.
- A failed embankment or cutting earthworks due to flooding, overloading, loss of vegetation, often a catastrophic event requiring immediate action would benefit hugely from knowledge of design criteria and dependencies.

Replacing an asset, say a bridge bearing, knowing what function and what technical specification of the original design would permit the maintainer to select the most effective replacement rather than searching through parts catalogues

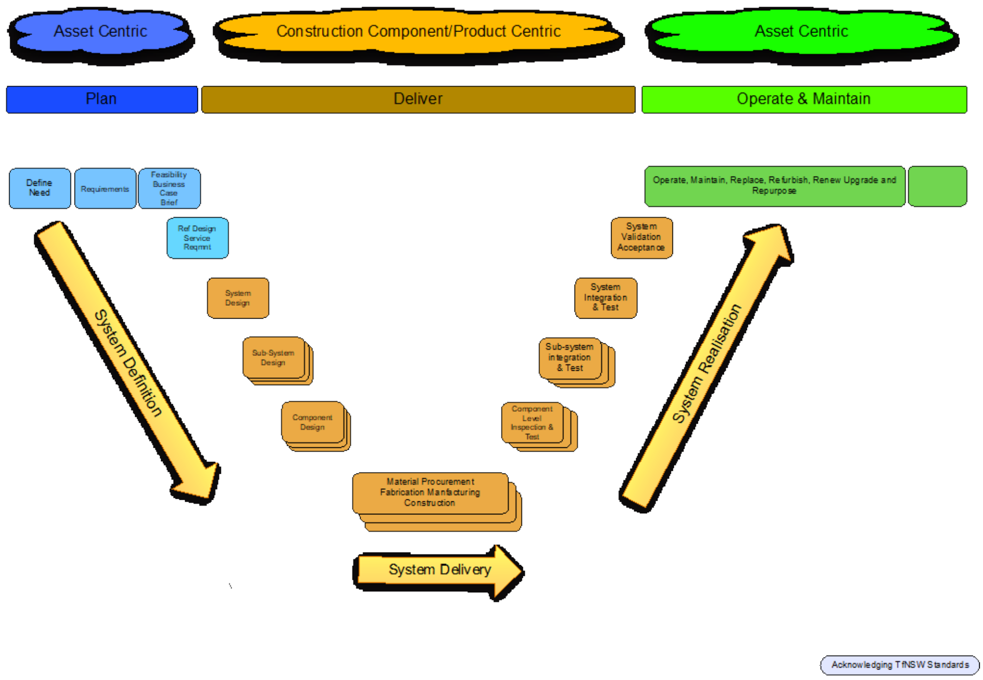
7.2.3 Decision led information

Information generated and captured during an assets life cycle is essentially to support decisions that are made during procurement and operation. It follows that at each stage of the life cycle the asset managers interest is in capturing information that supports their strategic planning, their portfolio management and day to day operational decisions.

7.3 Formalised Asset Life Cycle System Approach

That systematic delivery of information and asset can be expressed as a classic V diagram in systems terminology.

Transport for New South Wales (Australia) appear to have the most comprehensively developed view of this, discovered during the interviews, which is reproduced below with a few embellishments designed to map to our development of information requirements. In particular, breaking the cycle and staging down to the life cycle stages we have adopted for this project. Shown here in simplified form.



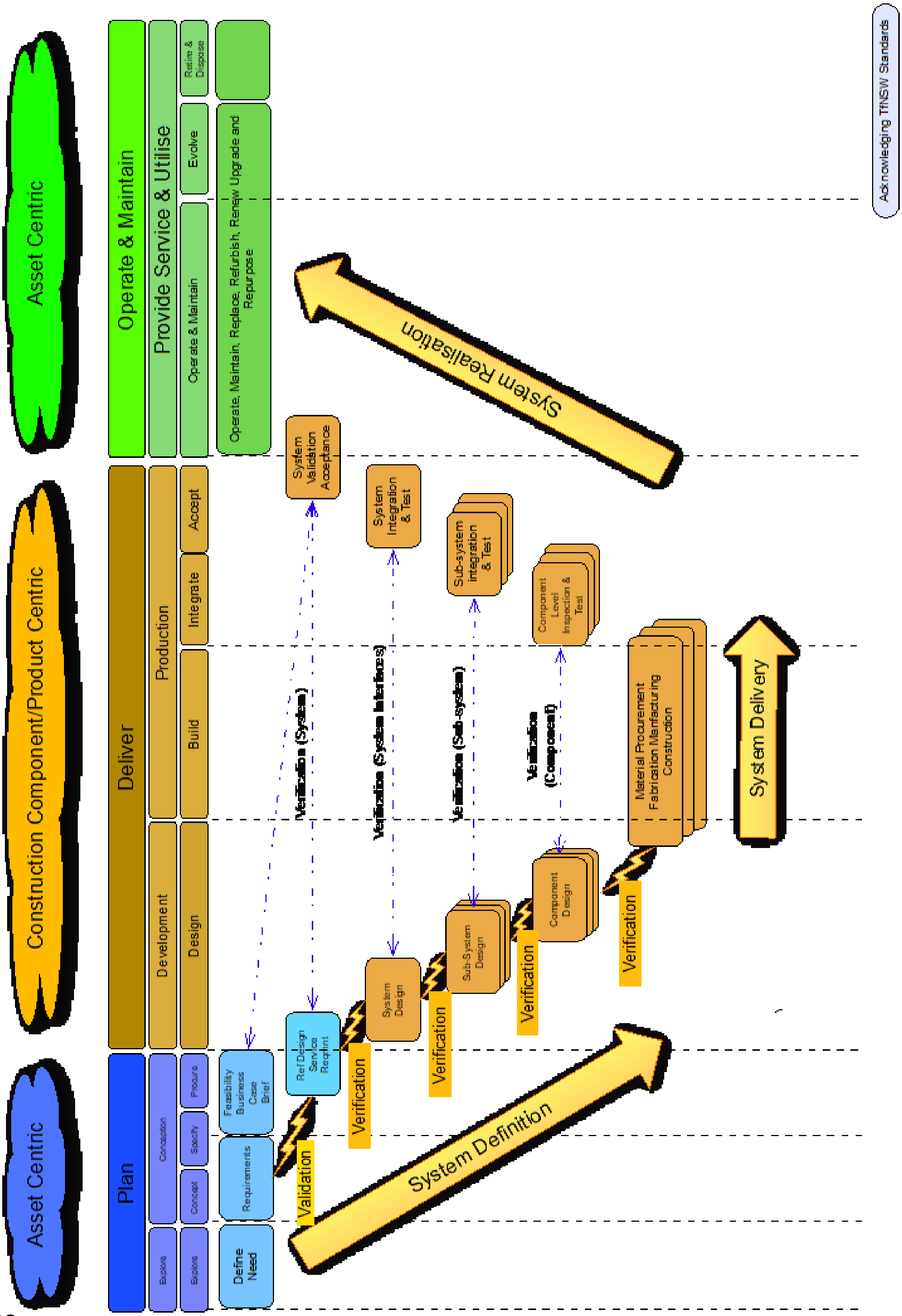
A more detailed and larger view is shown on the next page.

The detailed delivery stages shown map closely to many used throughout the industry however the interviews discovered that these vary considerably from organisation to organisation and from domain to domain. Those given in this diagram are sufficient for any organization or domain to map their processes.

7.3.1 Information Validation and Verification

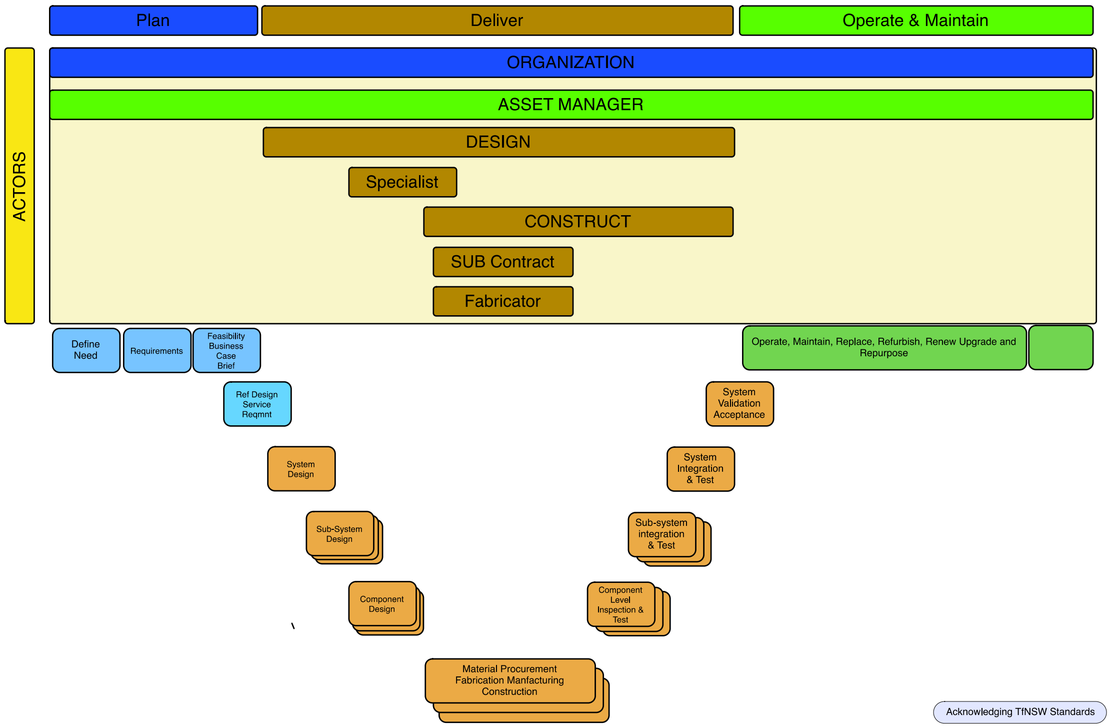
Fundamental to the systems engineering approach is the step by step verification of information requirements and their being satisfied. Hence each step of the V diagram during Systems Definition stages looks back to the previous stage and verifies that the solution meets the requirements set out for it. When any build is completed the resultant physical asset is commissioned, tested and verified against the requirements developed during the design stages.

Such verification provides the asset owner with an audit trail of delivered information thus allowing it to be incorporated into asset management systems without recourse to as built. In other words, ‘as built’ information becomes reliable and immediately useful.


Asset Centric
Construction Component/Product Centric
Asset Centric
Plan
Deliver
Operate & Maintain
Conception
Development
Production
Provide Service & Utilise
Explore
Explore
Concept
Specify
Procure
Design
Build
Integrate
Accept
Operate & Maintain
Evolve
Retire & Dispose
Define Need
Requirements
Feasibility Business Case Brief
Ref Design Service Reqmnt
System Design
Sub-System Design
Component Design
Material Procurement Fabrication Manfacturing Construction
Component Level Inspection & Test
Sub-system integration & Test
System Integration & Test
System Validation Acceptance
Operate, Maintain, Replace, Refurbish, Renew Upgrade and Repurpose
Validation
Verification
Verification
Verification
Verification
Verification (System)
Verification (System Interfaces)
Verification (Sub-system)
Verification (Component)
System Definition
System Delivery
System Realisation
Acknowledging TfNSW Standards

7.3.2 Life Cycle Actors Information Requirements

During the life cycle of any asset a number of actors play a part in the capture, delivery and use of asset information. To understand the part each play and what information they use, what can be considered local (restricted to an individual process) and what asset managers might require from those actors its worth listing in context.



The simplified V Diagram above show the high-level actors/stakeholders in the information life cycle.

Expanded these they will include amongst many others: -

Actor	High Level View of Asset Information Requirement
Asset owning organisation	Asset performance and risk
Asset Managers	Asset unique id's - Function, performance, attributes, condition ….
Owners Project Managers	Project delivery schedules, quantities, costs, progress, quality, verification ….
Master Planners	Business requirements, demand, context, environment, geography, existing conditions.
Lead Designers	Constraints, location, geometry, design standards, functional requirements …

Specialist and Domain Designers	Functional performance, technical specification.
Construction Contractors	Quantities, cost, location, geometry, specification
Construction Sub-Contractors	Functional performance, technical specification, quantities, cost, geometry …
Fabricators both on and off Site	Detail design attributes
Product Suppliers	Function, performance, geometry
Material Suppliers	Quantities, specification, test results

7.4 Information Ownership

It is critical that asset information is ultimately owned by the client/asset owner and not any contracting parties.

Hence at the point of delivery of each life cycle stage the asset owner assumes ownership of critical asset information which then comes under their change and data management control. Note this has direct implications for Linked Data Web Based information sourcing.

The contracting parties' may develop other information which assists them in carrying out their delivery task which will be of no interest to the asset owner however key information about the asset must be regarded and treated as being owned by the asset client.

If the content delivered by a contracting party requires changing for any reason be it due to changes in functional requirement or changes due to solving an issue or unforeseen circumstances the contracting party's expertise (or their equivalent) should be consulted and no changes made without their express consent.

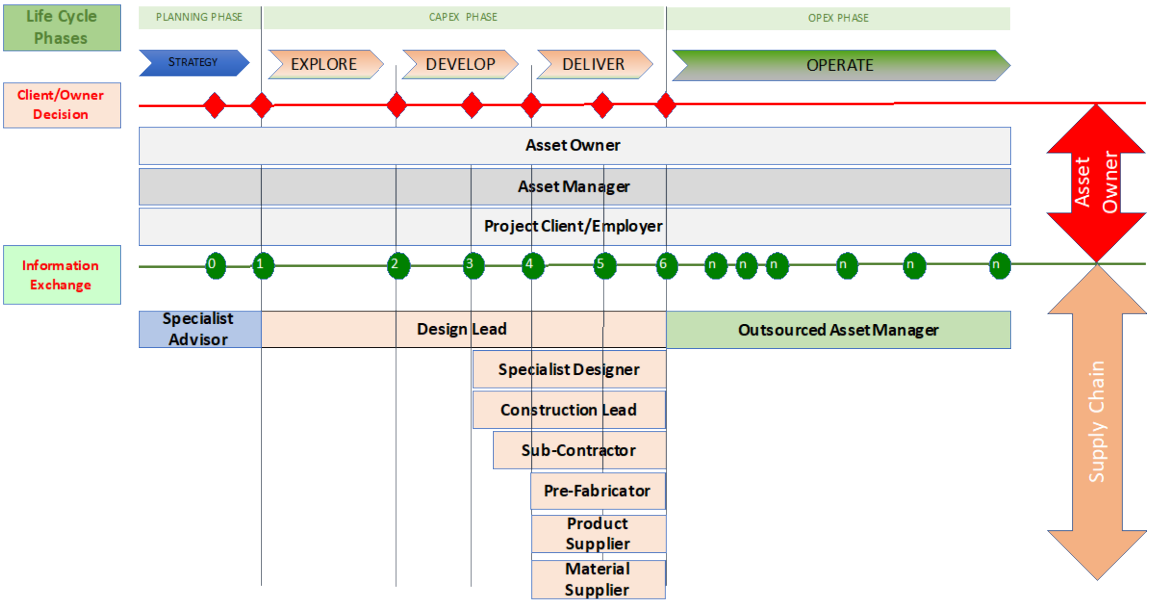
This has implications on the delivery process and the contents of delivery packages.

Reasons for this asset information ownership model include: -

- Infrastructure projects often have a protracted delivery period and may stop and start several times for public participation, environmental, economic or political reasons. Information loss during such periods is recognised as being costly in terms of money and time.
- New consultants, builders, fabricators, and experts may be contracted at different stages during the delivery. It is vital that information can be transferred between these contracts as complete data models.

- It is common in infrastructure delivery that early enabling projects preceding the main body of delivery. These might include utility diversions, waterway diversions, earthworks, and bridges. Again it is vital that this information can be held managed and transferred efficiently and accurately.

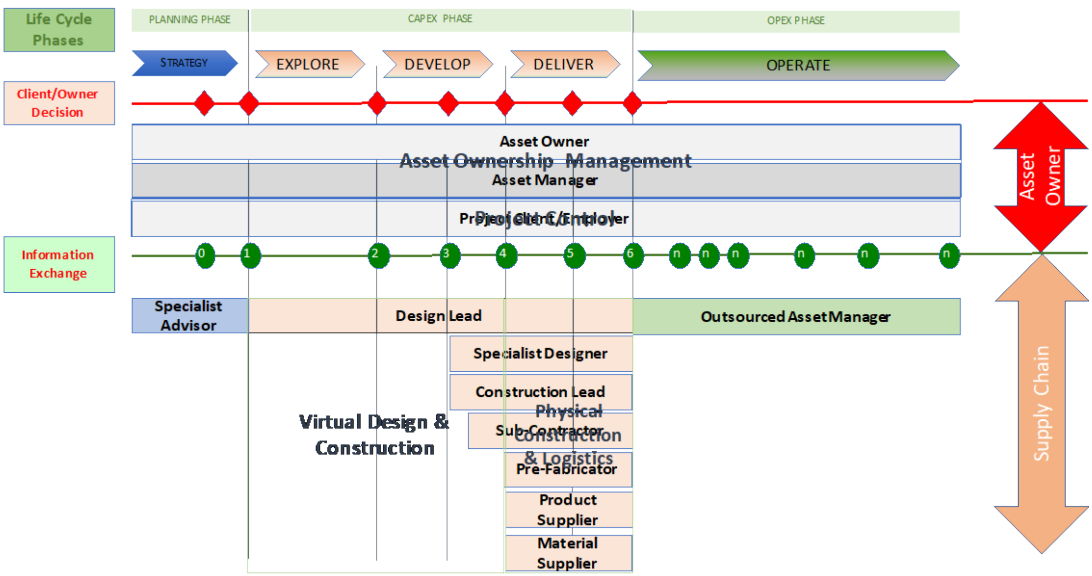
Expressing those players diagrammatically against the life cycle process shows us their relationships and how they contribute to the information



required by asset owners and managers.

Information is therefore captured progressively both from stage to stage but also from each contributor in the supply chain.

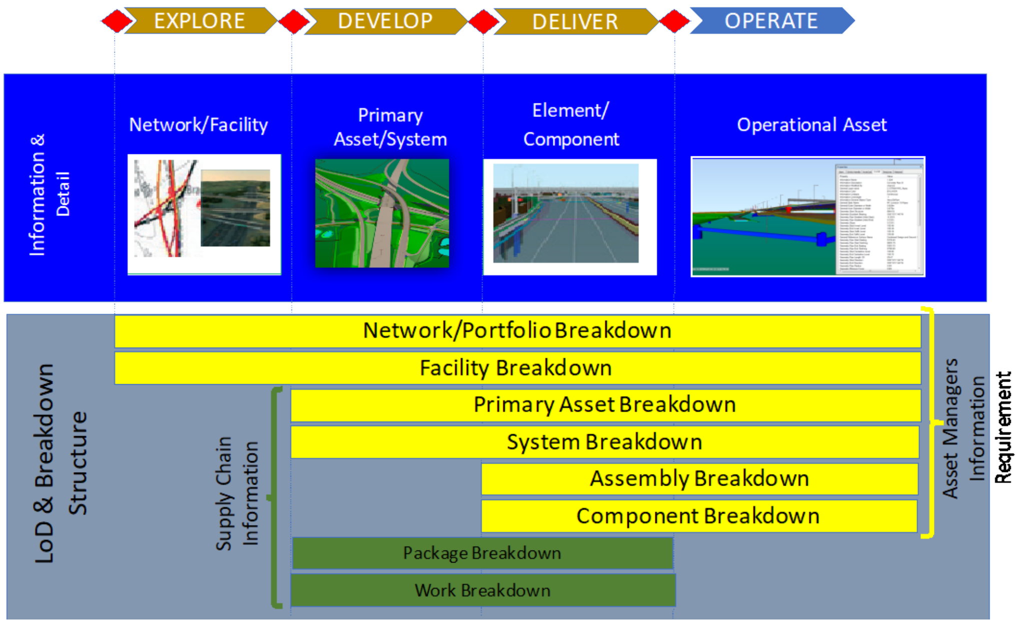
The asset managers interest is in defining what information the supply chain is required to deliver and exchange with them.



7.4.1 Planning, Design and Construction Roll up to Assets

To satisfy asset managers requirements a physical asset must be represented in ways that relate to the management of the asset rather than just the design and construction of the asset but that correlate to its function in operational life.

As discussed above each object may have different information requirements during project delivery which might relate to cost or delivery packaging, setting out, work breakdown or logistics. However as far as asset managers are concerned it is important that data modelling at each of these steps can be rolled up to meet asset objects. Hence this places a requirement on planning design and construction modelling techniques and procedures.



The diagram above attempts to illustrate this showing in yellow how the hierarchical breakdown contributes to asset information.

This has information object breakdown delivery implications for the different stakeholders from the supply chain. Breakdown is governed by: -

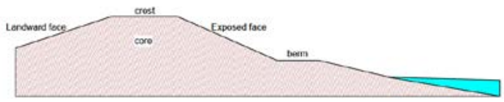
- For planners and concept designers
  - Overall Business requirements
  - Overall Outcome performance requirements
  - Network/portfolio service level requirements
  - Facility location and functional requirements
  - Primary asset location functional requirements
- Detail designers

  - Primary asset functional requirements
  - System/assembly location and functional requirements
  - Element location functional and technical specification
  - Component location and technical specification.
- Constructor, sub- contractors, fabricator, component and material suppliers
  - Fulfilment and verification of design requirements
  - Work package breakdown
  - Work breakdown

7.5 Information Delivery

7.5.1 Objectifying Assets

Currently design BIM/IFC deliverables concentrate on information connected to physical elements that can easily be broken down into discrete components and assemblies. The world of infrastructure presents wider issues that must be resolved in order to provide a platform for asset information. Infrastructure assets have additional characteristics that should be recognized in the deliverable components. A simple example of an embankment drawn from the Environment Agency Asset Management System illustrates this clearly. In this case the embankment has a number of discrete components, which need to be measured, constructed and maintained and hence delivered as digital information. This is made more complex as over the length of an embankment profiles may change thus necessitating segmentation of the embankment assembly.



To the uneducated eye an embankment may seem to be an object in its own right (which of course at the highest level it is) in fact it is a number of separate assets that compose a visible feature but not necessarily an asset - the illustration here shows the potential complexity of earthworks surrounding a bridge and its surrounding landscape which is made up of fill behind the bridge embankments, earthworks surrounding wing walls and ancillary supporting structures. Describing and embankment as a single entity is like describing a hill as a mound of earth. Embankment features the digital asset manager is interested in are the materials it is composed of and perhaps how they were laid and compacted plus the resulting new earth surfaces which need to maintained and have vegetation controlled.

Additionally, and perhaps more importantly, breaking down the continuous features that infrastructure consists of such as roads, rail, earthworks, and landscapes into maintainable objects will differ depending on what aspect the asset manager views it from. So, for traffic lane management we might break a road down into linear elements measured linearly from a given point or for road surface material and quality management it might be broken down into different blocks from another given point. Similarly, for network continuity management the road/rail might be broken down into fixed nodes and links between them. Or drainage runoff area might be broken down into blocks related to drainage systems. Or even an area of vegetation that requires management might overlap several other features such as cuttings and embankments and landscaping.

7.5.2 Object Information Hierarchy

An asset breaks down into a natural hierarchy of information that follow its natural development and provides inherited information to the next level of the hierarchy. There are multiple naming and grouping strategies for the levels of this hierarchy depending on domain, local and organisational practice and relationship to classification systems.

The following table gives an illustration of such a hierarchy. Note that the naming structure is given for example purposes only. It should also be noted that this hierarchy should not be confused with Classification Hierarchy which does not define things but indexes types of things in the context of information user.

Group(s) Network Complex Facility	**Group(s)** A grouping of assets sharing common properties such as location or purpose.
Primary Asset	**Primary Asset** A discrete piece of infrastructure such as a tunnel, bridge, highway section etc
Elements of Asset	**Elements of Asset** Major elements of an asset described by management requirements e.g. bridge deck, foundations, supports, track, sub-base etc
Components of Elements	**Components of Elements** Individual

Both primary assets and elements of primary assets can be systems or assemblies of elements or components. Each step in the hierarchy can be recursive. That is a further primary asset can exist within a primary asset or an element or a system asset element can contain hold further elements.

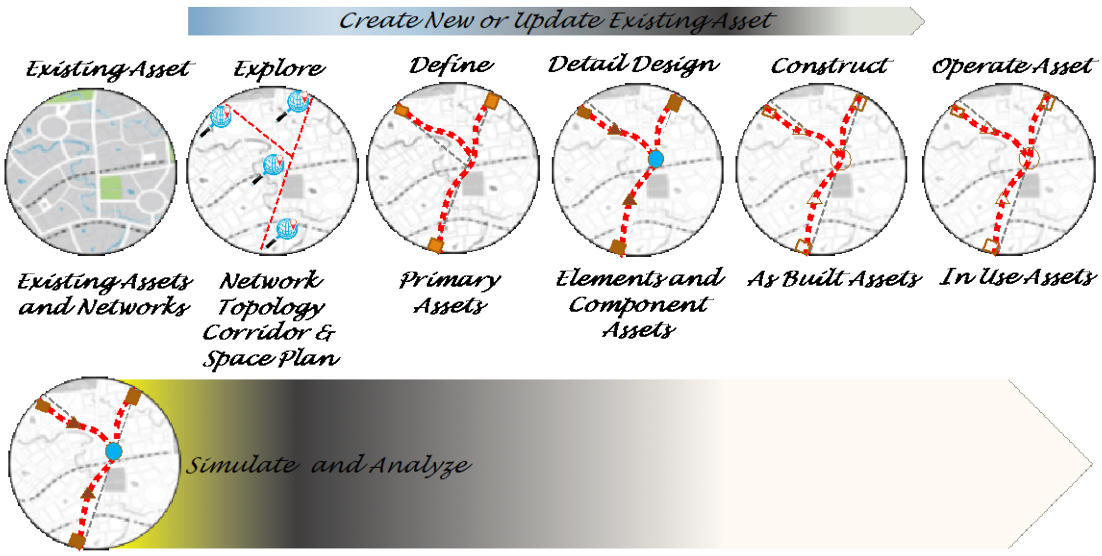
Breaking down the steps in the hierarchy will depend on the user of the information and local/national requirements.

7.5.3 Level of Definition - Breakdown & Granulation

Depending on the life cycle stage of a particular asset and the asset hierarchy information that fulfils the managers needs is required. This has been interpreted in various ways across the world and across domain disciplines. Often this has been interpreted as the refinement of geometric detail required at each stage of development and harks back to the age of scale drawing/CAD/GIS detail. However, a number of more recent developments have recognised that this needs to cover not just geometry or scale but the total information attribute and metadata content required. The UK NBS object hierarchy recognises this as Level of Detail (LOD) and separately Level of Information (LOI).

Depending on the stage, discipline, hierarchy or type of object different levels of definition may be required. Hence at the end of a stage or at a time in development a particular asset object may have geometric detail to one level and attribute information detail to another.

Information granularity is not therefore a continuously developed and refined object adding more detail but more a set of objects at each stage of development each with their own detail, accuracy and information content appropriate to the stage of development. Each inheriting the information from the previous stage but NOT replacing the object but adding new more detailed objects.



Asset manager's information requirements will therefore be related to the stage and level of information appropriate to the stage of development.

This should not only inform the BIM requirements but also the structure and requirements for future Asset Information Systems.

7.5.4 Information Accuracy, Utility and Purpose

Additionally, at each group in the asset object hierarchy and at each stage of development the required accuracy of information will differ.

It is important therefore to record within asset object metadata to what level of accuracy the information contained is produced and for what use or that information can be applied.

To illustrate at an early new project stage of planning or concept design a new road corridor might be modelled to ascertain basic alignment, quantities and land requirements. At this stage the level of accuracy required would be sufficient to approve a concept design and make basic decisions on budget. However, the information would not be accurate enough to complete detail design and set out the construction which would be fulfilled at element level with detailed alignment and offset geometry. At asset management stage accuracy should be held at a level that is suitable for location and for future updating construction.

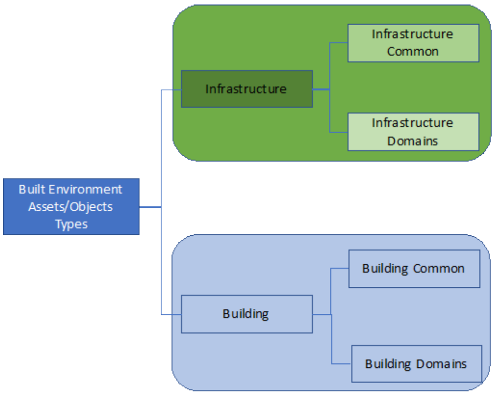
7.5.5 Object Type, Classification and Data Dictionaries

During the interview period and in subsequent discussions it has become clear that across the domains involved in infrastructure and across countries creating a standard universal dictionary of types that describes all assets is an almost impossible task. Each country, domain and each discipline view their assets differently and use different, classifications and descriptors that fit their own processes and needs. However, each need to collaborate and communicate across these boundaries and increasingly internationally.

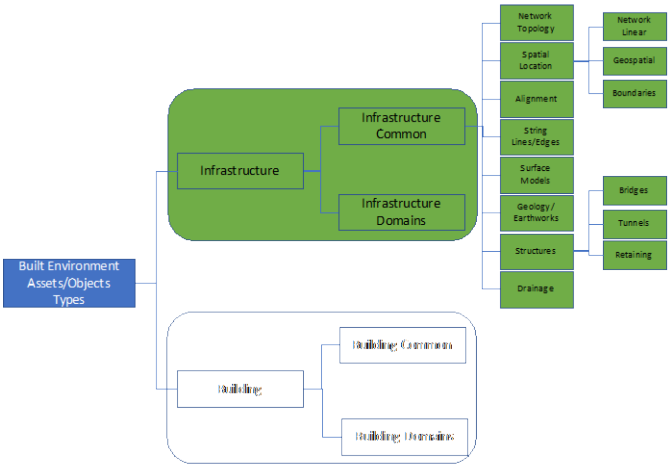
Built environment asset types and associated attributes have types that are common across all domains both in infrastructure and in building and each of these share common elements.

What is clear is that the move towards product data templates (PDTs) particularly those focussed on manufactured objects are not sufficient to meet the needs of infrastructure life cycle assets and the continuity of information required to support those assets.

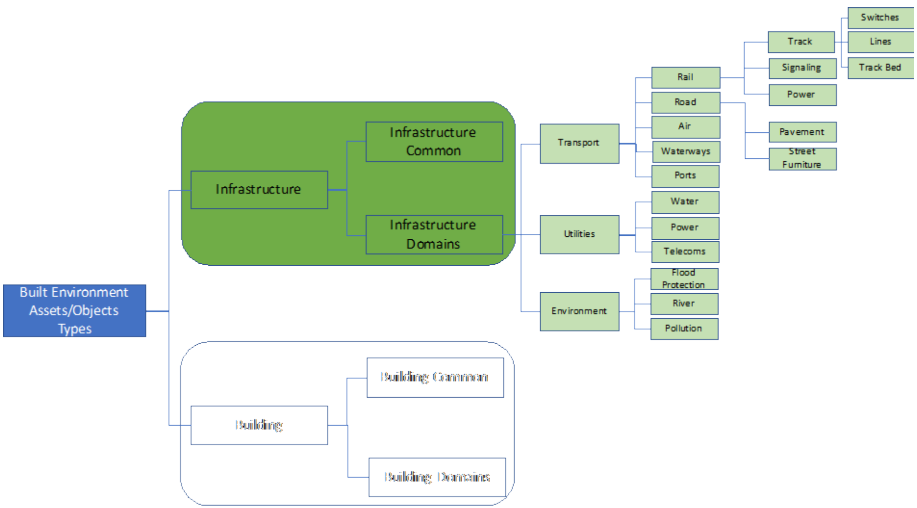
The diagrams below illustrate just some of the common object types and some specific domain object types showing the complexity of creation of common type dictionaries and the types of objects that need to be created and detailed for the purposes of asset management.



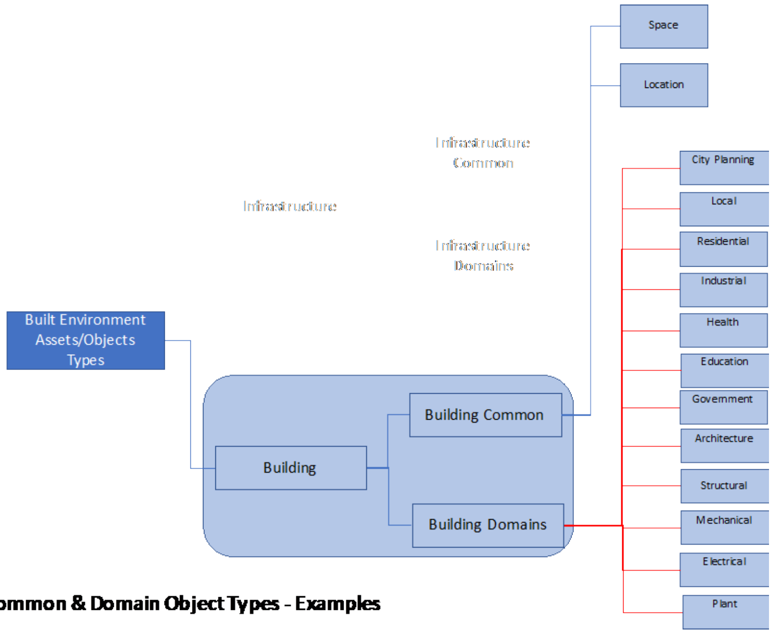
Built Environment Object Types



Infrastructure Object Types Examples



Infrastructure Domain Object Types - Examples



Building Common & Domain Object Types - Examples

There are of course common types of objects that span between Building and Infrastructure which further adds complexity.

7.5.5.1 Type and Classification

There is some confusion as to the difference between type and classification of assets. For the purposes of this report asset types are assumed to be groupings of objects with common characteristics and classification assumed to be the families of objects with common attributes and relationships. It is possible for a type of asset to have multiple classifications depending on the context of its observation. For instance, a foundation may be classified as spread footing, built in situ and made of reinforced concrete of a particular material class. It may further have condition and maintenance classifications that are relevant to the asset manager.

7.5.5.2 Data Dictionaries

Closely related to type and classification are data dictionaries that aim to define every object type and class together with potentially associated attributes. The buildingSMART Data Dictionary (bSDD) is a library of objects and their attributes. It is used to identify objects in the built environment and their specific properties. It provides for links to any classification system. At present the defined objects are mostly related to manufactured products for instance a door or a window allowing users define attributes in a common form and satisfy those requirements from manufacturers web based catalogues. It supports Product Data Templates (PDTs) and tends to look at the world from a manufactured product viewpoint. It's structure however would permit it to define object templates that are more generic and to be used earlier in the planning and design cycle.

7.5.5.3 Requirement for Unambiguous Type Objects

There is a need for an unambiguous naming and description of built environment conceptual objects which include not only physical objects such as bridge bearings, piles, beams, pumps, doors or windows but concepts to describe spatial objects such as network, drainage catchment areas, traffic lanes, local area precincts, parking zones, and urban settlements. These concepts need to apply to the whole life cycle of assets through their planning, design, delivery and operation. This needs to cover the multiple domains associated with the built environment from rail engineering through road and hydraulic engineering, groundworks and environment.

Whilst buildingSMART IFC objects and schema has the facility to hold object type and its commonly used attributes the types of object that define infrastructure assets in general are not fully defined within the current IFC version.

Current infrastructure IFC development, such as the common infrastructure schema, IFC bridge, road, rail, ports and harbours projects, will help fill in the gaps however there is real need to provide an asset managers view of object types that they commonly deal with.

The issue of type, classification and data dictionaries are being addressed across the surveyed organisations in a variety of ways.

- The Netherlands are developing a Common Concept Library (CB-NL) across its construction industry which is being used and extended by RWS into an Object Type Library for transport assets. The aim of this is to create an unambiguous definition of transport objects together with their attribute requirements. Using the concept of semantically linked data the object description can be searched through web resources and linked to other objects such as IFC, GML and documents.

- The Swedish construction industry has developed Co-Class a classification system based on ISO 12006 principles that provides a common language and object attributes across the industry and the lifecycle of an asset. The Swedish transport authority (Trafikverket) has been a leader in this development and is adopting the results in their future projects.

- In the UK NBS have developed UNICLASS 2015 to classify and describe objects within the built environment. It too is based on ISO 12006 principles.

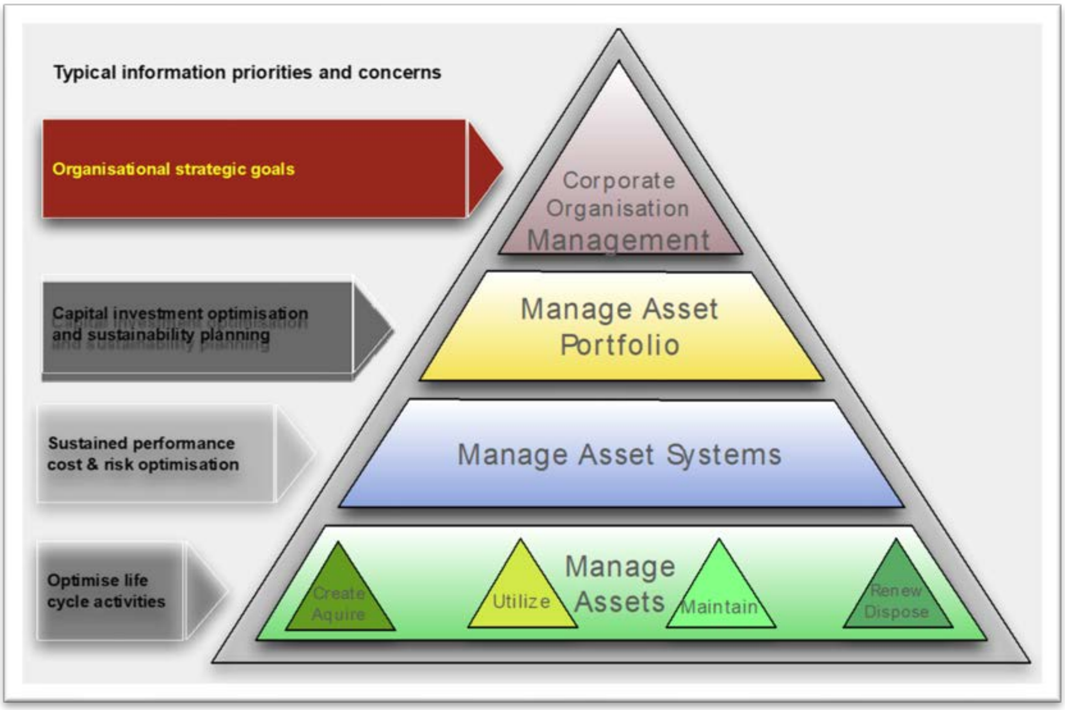
- Others are adopting UNIFORMAT a USA interpretation of 12006

- London Crossrail have developed a series of Asset Data Definition Documents (Commonly called as AD4s) which describe asset object types and their required attribute information. Collectively they form the basis of a data dictionary for a rail type asset. Each document describes required attributes and include not only the product definition but also the function and functional requirement of each asset object. Finally, it has a method for locating and instantiation of an asset and a tagging methodology. Other UK infrastructure owners have been slowly helping to develop the AD4s further through an industry grouping.

7.6 Information Content Requirement

7.6.1 Asset Information Hierarchy

Required asset information can be expressed as a hierarchy of support requirements shown diagrammatically here.

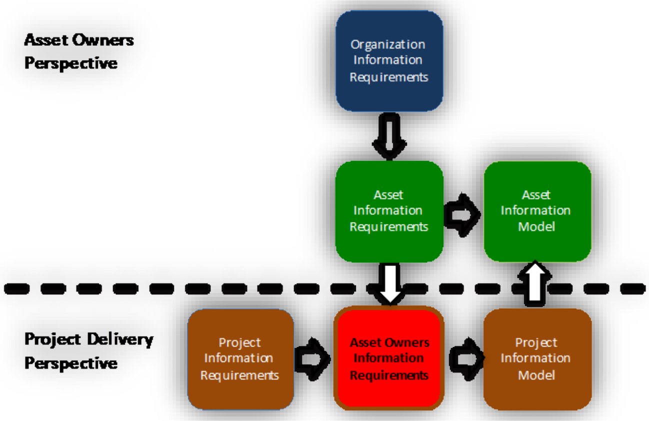


- Information that supports updating, reporting on and analysing corporate organisational goals. These might include KPIs and service performance.
- Information that relates to managing a portfolio of assets. Optimising investment, planning for demand forecasts, sustaining overall service and mutual support of all assets.
- Information that supports asset operational management, service level, performance, assessing and managing risk, and quality.
- Information that supports management and maintenance through an assets life cycle from acquisition through to operation and disposal.

7.6.2 Asset Centric Information

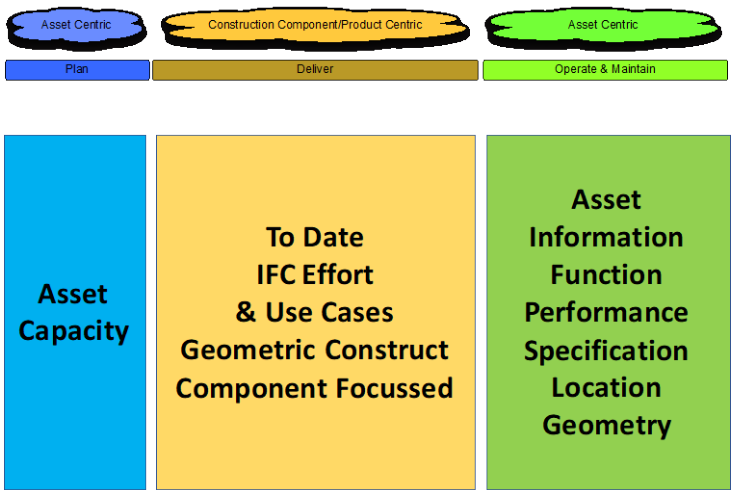
These set the parameters for asset owner/managers information requirements utilising BIM for project delivery. These can be summarised diagrammatically:

- Information that supports the organisational needs.
- Information that supports asset operational management
- Information that supports the project delivery
- Each being summed to the inform information requirements to be delivered by BIM



That information clearly supports not only asset delivery/construction but supports the asset through time not only through project Capital Expenditure (CAPEX) but also as the asset continues its life into operation. Information delivered at CAPEX therefore not only should include that which supports the delivery of the project but also that which supports OPEX and the operational stages of life cycle. It is that OPEX information requirement that this project is seeking to define and give a framework for itemising.

Information falls into two categories 'Asset Centric' and 'Construction Component & Product Centric'. To achieve the ideal BIM delivery, the 'Construction Component Centric' stage should deliver information that supports assets and the Asset Centric stage must provide information that supports operation and future design and construction. To date much of the BIM delivery processes, including IFC, and systems have focussed on the Design and Construction stages. The requirement for asset



Managers is to focus on the Asset Centric information and ensure that it supports the overall asset management goals.

7.7 Avoiding Information Silos

Information is critical in managing any asset through its life cycle. BIM used in design and construction is helping in breaking down barriers between the different technical domains involved in infrastructure. Assisting the disciplines in working together.

Silo solutions have evolved through the historic ways budgets and operations have been carried out, leading to individual approaches to delivering and managing information.

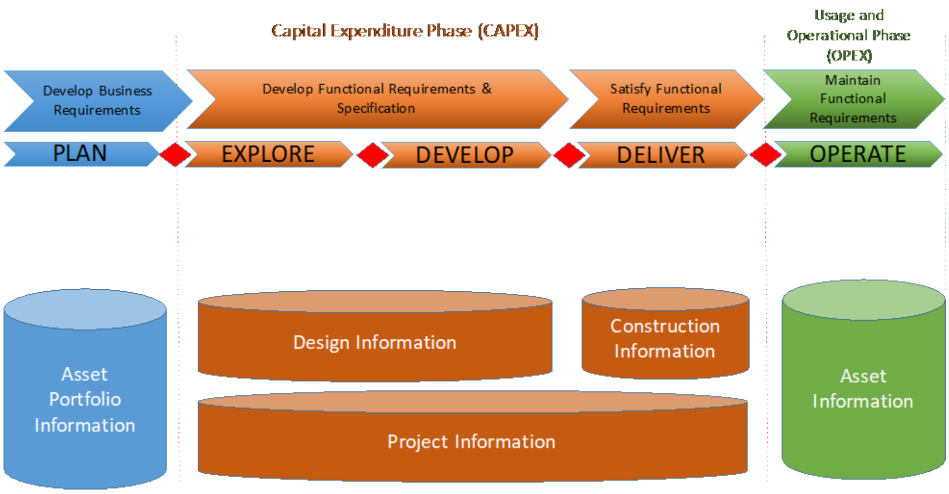
7.7.1 Systems Information Silo's

Technical systems to support individual views of information have evolved over time.

Geographic Information Systems, Building Information Modelling (BIM) and Asset Information Systems (AIM) are each seen as individual disciplines each with their own language, proponents and even professions. Whereas they all in fact different views on or use of 'things' with 'Information' as the common denominator. Hence any set of information requirements must recognise this commonality.

7.7.2 Life Cycle Information Silo's

The division between project led capital expenditure and operation expenditure has led to segmentation of the process and created further silo'd views of information. Breaking delivery into silos of Capital Expenditure and Operational Expenditure often handled under different budgets and success criteria. This has encouraged a 'Project Information' led approach to project delivery with Project Information being treated as a silo rather than the continuum that is truly is.



Whilst there is undoubtedly information that relates to the tasks performed during these phases that are unique to the phase and not useful beyond any asset information requirements should recognise the need for continuity of information and a progressive capture of the information that is relevant to the phases that follow.

7.7.3 Business Information Requirements

Asset are acquired and implemented to serve a business purpose. The business requirements are therefore the root of all asset information requirements and each detailed asset is planned, designed and constructed to deliver and comply with those business requirements.

Any BIM project delivery therefore starts with a set of business requirements.

Requirement	Note
Function	The function the asset is to perform e.g. passengers, flood alleviation etc.
Demand	What demand does the asset meet
Capacity	What capacity should the asset have
Performance	What are the performance characteristics for the asset for instance availability, life span etc.
Sustainability	Environmental, social and economic sustainability requirements.
Constraints	Any constraints placed on the asset delivery.

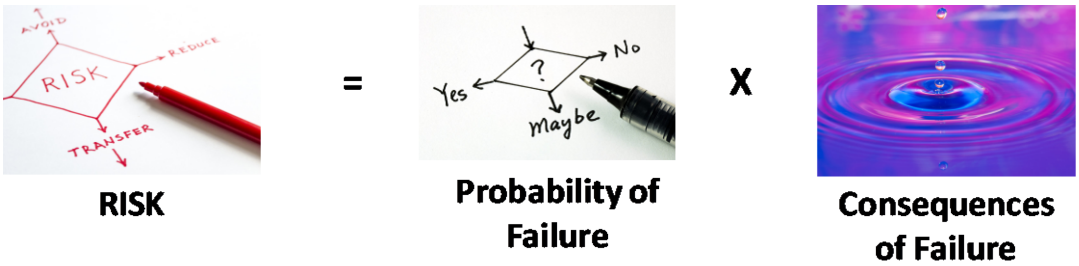
7.7.4 Service Level Information Requirements

The trend for infrastructure asset management is to deliver a service hence the service level requirements form a basic set for information delivery. That is information to ensure that service levels are maintained and improved.

Requirement	Note
Service catalogue	Services the asset supports for example reliability, congestion, speed, journey time and smooth travel.
Function	What function the asset carries out
Risk Criteria	See Risk below
Customer relationship	Will require location and relationship to supporting systems

7.7.4.1 Risk

Information to enable the asset manager to evaluate risk & mitigate against them.



Requires
- Performance characteristics
  - Functional specification
  - Technical specification
- Design life
- Condition
- Maintenance history
- Incident history

Requires
- Function
- Location
- Relationship to other assets
  - Network
  - Connection
  - Entity
  - System

7.7.4.2 Event Planning, Response & Recovery

Information to plan and mitigate against risk scenarios including response plans and recovery plans. This could include flooding, structural collapse, accident response, emergency repairs, power failures, communications and signalling failures

7.7.4.3 Operational Maintenance

For day to day operation information that relates to the asset’s operational cycle and maintenance needs is required along with knowledge of constituent components functional and technical specification and if appropriate manufactured installations.

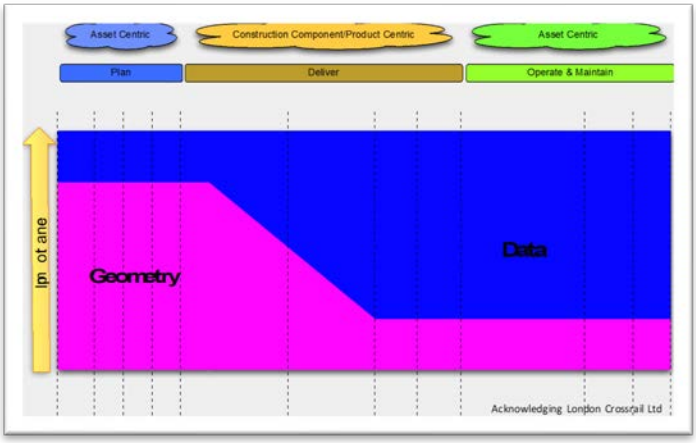
Requirement	Notes
Design life expectancy	The design life of the asset
Preventative maintenance	What routine maintenance should be carried out
Inspection routine	Frequency and scope of inspection
Functional specification	The functional performance requirement of the asset
Technical specification	The technical solution designed to fulfil performance requirement
As built solution	The solution built and commissioned
Manufacturers Part	If appropriate what manufactured solution was installed
Material	If appropriate what materials were used in construction with reference to quality tests

7.8 Object Attributes, Parameters and Metadata

In creating Infrastructure Type Libraries these attributes should be included.

7.8.1 Geometry v Data Attributes

Much early work in BIM has concentrated on geometry and geometric construct information placing importance on virtual construction, visualisation and clash detection. Viewed more holistically through the asset's life cycle attribute data that describe asset characteristics, function and performance has an important role to play. Through time the importance of that attribute data becomes increasingly important as can be seen in this figure drawn from London Crossrail experience. Not only does that data increase in importance but it increases in relative volume.



7.8.2 Geometric Models 2D and 3D

An asset manager's requirement for a 3-dimensional model is somewhat different to that used during design and construction. Design and construction modelling concentrate on collaboration, stakeholder understanding, clash prevention, scheduling and planning, cost modelling and procurement. An asset manager model requires information that facilitates performance analysis, location of asset, asset dependencies, understanding the context of the asset, acquiring access to an asset, how an asset is assembled or disassembled, and how the component parts fit together. It follows that these requirements should be delivered as a result of design and construct BIM.

For the purposes of access to that information, a classic BIM software model is unlikely to meet all the needs of the asset manager but, as said above, it will be the source of some critical asset management information. It may be that an augmented reality view of navigation to or access to an asset is required which turn links to related data, drawings, diagrams, instructions and even videos. So, the information requirement might be sufficient to create an augment reality view in a games engine with capability of linking to a detailed 3D BIM model and associated information.

7.8.3 Dimensional Attributes

Attributes that express dimensions of an asset have different uses throughout the life cycle. At design and construction stage they may express the dimensional characteristics to define and construct the asset in question. Or at construction stage critical dimensions for access and assembly. At the operational stage of life cycle critical dimensions are those that define extents of the asset, extents of access such as door openings or space required to replace something.

Such dimensions must be explicit and their reference to the object not open to misinterpretation. So any type library that defines an asset must be able to show exactly what each dimensional attribute means. Terms like breadth, depth and height are not sufficient. Crossrail's AD4s overcome this by containing illustrative diagrams that define the context of each dimension.

7.8.4 Location

To date the BIM community has treated location as where a particular object might be found in a building using terms that are building centric such as storey/floor, room and grid coordinates. These terms or criteria do not fit the needs of infrastructure despite a few attempts to try to distort them to fit. In fact, the terms floor/storey and space/room are particular types of a generic location attribute.

To achieve location goals information needs to be available to understand the context of the asset, understand dependencies between assets, support navigation to the asset and to gain access to the asset. This would include: -

- Where in absolute geospatial coordinate terms is the asset located.
- Where on a network the asset is located?
- What assets are connected to and depend on the asset for instance to what systems or larger assemblies does the asset belong.
- Where on an access network approach can be gained which might include a road, trackway or footpath that is not part of a primary network.
- The space within which the asset is located which might be a roadway, an offset from a reference line, embankment, planting area, bridge deck etc.

7.8.4.1 Connected (Topological) Location

Information that defines the spatial relationship between adjacent or neighbouring features. In particular this refers to the network that the asset is associated with or located as part of. Hence asset information delivered by BIM should hold either implicitly through relationship or explicitly its connected location. Is important as it defines how failure or impeded function of and asset impacts the greater asset group.

7.8.4.2 Geospatial Location

Describes where in geographic space an asset is located. In building terms, this is often related to a simple building grid however in infrastructure, which covers much wider geographic space, however this relates to position on the earth's surface and may involve map projection, a local or project grid. It follows that BIM delivery should include how this is translated in coordinate form.

7.8.4.3 Linear Location

Finding an asset and locating an asset in place in relation to a linear feature such as a pipeline, tunnel, roadway or railway is not always best achieved by absolute coordinates. Features such as street furniture, speed attributes, location of signals, and overhead gantries, changes in camber/cant location of drains along kerbs and kerb offsets are best located by linear position along a reference line.

Often position relative to an alignment is the most important feature for obstacle clearance such as dynamic rail vehicle envelopes in tunnels or under bridges.

There are many types of linear positioning which can include chainage along a route, walk up distance from a tunnel portal, relative distance to a marker.

Those location attributes required for each of the above and more are defined in ISO 19148:2012.

7.8.5 Functional Attributes

The systems approach to information delivery necessitates the recording of the functional requirements of each asset object as it is developed and for those functional requirements to be refined and become more detailed as the planning and design progresses. Each development stage inheriting and building on the less granular object information from the previous stage. Not a replacement process but an additive process.

Functional requirements should include the performance requirements of the asset for instance capacity.

At a primary asset level for instance a bridge might be defined as an over or under bridge with capability of supporting a number of traffic lanes or rail track to a particular load specification.

At a component level a bridge bearing might have performance criteria that requires carrying a specific load, have restraint characteristics and translational movement capability.

7.8.6 Technical Specification Attributes

At the point of design completion details of technical specification for asset to be built should be recorded which will include design criteria such as strengths, structural analysis force requirements and material specifications.

7.8.7 As and Built Commissioning Attributes

At the point of build the details of what has actually been constructed, assembled or installed to meet the asset functional and technical design specifications should be recorded. This might be a manufactured object, a pre-fabricated assembly or it might be an in-situ construction together with details of materials used and any relevant test results.

For assets that require commissioning then the results of the commissioning tests should be included.

7.8.8 Condition Attributes

At the point of handover into operation the condition of the asset needs to be recorded. This will differ depending on the type of asset being commissioned. A number of individual databases for asset management currently used by asset managers will give indicators of what that information might be.

7.8.9 Information Delivery Packaging

As mentioned earlier in this report the current use of the buildingSMART IFC objects are mainly to transfer information between software tools and processes. Often supported by a specific Model View Definition (MVD) that defines what information is required for a specific use case.

Model servers based on IFC have been developed but are not widely used. Similarly, software has been developed to carry out model viewing and model checking for example Solibri's tool set.

However, most of these systems are building model orientated and rely upon the existence of appropriate IFC to contain and interact with the model. Currently the IFC's to describe infrastructure assets are not available although they are under development.

The asset manager's requirements are to receive information in a form that they can utilise from each stage of an assets life cycle. That information may be used to complete an asset register database, provide attributes and meta data about those attributes to be captured and controlled in an asset management system.

Whilst the IFC schema can potentially contain much of the object information required by the asset manager it is unlikely that the requirements of an asset manager could be fulfilled by an IFC model. It is therefore more likely in the short to medium term future IFC files, that contain relevant asset objects information that include geometric and alpha numeric attribute, are the delivery package mechanism that meets asset manager's needs. Together with related support information contained in other sources such as documents.

Information will thus be delivered and exchanged in packages that meet information requirements at that stage.

The payload for those information exchanges will include information that includes models but also information that relates to objects in those models.

- Network Models
- Design Models
- Capability and capacity models
- Functional and technical specification
- Construction and as built models
- Object attributes not held in models
- Documents supporting the objects such as:
    - Sketches
    - Detail drawings

- o Manuals
- o Photographs
- o Instructional Videos
- o Safety instructions

Whilst in future it may be possible to deliver all this information via an integrated web based data source at present and in the immediate future the delivery will need to be packaged for delivery.

The UK BIM strategy characterises delivery packages as information exchange packages that fulfil information requirements at defined stages of the asset life cycle.

Two approaches to delivery packaging were discovered during this project: -

- The UK BIM Level 2 approach of delivering a native BIM model, together with supporting documents (which are coincident with the associated models) and an extract of attribute data for all the objects contained in the BIM model in a structured form using COBie (Construction Operation Building Information Exchange). It's implementation is set out in British Standard BS 1192-4:2014 which includes not only Building Spatial locations but extensions to deal with Infrastructure spatial and linear location.
- The RWS (Rijkswaterstaat) approach using COINS (Construction Objects and the Integration of processes and Systems) a standard for the exchange of BIM information. It provides a data exchange container for BIM related information. It is designed to meet the need for information deliveries which commonly consist of combinations of various data structures. Including functions, requirements, objects, GIS data and models, 2 D drawings, IFC models and object type libraries. It uses Object Type Libraries, Semantic Web data linking to relate information and is closely linked to the Dutch Object Type Library (OTL). It is currently being considered and developed as an ISO standard.

It is not the purpose of this report to compare in depth these solutions they both recognise the need in the current state of development of BIM to package information delivery from multiple sources and to interrelate that information in a structured fashion. COINs formalises that relationship whereas the UK Level 2 approach relies on COBie to make those relationship links.

COBie data structure has a distinct advantage in that its data content and structure is based on the IFC schema and hence information integrity is preserved when delivering IFC based model. It is based on a spreadsheet delivery format which helps when dealing with the whole supply chain providing a lowest common denominator delivery mechanism..

COINS provides a wider range of information source relationships and can accommodate flexible use of language and domain vocabulary. It is designed to incorporate differing modelling methodologies so can for instance include reference to GIS models as well as BIM models. It is designed to utilise IFC models as one of its model delivery solutions amongst others. It incorporates the buildingSMART messaging standard (IDM) to track and handle messaging between suppliers and receivers of information. However, it lacks the rigorous delivery process being developed in ISO 19650.
There is a danger that IFC model delivery is relegated to geometry only object model delivery, which would not use the full potential power of IFC or indeed GML, in adopting the COINS standard. However, COINS, as mentioned above, has been used successfully in a number of infrastructure projects in the Netherlands linking IFC objects to data extracted from IFC with additional attributes that extend beyond those currently contained in IFC.

There is therefore a requirement for the closer integration of Object Types outlined in OTLs and the Type function used in IFC. And a better use of semantic descriptors for types to ensure an integration of information delivery. Plus clear definition of object attributes to be delivered in an open fashion which does not need an IFC server to interpret and extract.

7.8.10 Linked and Semantic Data

As previously stated all required asset information is rarely delivered in a single BIM model but is the result of a number of information sources that are packaged together. These data sources may be looked on as individual but potentially linked information. The linking relationship between information objects can be fixed, dynamic or even inferred. That is information links might be fully and hierarchically structured or they might change depending on context or linked by inference and machine learning.

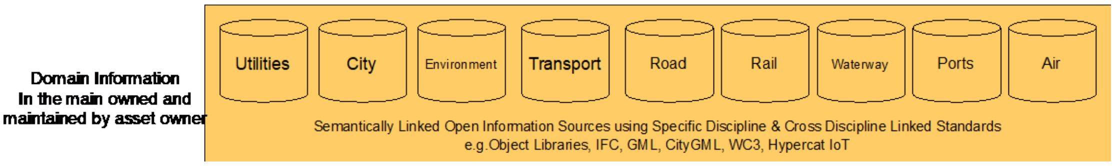
Asset object information therefore does not fit into relational tables but needs a capability of joining different data sources, technologies and relationships. Multiple data sources multiple data related to asset linking semantically rather than embedding in object.

Additionally, asset information is sourced from multiple domains each with their own vocabulary and structures. Some of those domains may be outside the direct control of an asset owning organisation but still needs to be available to support a service based asset management strategy.

The capability to link and make such information available is key to future use of asset information.

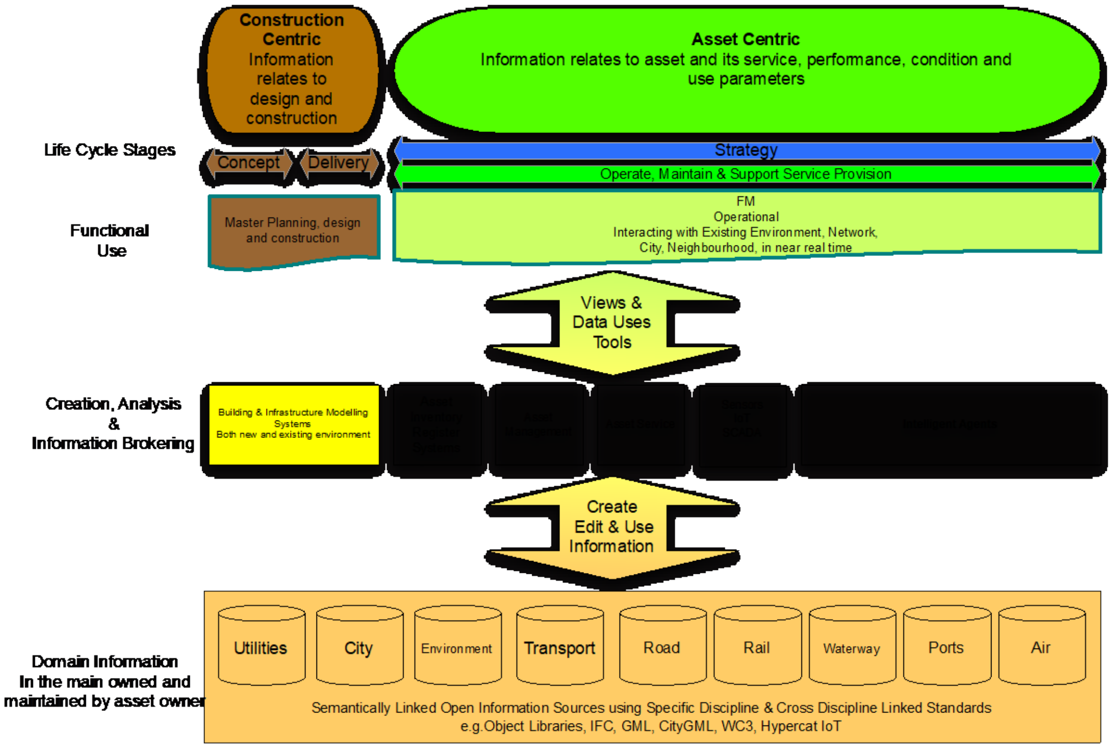
The World Wide Web Consortium (W3C) have developed standards to provide a common framework to share and reuse data across application, enterprise and community boundaries. This standard is reliant on using a common resource descriptor framework (RDF) for describing objects on the web in such a way that they can be search for and used without a common database. Commonly known as the Semantic Web it takes the principles of the world web from document sharing to data sharing.

The concept provides linking across multiple sources, owners and domains and also provides a platform multiple domain ontologies to be linked.



Thus information encoded in semantic web standards can be shared not only within domains but across organisations using the language understood by the individual user but useful to the wider community both inside and outside an organisation.

This exposes multiple users to information exposed beyond direct asset managers



The above diagram envisages multiple domains and organisations exposing selected and controlled information in such a way. The model allows asset information owners to capture and own information critical to their operation but also gives access to information via tools to other users and ultimately public consumption.

Such a model obeys a critical requirement in that asset owners ultimately take ownership of information about their assets, are able to control it and share it amongst their internal origination without relying on a single database using tools appropriate to the specific stakeholder’s interests. They are also able to share information across the public WWW to other stakeholders.

This has a number of benefits including being able to connect with national, organisational and domain data classification systems and data dictionaries. It overcomes the issue of building data dictionaries that hold unique names for every object hence can span multiple languages and interest groups.

As objects become self-reporting through the Internet of Things (IoT) using similar semantic languages such as Hypercat this will facilitate automatic data collection and a portal for its analysis.

The RWS Object Type Library and the delivery packaging COINS has adopted the principle of Semantic Linking.

In 2015 Conference of European Directors of Roads (CEDR) commissioned the INTERLINK consortium to carry out a research project to design and test an open, scalable basic object type library for road assets. The fundamental premise of the INTERLINK proposal was that the effectiveness of this European Road OTL relies on the capabilities of Linked Data and the Semantic Web. This will enable CEDR to implement a software vendor-neutral system, which is applicable to the whole life-cycle of road assets, accommodates various existing and future open data standards, and facilitates a hybrid approach of linking semantically-rich data to more traditional document-based information.

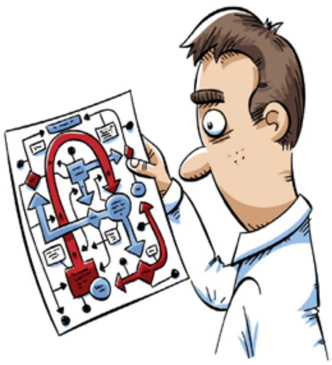
The project drew on lessons learned from an earlier European research project, Virtual Construction for Roads (V- Con)

During the course of preparing this report the author has shared findings and discussed outcomes with the consortium. The INTERLINK consortium issued a final report on requirements in March 2017. It provides an excellent introduction to the subject of OTLs and Linked data plus application and direction of further work.

A buildingSMART project to write IFC in OWL a semantic ontology language is underway but needs to be completed and integrated to support these capabilities.

7.9 Information Delivery Process

The findings of this report suggest that asset managers require data collected in a continuous process throughout the life asset cycle rather than exchanges between software applications or single 'drops' of information at completion of projects or asset updates. This implies that a key requirement is the availability and exposure of data in an open consumable and useable form throughout the planning, design construction, commissioning and operation. That that data has relationship to assets in all their parts and can be directly linked by structure and content.



To date much of the work of buildingSMART standards has related to exchange of information between specific tasks, interoperability or transfer between software. For instance, exchanging data between two design software applications. Or the final delivered products as a catalogue of things typified by manufacturers Product Data Templates which itemise those things without reference as to their purpose and functional requirements, in other words why they are there.

The Asset Managers requirement is to capture, configure, manage and maintain information about assets throughout the lifecycle process each step of the way not just at individual points of transfer.

To achieve this, we have seen that a systems approach to data delivery verified against requirements is essential. This cannot be achieved without adoption and use of a rigorous supporting process which ensures that the required information is delivered as part of the delivery contract and that the information is coordinated, verified and validated at each step.

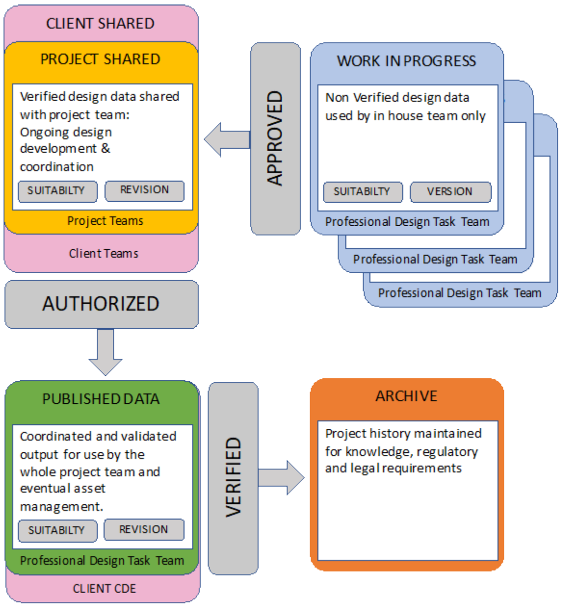
Whilst it is not the purpose of this report to recommend a specific process or processes it is suggested that the principles developed in the UK based BS 1192 series of standards give us an indicator of what is required. These standards outline how a collaborative delivery process should work alongside the steps for contractual delivery of information against a set of asset owner's information requirements. This standard is currently being developed into ISO standard as ISO19650. This has not yet completed its ISO drafting and agreement process so it is not yet published so we cannot quote from it directly. However, the diagram shown here, published with the drafting committee's permission, gives an indication of how the life cycle information process fits into the asset management and organizational management framework of an asset owning organisation.

With acknowledgement to ISO 19650 Drafting Committee

7.9.1.1 The Common Data Environment

Key to the process is the definition of a Common Data Environment (CDE) that sets out the principles and conventions to safely coordinate across disciplines using a federated data model approach including model segregation, data model development, revision and version tracking, purpose of use metadata, and approval states. It also provides the basis of a process for defining information requirements and a contractual process for delivering that information stage by stage.

It follows the development of multiple through the logical stages of individual task teams creating and editing Work in Progress to Sharing with other teams for coordination and collaboration and with clients for approval before publication for use for a defined purpose. The modified diagram shown here illustrates that process. Whilst, as explained elsewhere in this report, not all development information in the supply chain needs to be presented and held for asset management, that information will need to have gone through the CDE process to ensure it can be trusted and used by asset managers.

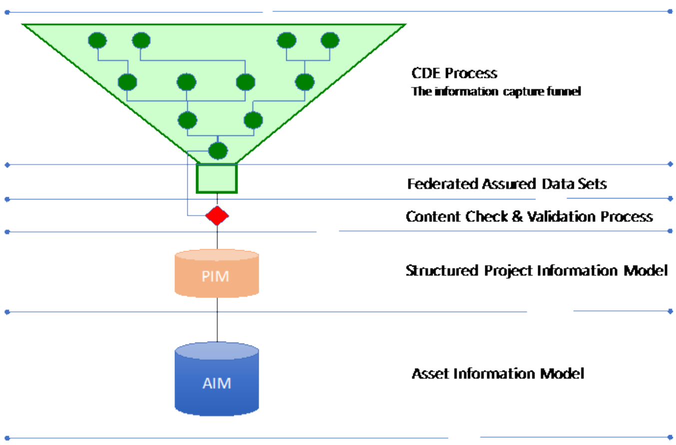


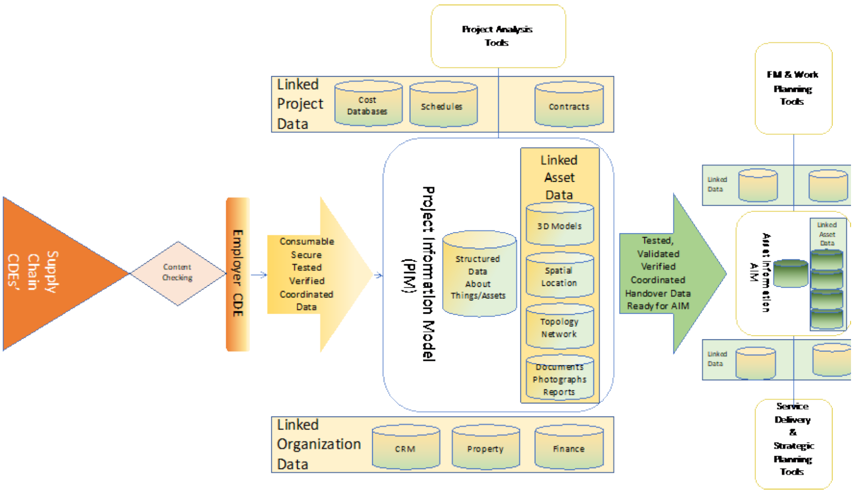
Information Coordination Process after BS 1192 and proposed ISO 19650

It should be noted that the CDE thus defined is not just a single source of truth data base but a process tracking and fulfilment methodology.

Using the process enables the asset owner to follow tracking of delivery of verified data that has been checked in development.

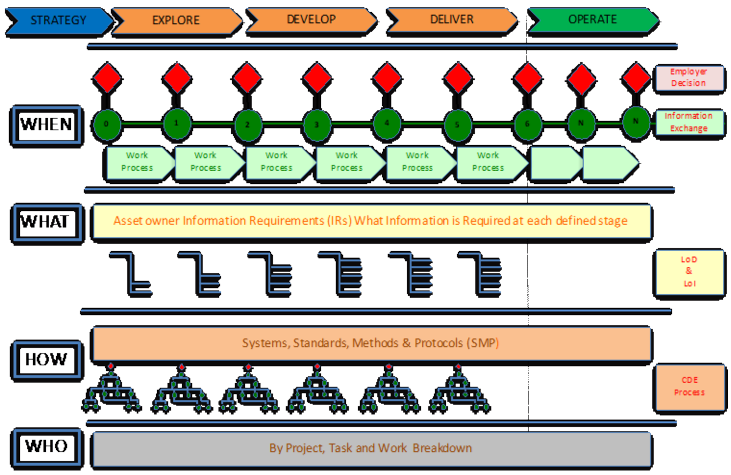
The Common Data Environment process is designed to be cascaded through the supply chain to deliver information to the asset owner as verified information ready for checking of content in the asset owners CDE. Acting as an information capture funnel of federated data sets, linked semantically to other related data and that can be checked for content, validity and verity before being passed into the asset owners information systems.





7.9.1.2 Contractual Information Delivery Process

The standard goes on to define the contractual delivery process defining what information is required to be delivered at what time/stage of a project and how that can be delivered plus who will be delivering that information.



In order to satisfy the asset managers BIM requirements, the following will therefore need to be recorded as part of the information set:

Information Requirement	Notes
Proof of quality and trustworthiness	Proof that the information has been coordinated across supply chain
Verification against information requirements	Proof that the information is verified against requirements for stage of delivery against that specified e.g. as designed against as conceived, or as built against as designed
Information provenance	Source of information and its version
Information suitability	What purpose the information is suitable to be used for (accuracy and development)
Information completeness	Has all the required information been delivered.

Current buildingSMART standards do not support these process delivery requirements and need to be developed to accommodate these requirements.

The Information Delivery Manual (IDM) together with Model View Definitions (MVDs) does define process it generally has been used to look at the process between different delivery tasks or software applications.

There is therefore a requirement to re –think the MVD not as a software to software process but as a connected flow of asset information stage to stage through project delivery and asset configuration manangement.

The BIM Collaboration Format (BCF) is designed as a communications tool between software, it therefore takes care of messaging during coordination and collaboration and tracks change however it does not track provenance and completeness.

BCF 2.0 which extends the content however to fit in with the concept of a systems approach to information needs to be extended to support ISO 19650 information delivery processes.

There is potential to look at these as possible process information capture tools. However, a more promising longer term avenue for exploration is the use of ‘Blockchain’ technology – a distributed database that can be used to maintain a growing list of records, called blocks. Each block contains a timestamp and a link to a previous block.

8 Acknowledgements

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In particular for the help of Richard Kelly, Jim Plume, Benno Koerhorst from the committee and Anne Kemp of Atkins for their positive input and critique of the document as it has progressed.

For the all interview and discussion participants for their patient listening and contributions.

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10 Appendix A – Pre-Discovery Session Briefing Documents

10.1.1 Overview

This project commissioned by buildingSmart International InfraRoom is designed to assess and define the information needs of infrastructure asset managers in receiving and keeping pertinent and accurate information regarding the assets as they are planned, delivered and maintained.

The infrastructure construction industry is shifting progressively from recording information with documents and drawings, which are paper-based, to adoption of computer technologies and a shift from electronic documents and drawings (file-based) through to digital data. Increasingly Building Information Management (BIM) will embrace structured and unstructured data and information collected over the entire life of assets, including geospatial, survey, condition monitoring, operational, maintenance, condition, performance and utilization of assets. BIM is therefore triggering a digital transformation of the infrastructure industry, with development and management of the virtual world becoming as important as the physical. This embraces not only the built but also the surrounding natural environment as well, including our interaction with the overall physical environment which we inhabit, and which our industry works to support.

In this context, the manager of assets has a vital interest in receiving complete, accurate, validated, quality information and in keeping, managing and maintaining that information during an asset operational lifespan. This makes the Asset Manager a key stakeholder for digital information providing a clear requirement driver for information standards. The demand for this Asset Manager Information is now being recognized as a key deliverable from projects and hence an important factor in delivery using BIM in projects both for new assets and updated and maintained existing ones. Some procedural standards, such as the ISO 19650 *(Specification for information management for the capital/delivery phase of construction projects using Building information modeling)* currently under development, are recognizing this need for collecting Organizational and Asset Information Requirements. However standards for delivery of that information are often overlooked in the development of openBIM, GIS and other standards.

10.1.2 Project Goals

Recognizing that asset managers form an important stakeholder group in the life cycle of Infra information and that coherent quality information developed and tested during project delivery to handover and future use. This project aims to bring the requirements from asset managers into view to inform the commissioning and development of future bSI Infra standards. Analyzing the requirements, reporting them systematically against existing and projected standards to provide a recommended roadmap for future standards development including potential benefits and an outline business case.

These goals can be summarized as: -

- Discovering, clarifying and making explicit the requirements for delivery of asset information from the perspective of organisation and their asset managers.
- Understanding the asset managers requirements for BIM information in the strategic and operational management of assets.
- Translating the requirements into openBIM Standards requirements.
- Providing a Roadmap of steps responding to the requirements.
- Disseminating the results.

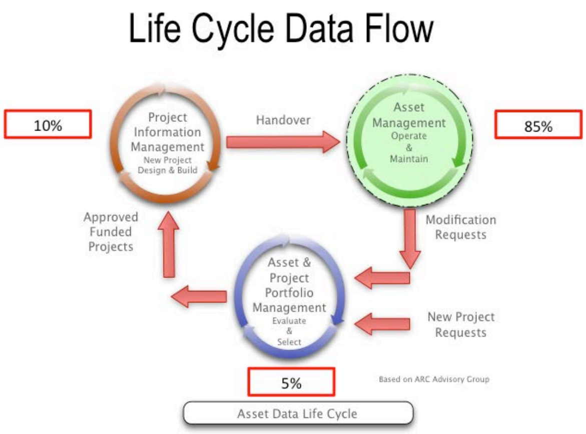
10.1.3 Discovery Sessions

A number of discovery sessions are being held with infrastructure asset owners followed by a more general survey of requirements.

During these sessions we are aiming to understand how the organisation being interviewed currently handles capture of asset management information and what their plans are for the future and in particular how they anticipate incorporating information created and managed during the lifecycle using digital tools such as BIM models into their procedures and systems.

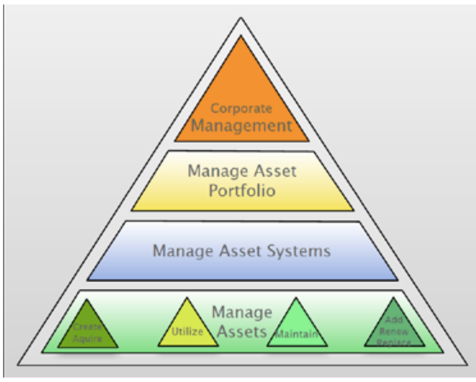
10.1.3.1 Information Life Cycle

The project aims to follow information requirements through the lifecycle of assets and categorises information into three natural divisions illustrated by the following diagrams:

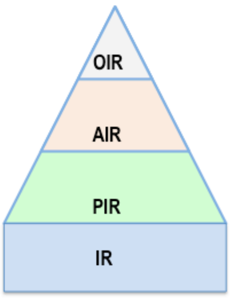


- Information required by the owning body to manage the overall portfolio of assets and their performance.
- Information required for managing assets during their operation.
- Information required for managing the delivery of the asset during its planning, delivery and handover stages.

Supporting this life cycle information needs to be supplied and managed as a continuum covering and supporting the responsibilities of the owning/managing organization.



During delivering a new asset or updating and existing one information needs to be captured, verified and validated against three distinct requirements.

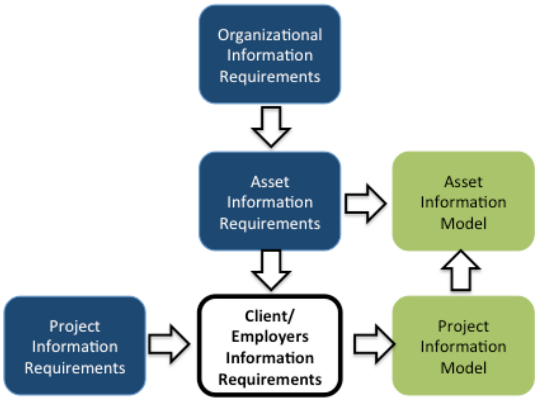


Content	Notes
Information supporting the Business & its Functions	Information for the business strategy and signoff
Information about the physical assets being delivered & operated	The core of information delivery requirements based on Asset Data Definitions
Information supporting project delivery	Information required during project delivery e.g. environmental data, cost, etc
The sum of OIR, AIR and PIR	

These can be characterised as

- Operational Information Requirements. (OIR);
- Asset Information Requirements. (AIR)
- Project Information Requirements. (PIR)

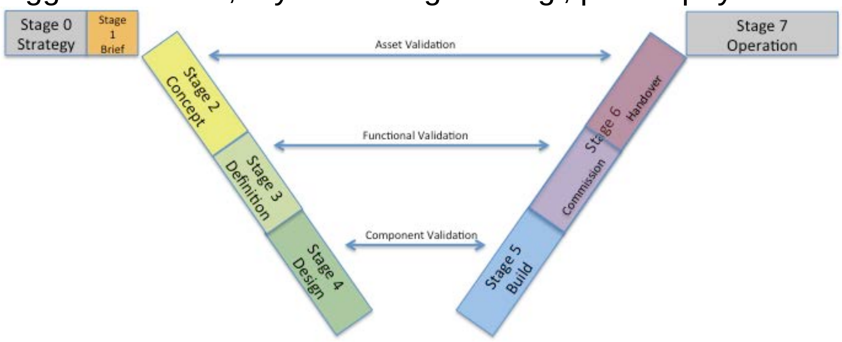
These fit together to form a map of information requirements for delivery during any asset change be it a large new project or a small operational change and provide the asset owner with a rational information flow. In many current BIM projects this holistic view of requirements is often forgotten and the information collected concentrates on the geometric configuration and construction logistics. However in order to achieve our long term operational goals a more complete set of requirements are critical. It is these requirements we want to bring into view as new open standards are developed.

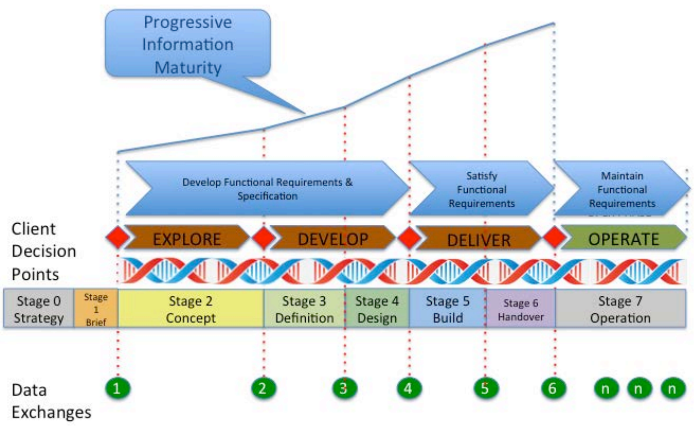


During our discovery sessions, we want to understand how your organisation handle these categories of information including current and future planned systems.

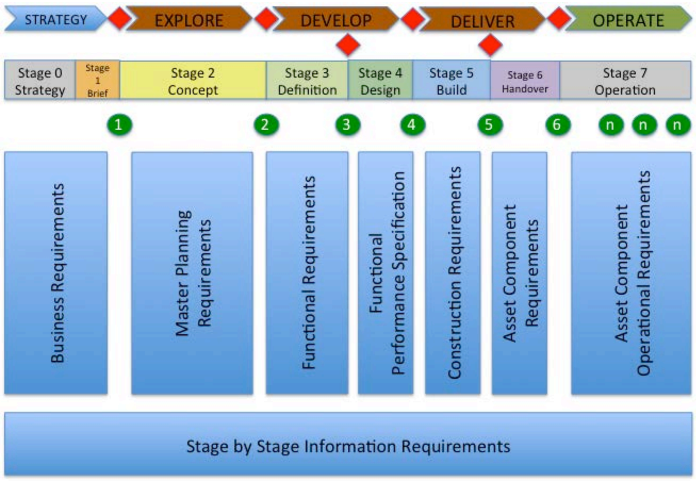
10.1.3.2 The Systems Approach and Embedding Functional Requirements

In order to develop a logical approach to capturing and delivering these requirements it is suggested that a, 'Systems Engineering', philosophy is adopted. Taking the delivery of any asset through its various stages from planning to operation and ensuring that the information is captured progressively. The delivered solution becomes one of satisfying planned, designed and delivered assets that meet the requirements embedded in the process.





Information then becomes progressive and carries with it the DNA of the developing asset through the process.



Thus delivery of asset information becomes one of satisfying a series of increasingly detailed requirements developed during the stages of project delivery. It is then possible to not only find the position and physical characteristics of an asset but also why it has been designed, built and installed and what part of a wider requirement it fulfils.

During our discovery session we want to understand how your organisation currently or plans to fulfil this need and to collect any observations you have on the approach.

10.1.3.3 Asset Data Dictionaries/Libraries/Templates & Classification

Delivery of information needs objects/things to deliver information against. Typically these have been traditionally delivered using as built paper documents together with specifications and bills of materials. As the delivery of projects and operational repairs/modifications become digital (BIM) these need to be defined as components which can be logically understood and digitally described at each stage of delivery. Whilst it might be tempting just to look at things from the final asset point of view the build up of those assets and their underlying information is equally important.

A logical way to approach this is to provide object template libraries aligned to the Work Breakdown Structure (WBS) for delivery and management. Thus an asset might be made up of systems, assemblies and components that satisfy the requirements of primary assets and overall facilities.

During our discovery session we want to discover what asset libraries, templates and component classifications are currently being used in an organisation and whether they have any asset dictionaries and data templates.

10.1.3.4 Current Asset Management Systems

Many organisations have current systems to manage their assets based on historic information delivery mechanisms such as handover of drawings, documents, specifications and re-survey of as built assets. We want to gain and understanding of what asset management systems are currently in use in your organisation and what future plans the organisation has for these systems.

10.1.3.5

10.1.3.6 BIM Potential

Finally we understand as BIM matures it offers many opportunities to collect, manage and use significantly more information than many Asset Management Systems do not recognise or handle. Plus a good BIM delivery should offer the opportunity to deliver tested and trusted information to the asset manager removing the need for re-survey or manual interpretation and input of drawing and documents.

We want to understand what the organisation might feel the potential for BIM delivery is, how much information is useful to collect about materials, conditions and issues during construction for instance. It will be technically possible to deliver full 3D models to associate with the asset database. What is the utilisation potential for such models bearing in mind the long-term maintenance implications of such models?