# Nordic Study of Classification Systems for Infrastructure & Transportation

Author: Phil Jackson
Intra Teamit consultants

Version 1.0 July 2020
bSI Document Number: IR-2020-1022-TR

Practical Requirements for Classification of Information in Digital Engineering & BIM

**Report Key Contributors:**

Knowledge without understanding is meaningless. – *Douglas Adams – 'The Hitchhikers Guide to the Galaxy'*

We are stuck with technology when all we really want is just stuff that works. How do you recognize something that is still technology? A good clue is if it comes with a manual. – *Douglas Adams – 'The Salmon of Doubt: Hitchhiking the Galaxy One Last Time'*

## Table of Contents

# 1 Executive Summary

The report investigates the current state of classification for the built infrastructure environment, while acknowledging that present tools and systems need to recognise the rapid move towards a full digital description of assets and their functions. It examines criteria for transition and future classification systems. In addition, the report looks towards fully information modelled outputs and linked information, which create a 'Smart Infrastructure' world.

# 2 Conclusions Summary

The following are a summary of conclusions drawn in this report:

- Classification allows us to understand and identify object types and the properties associated with them.
- There are several critical criteria that should characterise choice of classification tools, identified and laid out in the report.
- Most current classification systems are still evolving and developing and hence do not meet all future and present requirements. All require further development to fill the current gaps in their implementation.
- There is a danger of trying to force fit BIM requirements into classification systems that were designed for the analogue era rather than evolving them for the digital engineering future.
- The industry is in a transition phase moving from analogue information capture and distribution to a fully digital one.
- The tools we choose during this migration phase must support both but lead us towards fully digital as soon as possible.
- There is no specific Classification system that can be recommended; however the features and aims of CCS & CoClass (which combine the requirements of current facet and enumerated standards plus uses reference designation approach defining relationships and aims culminate in asset delivery) comes closest to meeting the criteria. However, it is recognised that there are some issues relating to the use of function as a main sub-divider which need to be resolved.
- Although classification is often used to generate intelligent name labels for objects and features in CAD and BIM Models this should be regarded as a transitionary process used whilst users still rely on current design tools.
- The question of the difference between a Project Information Model (PIM) and an Asset Information Model (AIM) is redundant. Information about an asset is created at the start of a project and evolves through the life cycle, which includes planning and delivery projects to become the complete asset information. In other words, information through life cycle is progressive. The only difference would be that during the design and construction stages contractual and progress information would be attached to the asset under development.
- A rigid hierarchical view of classification should be avoided in future classification but rather a more recursive hierarchy be adopted.
- There should be an effort to simplify classification.

- Future digital engineering should look to identifying an object type, instantiating it with a unique reference and linking it to properties that define that object rather than cross referring to multiple complex tables. In other words, simplifying identity rather than adding complexity by including in a string of constructs from many tables.
- The use of object types with related properties associated with classification has potential to simplify what has become a very complex subject.
- The existing systems have much information that could be used as a basis to build object type libraries.
- It is suggested that development of Nordic Object Type Libraries would bring together many of the current disparate approaches.
- Whilst the object type library and semantically linked information approach to identifying and relating information is in its relative infancy there is little doubt that it provides a good solution to the industry’s needs in the medium to long term.
- Although the industry is not yet fully prepared for a linked data approach, we should endeavour to prepare for it by incorporating it into our standards and make it our direction of travel.

# 3 Introduction

## 3.1 Background

The use of classification in the construction industry has a long history and many studies, presentations, words, reports, research project outputs and numerous standards have been written to meet the needs of the many stakeholders involved in the industry.

Early classification systems (such as CI/SfB) concentrated on the location, indexing and filing of documents and their contained information. Over time the need for a more accessible and data related forms of indexing has evolved and a number of classification approaches have emerged covering various aspects of the industry. Many of these have been developed to meet needs of specific information domains, for instance quantifying material and cost involved in construction. Some concentrate on product information, that is the products chosen from catalogues to meet specific project needs rather than capturing the functional and relational information requirements of potential solutions. There have been many national efforts to develop classifications that suit local conditions and industry supply chains. Most have concentrated on the classification of buildings and their components and few on the broader aspect of infrastructure and the assets that are included in that broader view of construction.

Building Information Management (BIM) is changing the way we deal with information across the industry moving from information contained in documentation to data related to specific things and processes each captured stored and managed in information technology solutions. There are many definitions of BIM, however, the essence of the current information revolution in relation to construction stretches beyond many of those definitions to encompass all contained and related data involved in built assets through their lifecycle of planning, design, build, operation and deprecation.

The advent of BIM and Digital Engineering has, as mentioned above, set off a disruptive revolution in the world of built assets across their whole life cycle from concept through exploration, design, construction and operation that is changing processes and delivery for all involved. Moving from an analogue approach to one where all disciplines involved in that lifecycle take a digital view of related information and the creation of digital virtual versions of assets (sometimes referred to as 'Digital Twins') that can model physical position, construction, predict performance, measure actual performance and analyse behaviours of assets are created, managed and maintained. To support that revolution, the methods and tools of identifying assets, their components, costs and function must be modified and improved. In other words, how things are classified and recognised needs to be developed and modified. This inevitable reflects on how we classify our built assets and their construction.

It is, however, true to say that we are in the midst of that revolution and during the move from analogue to digital there will need to be a corresponding evolution of the tools and techniques we use en route. Hence any development of classification must reflect the needs of that journey.

It is with these thoughts in mind that this study and report has set out to distil some practical thoughts and recommendations answering the questions set out in the brief below.

## 3.2 Authors Note

The author wishes to be clear that he makes no pretence of being a classification expert but rather is an engineer who needs to understand the use and application of classification in the tasks and processes that need to be undertaken during the life cycle of a built asset. Discovering and sorting the various reports, standards, classification systems, codes of practice, technical terms, and technologies associated with classification has proved to be a difficult process. There are various reasons for this: -

- Many classification systems started their life with specific purposes and related to particular tasks in the design and construction of products rather than a holistic view of asset planning, creation and operation.
- The language and terminology used by classification experts and more recently those involved in technology-based modelling systems is confusing. All too often terms like taxonomy, ontologies, semantic language, organisational architecture and modelling languages enter into the discussion. These are terms that most engineers are not familiar with and hence they soon find it difficult to direct their thoughts in applying their knowledge.
- The industry finds itself in a half-way house position having to deal with legacy information, tools and systems but be getting ready to and making the migratory journey to the world of information systems, internets of things (intelligent sensors), semantic data linking and what gets termed 'Big Data' which involves the analysis and application of artificial intelligence to information collected, created, captured and delivered during the life cycle of an asset.

For these reasons this report approaches the problem from a practical working engineer's point of view and attempts to find requirements that are both simple but able to deal with the complexities of the world of digital engineering.

Some of the questions in the original brief remain unanswered or at least not completely answered. Questions such as what of the current systems should be the basis for future use or what of the current classification standards are fit for foundation are difficult to answer. The author finds that many of the answers to those questions need to evolve rather than be categorically evaluated at this stage due to the transitionary nature of digital engineering development.

## 3.3 Brief

The Nordic Road and Rail BIM Collaboration Group of organisations (see list in Appendix A 2) responsible for Road and Rail transport in the region are seeking to coordinate and collaborate in their approach to a move towards the, ‘Digital Engineering’ (BIM), transformation of the industry and the assets they plan, develop and control. As part of that collaboration they have identified information classification as an important key to delivering the processes and tools for the effective utilisation of information. To that end they have commissioned this study to understand the important aspects of classification that should be considered in choosing and developing the best approach to adopt both now and in the future.

A full copy of the Brief for the study is available in Appendix A - 1 of this report

Principle deliverables of the study are to clarify:

- What is classification system?
- Why it is important to have a classification system?
- Which major classification systems are available?
- Which ISO standards are behind the major classification systems?
- What are the differences between the major classification systems?
- What is linked data?
- Is the construction business ready for linked data? How do we secure the information flow before linked data is in place?
- Is there any conflict using classification systems and linking data at same time?
- What are the tendencies for development of classification systems?
- Comparing different classification systems are there any of them better covering linear assets?
- Comparing different classification systems are there any of them better covering lifecycle including asset management?
- Comparing the classifications system if they allow to split up and follow the asset as a function and the physical element that realizes the function.
- What are the challenges and benefits implementing the compared classification systems?
- Which criteria are important when evaluating classification systems?
- What other standards are needed to describe linear assets?
- What other standards are needed to describe the different aspects from PIM and AIM

# 4 Research

In order to understand the current state and use of classification and to look at future requirements initial research was carried out to review classification standards, supporting standards and to review both present and projected use within the participating organisations.

## 4.1 Desk Study of Classification Standards and History

An initial desk study of standards, related standards, documents and classification implementations was carried out.
Baseline Standards

A number of international and national standards and codes of practice that inform the development of classification in the industry were gathered, studied and reviewed to provide a framework for the project.

During the development of this report several standards were discovered that have some relevance. Every effort was made to include as many of these as possible in the study however the author is sure that there are probably more undiscovered standards. It is hoped that this report at least covers the basic principles of classification that impact the industry.

The table in appendix A - 3 sets out the most significant of these standards together with some brief notes on their application.

### 4.1.1 Related Standards

Although they are not directly related to classification there are several standards that are useful in understanding information requirements and classifying that information. These have been studied to help in understanding the criteria to draw conclusions.

A list of such standards studied are shown in Appendix A - 4

### 4.1.2 Classification System Implementations

A number of classification systems implementations based on the above standards have been developed over the years. Many of these have a domain, local and national context and have evolved over time. Taken together they inform current requirements for classification and hence have relevance to this study. They also present to us potential choices for future development and a basis for wider classification needs of the digital engineering future.

## 4.2 Meetings with Organisations

These studies were supplemented by a series of interviews with the participating organisations to ascertain their current practice, future strategies and forecast requirements.

## 4.3 Conversations with Colleagues and Other Projects

Inevitably when developing reports and exploring the issues that are involved opinion is evolving and input is required across a wide field of knowledge. Accordingly, the author has discussed the problems of classification with friends and colleagues met during the course of investigation.

# 5 The Digital Information Challenge

## 5.1 Analogue to Digital

In the built and natural infrastructure environment 90% plus of assets we deal with are already in existence and delivering service. A new project starts with what is there both physically and in reported data stored in many places. In many cases that information has been collected and stored over many years in various formats most of which is in analogue form or in databases created for a specific interest and of a scope limited to specific function. It is quite common to find a number of different specialist operational databases within an organisation including, drainage, structures, earthworks, pavement etc. These might identify specific assets, hold data about those assets including their location, condition plus control work on their maintenance. Rarely are these consistent in their formats, content and quality.

Current data capture during an assets life is predicated on these specialisms and data systems. As we move towards a more digital view of records and smart delivery of operational service we need a more consistent and related view of information. Capturing not only the physical properties of an asset but also a digital description of functional requirements, technical specification and location.

The challenge we face is to manage the transition from existing analogue systems of information organisation to one that suits and fits the move to digital systems smoothly and involving the diverse and widely distributed industry. To include not only the large organisations that own, procure and manage assets but the whole supply chain from small specialist groups through large design consultants, construction contractors, fabricators, on site build, testers, project managers, and operational managers.

## 5.2 Bridging the Gap

To do this classification tools need to be both forward and backward looking. That is, they need to support and encourage the move towards digital engineering and digital twins by ensuring new work is captured primarily digitally, link to information that is not currently digitally captured but with a view to making that digital as soon as possible and finally linking to existing information that will be in analogue and hybrid formats.,

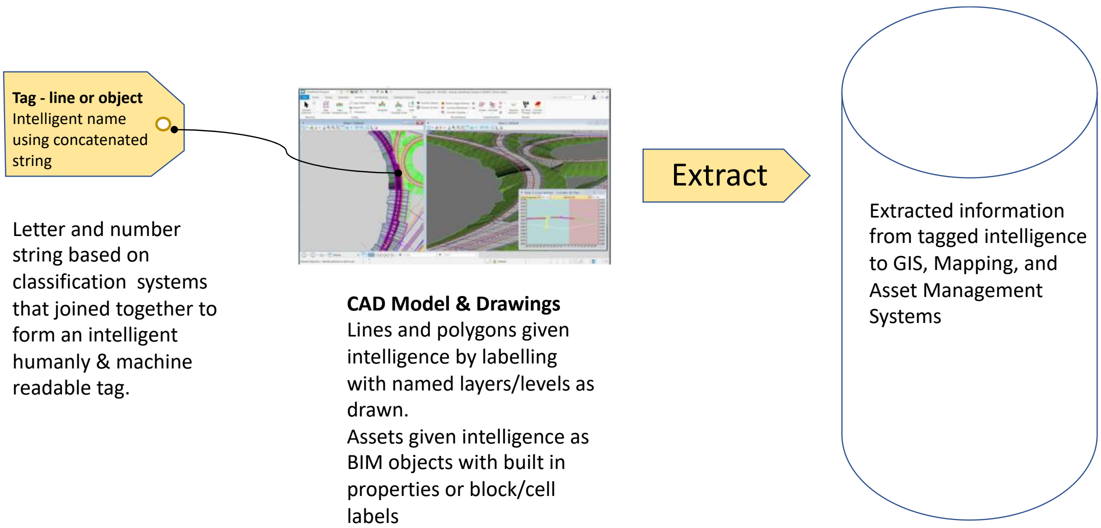
Any chosen classification should be able to make the bridge between the analogue and digital world.

## 5.3 Labelling Intelligence to Smart Sharing

It is worth exploring at this stage the transition process in identifying assets and their data that the industry finds itself going through and to look at the stops along the way.

Currently we find ourselves tagging or labelling things in the existing environment, in our CAD models, BIM Models, photographs, drawings, manuals and geographic information systems. Then using the intelligence those tags give to extract information for our asset management systems, project management systems, construction systems, geographic information systems.

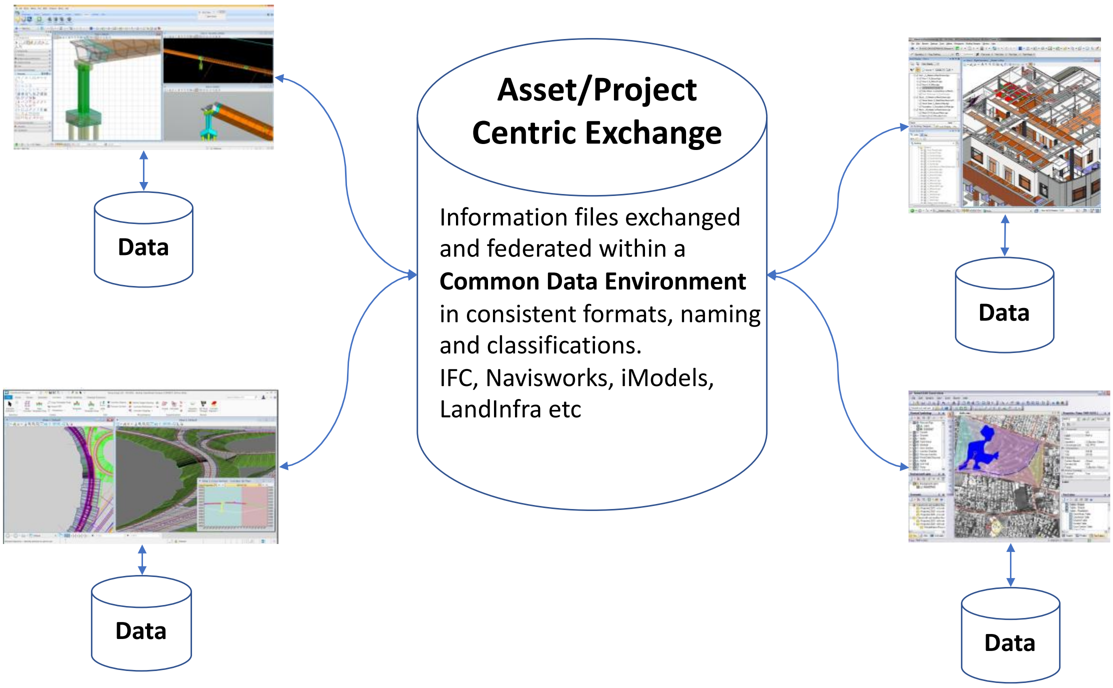
Those tags using current classification methods are drawn from naming conventions set out in classification tools that embed intelligence by concatenating letters and numbers.




This approach provides a practical way using current tools of adding intelligence but has limitations. Properties beyond direct relationships quickly become unwieldy and relationships between systems, objects, assemblies, products, material, construction methods, costs, energy and many other important attributes are lost.

However, its use is the basis of most current approaches whether they be CAD layer modelling or BIM object modelling and therefore need support both in the immediate future and the medium term.

The current round of BIM development has led us to what has been labelled "Level 2 BIM' where information is exchanged and federated in a collaboration process that makes embedded and connected data available across projects or asset collections.



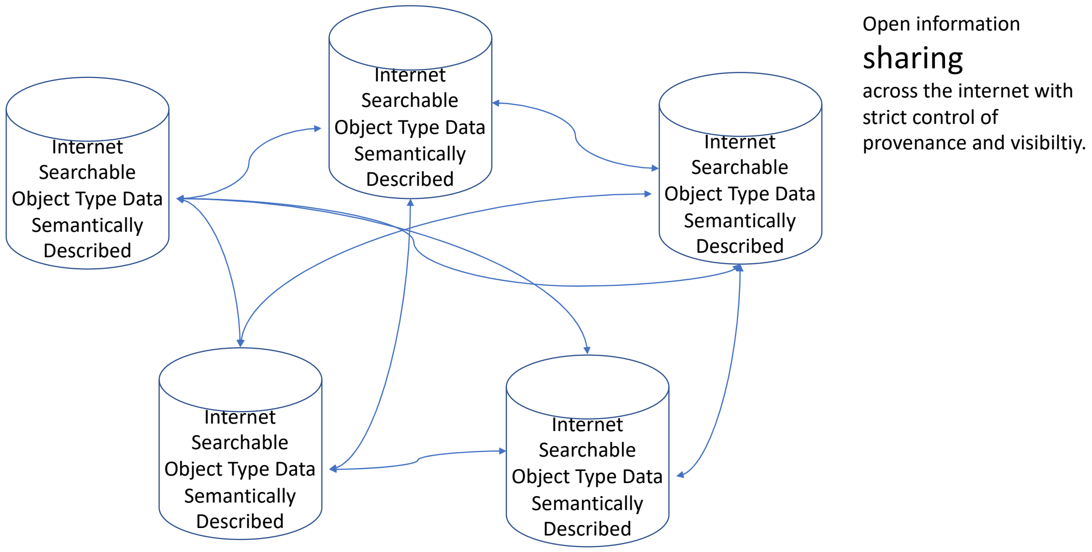

This approach is the basis of the ISO 19650 series of standards that defines what information is required during the life cycle of an asset adding a collaboration process for sharing and coordinating that information in a Common Data Environment (often referred to as a CDE) which not only stores the exchanged results but manages the change control of information across the multiple sources providing a reliable single source of truth to all who are given access.

Such an approach needs common naming and schemas of data across a project and asset constellation. Hence having a classification system that enables this federation of information to be consistently applied is essential.

The resulting 'federated' information could be merged into a single model and some solutions attempt to do just that; however, the idea of federating data fits the needs of the smart world than trying to fulfil a one database approach.

The exchange approach has been developed mostly in the design of new assets with some ventures into project management and construction but not so much in asset management.

Which leads us to the approach of semantic information sharing across which combines federation with the capability of sharing data across a wider environment beyond the immediate project or asset domain.




Information about assets is described in a sematic machine interpretable coding which can be linked using properties and mappings. In such an approach information sharing is not restricted to internal data sharing but available domain to domain, business to business and beyond. But controlled in availability by provenance, validity, verification (through processes like ISO 19650) and to those who need the information depending on tasks, duties and security.

The concept is explored further in Section 10 of this report.

# 6 Defining Classification

## 6.1 What is Classification

It is very easy to get into extreme complexity when considering what classification is. However, we all classify things every day as part of making sense of the world around us and our interaction with it. In essence it comprises putting things into groups or categories that have common characteristics. We might categorise personal transport vehicles as cars and further group them into types of car such as sports cars, SUVs, saloons etc. Of course, they belong to a wider category of transport systems and they may be further sub-divided into petrol, diesel and electric cars. In other words, classification helps us understand, filter, make sense of and find things be they physical or virtual.

Classification is essentially about how organise our knowledge and be able retrieve vital information.

Common classification systems that most of us are familiar with are those used by biologists to classify flora and fauna into different genetic families. Other familiar classifications are those for libraries that classify books, documents and other artefacts into logical sets that can help users find information. Unlike biological classification in library classification there are objects that could occur in different sets or in fact cross many sets so the classification used is usually a best fit. Similarly, there is no single classification for everything in our industry but things can be classified in any number of ways that are suitable for different uses and interests.

### 6.2 Is Classification Necessary

Before we look at the principles of classification it is worth asking the question is classification necessary? If all of our data is collected digitally and stored as object related then modern computing methods are quite capable of indexing, relating and analysing information exceptionally quickly and dynamically. Such tools can be used to make inferential links that exceed immediate human capabilities. In other words, we can use ‘Big Data’ techniques and artificial intelligence to classify our data dynamically, seek out trends and provide a basis for smart learning.

However, in order to capture and collect information that support such capabilities we need a scheme of identifying/labelling our objects/assets, the properties that describe them and their relationships. It is therefore important that such labelling is coherent and simple to implement by all the stakeholders. It is for these reasons that classification plays a key role and why, particularly during our current transitionary stages, we need classification tools.

### 6.3 Classification Principles

Good classification should be simple and become invisible, taken for granted by their users is a good underlying principle. However, in the world of infrastructure assets the needs of users and their different interests make the application of that principle difficult and complexity very soon arises.

It is not the purpose of this report to write a treatise on the many aspects of knowledge of information organisation and classification. To help in understanding some of the basic underlying principles are outlined below. In truth classification is a combination and permutation of these principles. These notes are not designed to be comprehensive but give an idea of the complexities of the subject.

#### 6.3.1 Taxonomies

Taxonomies are the rules and conventions of order or arrangement of things, thoughts and processes. They are therefore part of the fundamental building blocks of classifying knowledge. They have three key attributes: -

- A classification system - designed to group related things together so you if can find one thing in a category you can easily find other things in that category. Definitions are flexible in order to cater for the many things in the world we organise and relate. Examples might include but also be more than just physical properties but include functional proximity (things we might do at the same time or in the same operation say shopping), causal relationships (things that result in something else occurring) or organisational relationships.
- Semantic – that is they are descriptive and provide a vocabulary to describe their knowledge. An important concept in linked data.

- A knowledge map – providing a map and structure of the domain covered by the taxonomy. A navigational aid to understanding knowledge organisation.

Taxonomies can take many forms probably the most common are tree shaped showing interconnection and hierarchy of knowledge however they can be lists related to concepts, matrices, facets and system maps.

### 6.3.2 Concepts

In an any information system a classification scheme must not only be able to deal with simple subjects which consists of single concepts such as Railway, Road or Canal but for more complex subjects which are formed by combining concepts for instance Railway Track, Railway Signalling, Railway Power Transmission or Road Pavement.

In order to achieve this, objective classification systems may adopt a faceted, an enumerated (hierarchical) or a mixture of both.

ISO 12006 Part 2: 2015 in presenting principles for construction classification quotes ISO 22274 saying that classification tables can be enumerative, faceted or a combination of both with an entry class.

### 6.3.3 Enumerated or Hierarchical Classification

Essentially a top down approach to classification. Enumerative classification systems attempt to list all possible classes within their defined area of applicability. They are often represented using hierarchies or tree form. Each sub—group of a larger group forms the lower branch of the tree. Members of the lower classes are also members of the super classes above in its tree and inherit characteristics from that super class. As the process of sub-division continues, the hierarchical classification lists or enumerates complex subjects

### 6.3.4 Multi-Faceted Classification

Essentially a bottom up approach to classifying. A Multi-Faceted approach recognizes that subjects can be broken down into many different aspects which can be seen as facets or sides to the whole. We will see later in the report that there are many users and users of classification. Often these require information related to a particular facet of an asset. So, for instance, a cost consultant might be interested in specific classification of objects such as materials, quantities and measurements. Each of these can be seen as facets of classification of a subject.

### 6.3.5 Example Categorisation, Grouping & Facets

#### *6.3.5.1 Objects*

Entry classes and sub-classes group objects into families of parts with similar characteristics.

#### *6.3.5.2 Quantity and Measurement*

Facets of object classifications that expand on measurement of quantities and volumes.

#### *6.3.5.3 Materials*

Materials are facets of object classifications that expand on the materials used in manufacturing.

#### *6.3.5.4 Processes*

Processes are facets that classify work and activity related to an object.

#### *6.3.5.5 Locating*

Location is a facet of object classification that expands on where an object is geographically, topologically and spatially found.

## 6.4 Critical Criteria for Classification

The following criteria been discovered and developed in this report: -

### 6.4.1 Practical, Useable and Understandable

Classification should be understandable and applicable by the engineering practitioner and users supported by technical specialists and not driven by technical specialists.

The whole aim of classification is to enable users to make sense of, identify, filter, index and analyse information in a way that fits their knowledge and expertise. It follows that whenever possible we should use classification to reduce complexity and simplify the tasks that we carry out and to enable the information involved in creating and managing assets to be understood and analysed digitally.

### 6.4.2 Sector/Domain Neutral

The industry consists of and requires a wide variety of expert and specialist's domains that work together to create and manage information. We will look at some of those domains and users in a later section of this report.

Early work on classification concentrated on buildings and neglected the wider infrastructure world. They also concentrated on specific aspects such as cost or function rather than a more holistic view of all aspects of information. That has been addressed somewhat in more recent standards and implementations however in order to deal with the variety of needs across the industry a broader view that encompasses and interconnects the many expert domains and users encountered in the planning, creation and use of a typical infrastructure asset. The information that results from each domain of interest needs to be capable of being related, linked and utilised across all involved sectors.

### 6.4.3 Asset Centric

The result/outcome of construction activity is the delivery of a physical asset or the modification of existing assets be they natural ones or man- made and the service they support. The systems, components, processes and tasks that contribute to that asset need to be recorded, related, managed, retrieved and analysed in a logical and progressive fashion.

Many current classification systems have concentrated on the process of delivery. ISO 12006:2 for instance use the term 'construction' in its title and follows the production aspects of creating a new asset despite paying some regard to operation and planning in its most recent revision. Hence, they are driven by a particular view of requirements. It is suggested that these were quite rightly, initially driven by the need to meet the design and construction information requirements. However, as we move towards the use of digital models that can simulate process, behaviour and service throughout the lifecycle (see below) the common point of information context is related to the asset being planned, designed, constructed and operated.

It is therefore suggested that information and its classification is centred around assets, their production and eventual management. The necessary information flow starts as an asset is conceived not when it is finally built.

It is suggested that classification should be asset centric and not product centric as many systems are. The difference between the two is subtle but important. Asset centric involves the complete set of information through life cycle including its constituent systems, assemblies and components some of which are pre-manufactured others created in situ. Product centric looks at the final product, often by inference a catalogued item, rather than the intended function, performance and system dependencies.

### 6.4.4 Digital

As previously reported current asset information flows, exchanges and linking are a mixture of media including, surveys, documents, drawings, specifications, as built reports, analysis results, analogue reports, spreadsheets, 3D models, BIM Models, product data, test reports, condition reports, maintenance schedules, and multiple others. Although some of this is digital information and much of it analogue the capability of relating information across an environment is not digitally optimised and linking is often manually mapped.

### 6.4.5 Digital Twins

The term 'Digital Twin' has most recently become a fashionable way to describe the capabilities of digitally modelling products and assets. The concept is that as digital information is captured, created and delivered it can be used to create a software/cloud-based doppelganger of the physical asset or assets to enable simulation of the asset and its performance.

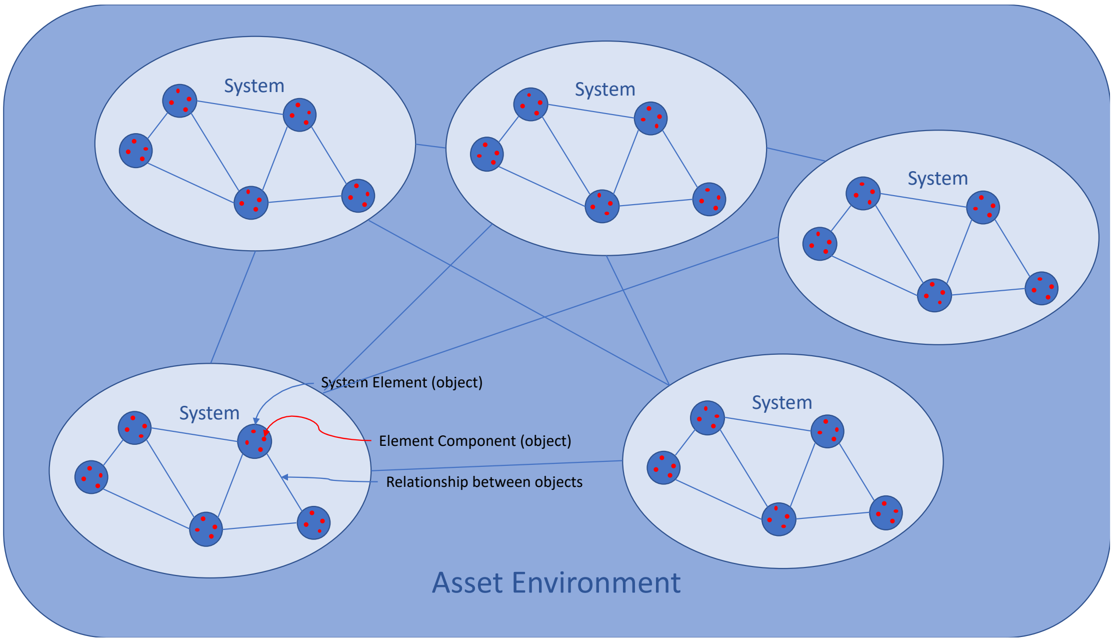
As digital modelling evolves the potential use of 'Digital Twins' of infrastructure are being proposed as an effective management tool for all stages of asset life cycle. These twins are a natural extension of BIM taking it beyond a 3D model and are designed to represent the physical world and its systems as digital models. The potential of such a digital model is significant in carrying out planning and design where scenario planning, performance and sizing analysis can be carried out. If that data is captured during design and build stages and linked to the operational model together with intelligent sensors to simulate performance, mitigate against incidents, plan updates, look for improvements as more information becomes available.

It is not the purpose of this report to develop the concept of 'Digital Twins' however it is felt that their success will rely on the capability of recognising and relating data across the asset in a smart way. How we classify data will therefore have an important bearing on our future assets.

It is important to note that a 'Digital Twin' is not a single model but the linking of many intelligent models that make up the 'System of Systems' that comprise the built and natural environment. The capability of recognising and relating information across these systems is a fundamental foundation and classifying will assist this.

### 6.4.6 Support a System of Systems

Assets exist in a universe of many systems and any new or existing asset can be regarded as part of a 'System of Systems'. Each system works within an over asset environment and information between each system information needs to be at least related and linked with other systems to make the asset environment coherent and function as a whole. Similarly, each system consists of elements and components which need to communicate their information to each other.

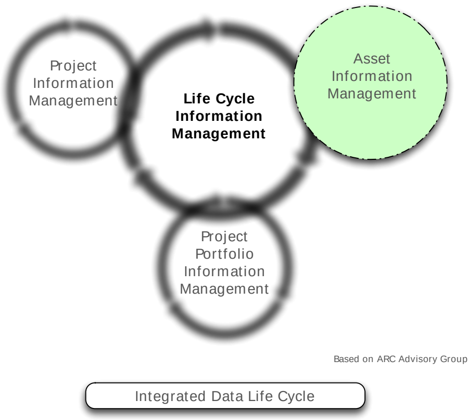


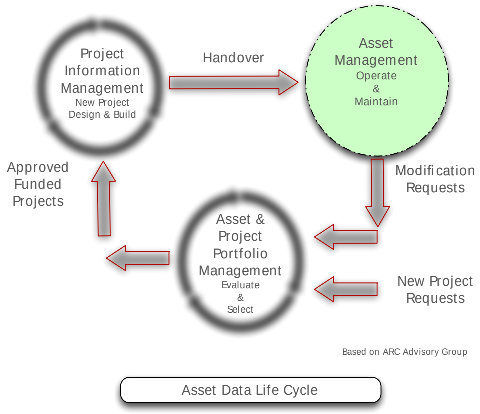

Of course, each asset environment exists in a wider context of the world in general and other asset environments for instance the railway will interact with urban systems, the natural environment, road systems, utilities and more.

Hence, we need an approach to classification that enables system to system information linking without placing constraints on each environment or that limit their flexibility and capability to communicate within their own domain.

### 6.4.7 Support Full Life Cycle of Assets

Any classification system for information should be designed to cover the full life cycle of an asset and the systems that make up that asset.



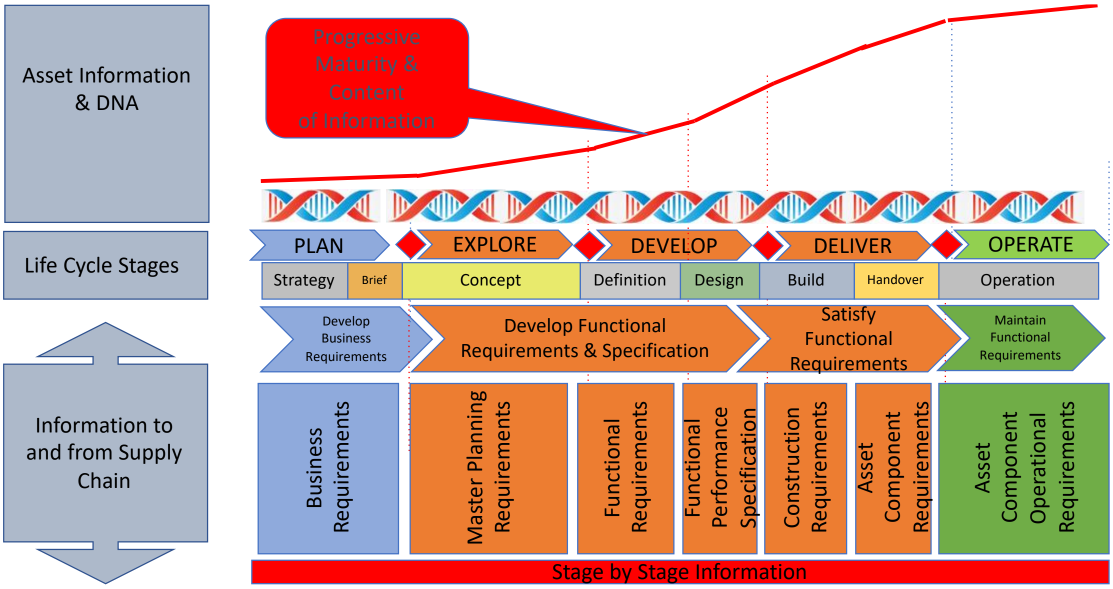




Many early classification systems concentrated on the design and construction stages of an assets life cycle. As we move towards a full digitally modelled approach to information the other critical stages of an asset's life cycle should be considered and included in the information captured, created, analysed and managed. The capability of linking and using data across these stages are essential to creating a digital information model.

Those life cycle stages are illustrated in the diagrams above and include:

- Asset Operation and Management – the period of delivering the service the asset is designed for which includes day to day maintenance and repair, predictive maintenance, service delivery, dealing with issues, mitigation planning for issues and maintaining service delivery. In many ways this the culmination of information created and captured in other stages. It represents the major effort and expenditure associated with an asset. It holds and maintains the continuity of asset information.
- Asset Planning and Portfolio Management – the owner/manager of an asset needs to manage their overall portfolio of assets in context and therefore sharing, linking and exchanging information at this level is essential. This portfolio management includes the planning of expenditure on existing assets as well as the work in gathering and assessing requirements for new or replacement assets. It is this stage that information is created that sets priorities for service maintenance, manages budgets, assesses the value of existing assets, plans interventions and new projects, and prepares requirements for briefing new projects.
- Once briefed a new project or programme of projects create new assets and the information required to design, build, and commission those assets. Ready to hand over for future operation and complete the life cycle circle.

It is worth expanding the life cycle to understand the whole circle of information that needs to be classified, captured, created, analysed, forecast, and used in a smart digital environment. The diagram below demonstrates how information develops through the asset life cycle from capturing existing environment through developing and planning business requirements, designing and exposing functional requirements and technical specifications for new assets, building those assets to fulfil the functional and technical specification requirements, testing and handing over the built asset and maintaining the requirements during operation.




How that information is supplied, categorised and exchanged throughout the lifecycle will vary depending on the task being carried out. During design and construction much information will be about the physical asset in digital form be it a 3D model or all the associated parameters, attributes and properties. Enough to create and understand a 'Digital Twin' (see below). During operation current condition, maintain, repair and replace will be supplemented by embedded and or mobile sensors powered by the Internet of Things (IoT) and 5G mobile networking that will monitor deterioration, performance, and behaviour enabling interaction with digital twin models.

### 6.4.8 Level of Information (LoX)

It is not the purpose of this report to delve deeply into the subject of Level of Information, Level of Definition and Level of Metadata/Accuracy (or any other quantity related to development of object information hence the term LoX). However, classification approach does have some bearing on this much discussed and misunderstood subject.

As assets progress through their life cycle they gain more detail in the form of new elements, as those elements progress through their life cycle they gain more property attributes related to their maturity and development status. A classification system must be able to cope with the base object types that constitute an asset as they increase in content and the faceted properties that increase through development.

Some classification approaches suggest that moving through the life cycle increase in detail information is expressed as properties of an original asset which of course it does. However, the author believes that as assets progress through the life cycle they not only do they have more properties but they have new objects (components) that fulfil requirements of their parent object and add detail. For example, at an early planning stage we may just have the need for a bridge over or under an obstruction that carry a certain load and traffic. When we get to the concept design stage we would add support systems and deck systems as new objects that are part (have relationship with) of the original bridge object and inherit its properties. When we get to a detailed design stage we would add piers and abutments to the foundation system and so on. In this way infrastructure differs from architecture where many detail objects are defined at early planning stage adding more properties as the life cycle progresses.

#### 6.4.9 Consistent Modelling, Referencing and Naming in BIM Applications

Many BIM applications have their own particular (peculiar) way of referencing and building relationships in models. A clear classification referencing approach should facilitate and drive common modelling standards and contribute to open information sharing.

#### 6.4.10 Location & Recognising the Continuous Nature of Infrastructure

Infrastructure by its very nature deals with a continuous world in which specific assets are constructed or formed. In some cases, those assets are continuous in nature for instance a road or a railway line. Locating assets within this continuous world consistently and classifying location for interoperability is an essential feature.

Many early BIM implementations constrained locational properties to those within a building such as floor or room which of course is a particular and specific classification of location. Future location-based classification should recognise a more geospatial view of an asset which might include surface, regional, urban area, rural area, street and linear features.

Of particular interest is location points along a linear feature such as a stream, road or railway where position might be expressed in terms of chainage or a distance from a given fixed point along a feature. For instance, a distance from a tunnel end, bridge, set of points, junction or a marker post. Whilst in the age of GPS and easy to retrieve coordinates by electronic means it might seem that this requirement is redundant, there are important functions that such locational information can support. These might include the need to overlay automated linear surveys of line or road quality on to models, use of distance to calculate timetables or just to know how far to drive to a particular feature.

Solutions to these problems are found in geospatial standards. ISO 19148:2012 Geographic information – Linear referencing lay the foundation for linear referencing, whilst the OGC LandInfra standard defines a conceptual model for alignments which implements the concepts from ISO 19148. The

LandInfra conceptual model for alignments was developed in cooperation between OGC and buildingSmart and is implemented in the OGC InfraGML encoding standards as well as the buildingSmart IFC standards.

#### 6.4.11 Discovery of Assets in Point Clouds and Photographs

In current practice, there is significant use of point cloud capture of information. This includes Lidar Survey, Photographic Survey, 3D Scanning Technologies, Digital Photographs and Digital Video. As the name suggests the resulting data is made up of a number of points of information set in 3D space (or 2D photographs) with properties that give colour (from infra-red through the visible spectrum to ultra violet), x-ray reflection, light reflective attributes, and others. At present technology provides tools to convert those points into vectorised objects. However, future developments are likely to be able to recognise clusters of points as objects. For instance, face recognition technology will develop to recognise other physical objects. Common classification of object types and their related properties will assist significantly in that process.

#### 6.4.12 Legacy Supporting

As discussed earlier the industry is currently in the midst of change to a digital modelling approach moving from an analogue and document centric approach. It is essential that our approach to classification supports that migration and provides a bridge during the change. Overall change is bound to be protracted despite what the digital revolutionaries tell us so that a bridge needs to be sustainable for the foreseeable future as well as facilitating the change.

Existing information describing current assets and their history will have information held in many forms, structures and schemas.

#### 6.4.13 Maintained and Freely Available at the Point of Use

Classification is not a static subject nor is it ever perfect. There is no single way of classifying objects that will be correct for all circumstances. As digital modelling and its use evolves new connections and types of information will need to be incorporated and integrated under change control and recognising backwards compatibility. It follows then that any classification system chosen should be under consistent management and updated regularly.

Such maintenance costs and those costs will have to be maintained and supported by industry.

Various models of support have been used and it not the point of this report to discuss the merits of these. However, it is important that its use is simple to apply and barriers of cost at the point of use mitigate against uptake and success.

Therefore, a major consideration in choice of system is currency of the system, it being simple to use by all and free at the point of use access.

### 6.4.14 Global

The construction industry is increasingly global with many of the supply chains involved being international companies.

Whilst there will always be local legal and commercial frameworks classification of information must cater for this globalisation and provide mappings from and to local vocabularies, language and culture.

This is not suggesting that there should one global solution to classification and naming rather to suggest that there should be a solution that incorporates asset types and their functionality across the life cycle that can cross refer and map to local vocabularies, languages and structures.

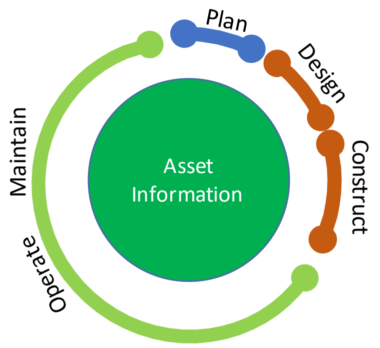
Different industries use different terms and processes all contribute to the system of systems that make up our infrastructure. New roads for instance interact with the environment, drainage, utilities and other transport networks. Forcing a common vocabulary and language upon each of these industrial domains is an impossible task. However, making each understandable and linkable is a goal we should aim for in classification.

### 6.4.15 Smart Infrastructure Enabling

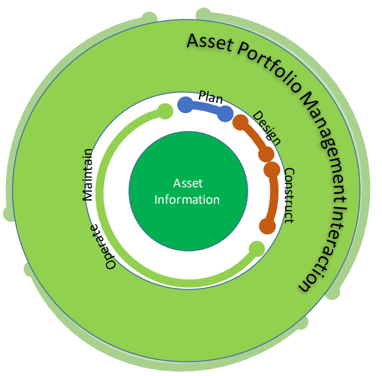
As digital models evolve and digital twins become common as a means to specifying, designing, constructing and manage assets so the possibilities of 'Smart Infrastructure' become feasible and the benefits to all stakeholders become achievable.

Smart infrastructure might include smart management of a road or railway from the perspective of a single asset owner. However, the possibility of joining and intelligent linking across multiple asset ownership to enable smart cities, smart environments, smart travel and many other areas. So classification needs to support linking across many aspects of our infrastructure rather than acting in isolation within a particular domain.

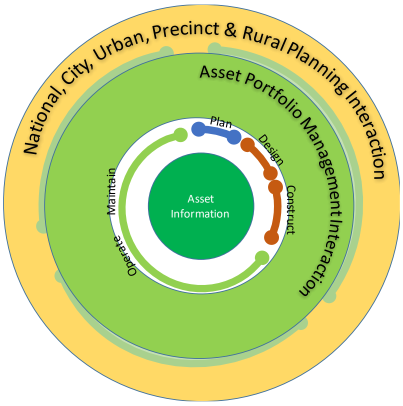
Looking at this as an ever-expanding requirement for information sharing.



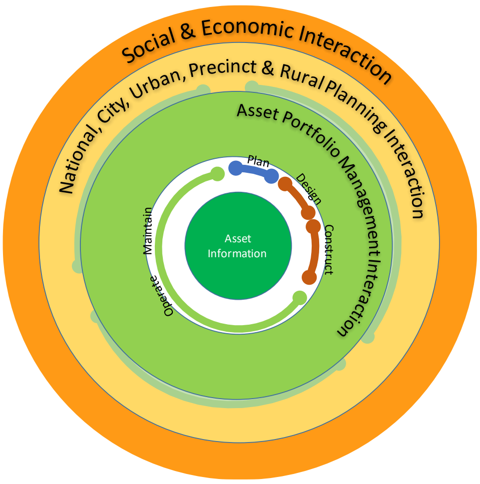

Starting at the owner of a specific asset set they are interested in their specific asset and its life cycle of information. Capturing, creating, managing and change controlling information. Linking it and retrieving it to support the activities and performance of managing that asset. That for instance might be a specific road within a network or an airport runway.




The owner of that specific asset needs to share information across their portfolio of assets to manage the whole of their interests linking common issues, performances, problem mitigations, timetabling and future planning. This might include the network of highways, railways or the whole of an airport.



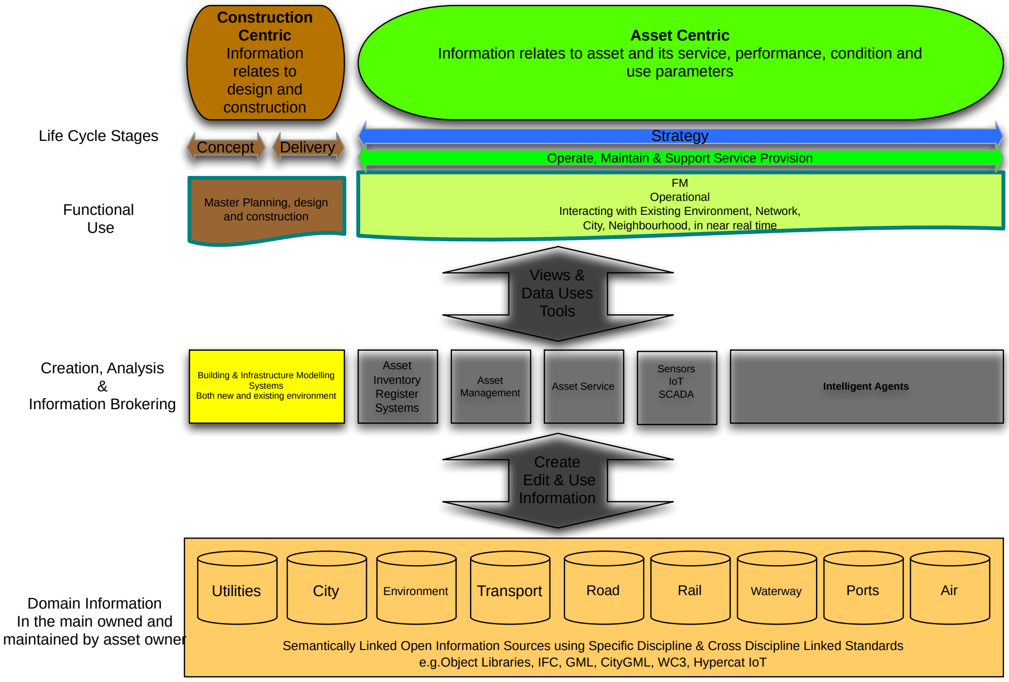

In turn the wider environment of cities, urban areas, precincts, rural areas will have an interest in the information held by individual asset authorities to enable smart planning and operation of facilities within those interests. It is clear that each city building a database of all this information would be time consuming, resource hungry and inefficient. However, linking to underlying data classified in a common way would provide a mechanism and platform for smart interaction.




Finally making information available socially to the wider public to view activities at each level from asset through planning, smart interaction with authorities needs a linking capability essential. Providing the full smart environment and opening up multiple opportunities.

Looking at this as the supply of information for a smart world from multiple domains some of which are shown in the diagram below shows need for a linked data environment that recognises the multiple sources of information but is able to share that information in a coherent way.

## 6.5 Support for Cloud/Edge/Internet Semantically Linked Data

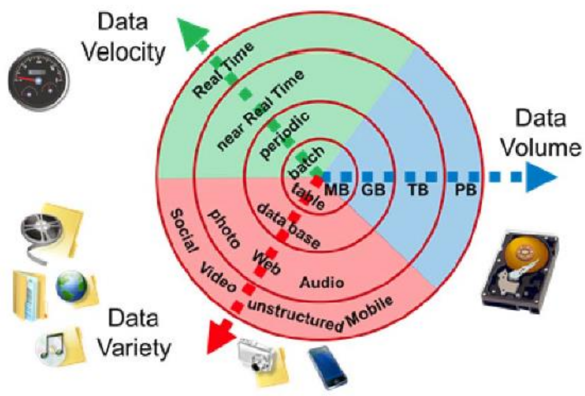



Enabling Smart Infrastructure therefore will require support for linking data intelligently across the wider network of servers, cloud storage, cloud computing, servers made available to the internet (often referred to as Edge Servers), intelligent sensors, intelligent objects with their own computing power.

Section 10 of this report examines the use of data modelling and linking of data in more depth. However, it is clear that support for and enabling the linking of data across domains, disciplines, and wider application is an important foundation to build in to our methods and use of classification.

## 6.6 Big Data Supporting

The data we currently collect is small and limited to the expertise and historic tools we have used.




Digital engineering collects increasing amounts of data as technologies improve this will happen at higher speed eventually approaching real time. The variety of data collected will expand and the corresponding volume will expand hugely.

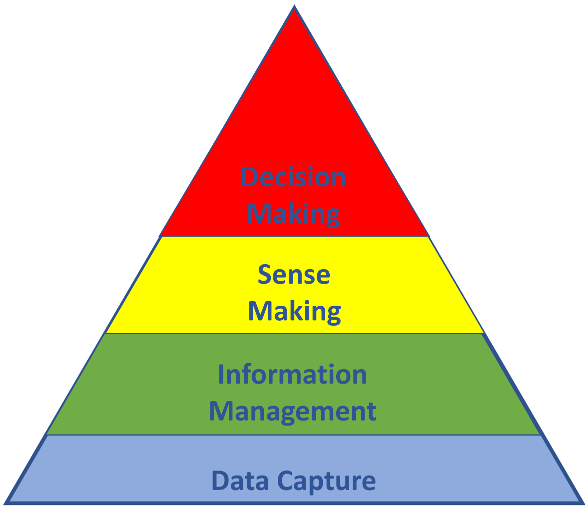
This diagram (attributed to By Ender005 - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=49888192) illustrates this expansion.

Classification and identification of assets that data is associated with will support and drive a “Big Data” expansion that will enable future analytics.

# 7 Why Classify

There are many reasons to classify information. Ultimately any tools we use in the smart digital world should support and enhance our capability of: -

- Capturing data effectively and effectively meeting the overall information requirements for each stage of an asset's life cycle. Identifying that data in a consistent way.
- Managing that information, relating it, controlling change and supporting cross asset analysis.
- Retrieving and reporting that information in such a way that it makes sense and adds to our knowledge of our assets.
- Finally, that knowledge is sufficient to allow us to make smart decisions.




Unfortunately, many interpretations of classification tend towards making a list of things and how to name them and what properties to collect about them. Whilst this is, of course, part of the purpose of classification its overall purpose stretches beyond this basic concept and has many other uses.

In the descriptions below we use the concept of things to identify specific physical assets, their components, the systems they belong to and the processes involved in planning, creating and managing them.

## 7.1 Grouping things

Identifying families of things and types of things with similar characteristics, understanding commonalities, and identifying properties that are associated.

## 7.2 Adding Intelligence

Adding information that identifies things that have been drawn, modelled or constructed in order to give intelligence for extraction or sharing. This activity is common in current BIM implantation where a CAD model has lines or objects that represent specific assets or components of assets. Often used to label layers/levels in CAD models so that the layer name can be used to identify the object the line/object represents.

During the interviews it became clear that this was a critical process in generating GIS and Object Models in many of the organisations involved in commissioning this report.

It has particular application in the world of infrastructure where finite objects are not specifically identified by the BIM software in use.

## 7.3 Intelligently tagging things

Similar to adding intelligence – to tag assets/objects and give it some intelligence. This might be just physically tagging an object a label that identifies it, its relationships, function and characteristics. It might take the form of a bar code or text label affixed to an asset linking it back to stored data. It might be tagging objects in BIM models for data extraction or use.

The process of tagging is synonymous with adding a barcode to an object which provides enough intelligence embedded to identify the object and other important information that is judged to be important about the object. In many cases the current classification systems make that 'code' rather than bars a sequence of letters and numbers that can be both machine and humanly interpretable. Thus, by cross referencing to tables users of CAD Modelling tools can add identifiers to objects that might be cells/blocks, BIM objects, lines or layers/levels and in reverse understand what those lines, objects etc. represent.

## 7.4 Where to find things

To give location to an object/asset in the context of a wider aspect. That location might be the space the object is to be found in, where is it in relation to a linear connected network, what its geographic location might be. It follows that objects might have several locational classifications.

## 7.5 Where things are stored

To identify where information about a specific asset/object can be found which might be physical storage as in a library or filing system but more often in digital stores.

## 7.6 Naming things

Giving a name to an asset/object that follows a given set of rules that are both humanly and digitally interpretable.

## 7.7 Uniquely Identifying at Instantiation

Whilst not specifically classification the need for unique identification of an asset when it is virtually planned and designed tracked through to its construction and maintenance is an important requirement of asset management through the life cycle. It provides the link to all the information about the asset and its classification designation.

## 7.8 Templating Properties to Collect

Classification indicates the common attributes of group of objects. Classification can include templates of further properties that could be associated with that group or type of object. An instance of an object will therefore by association with its classification have common attributes and potentially properties for which values can be associated.

## 7.9 Consistency

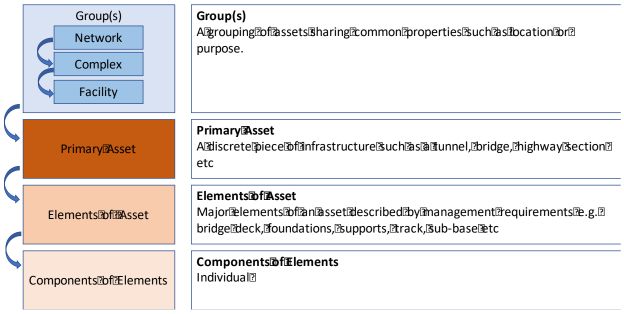
Doing all of the above consistently across an asset base and or a project.

## 7.10 Relating and Linking things

Understanding how things are related and inheritance of characteristics. Commonly referring to a hierarchy of relationships where a child of a particular asset inherits the characteristics of its parents and passes those characteristics and its own to subsequent children. See ‘Enumerated Classification’.

In many classification systems this has the form of a fairly rigid structure where Complexes are sub divided into construction elements and functional entities.

It is suggested that a more flexible set of relationships are required for future information needs which is recursive rather than rigid in structure.

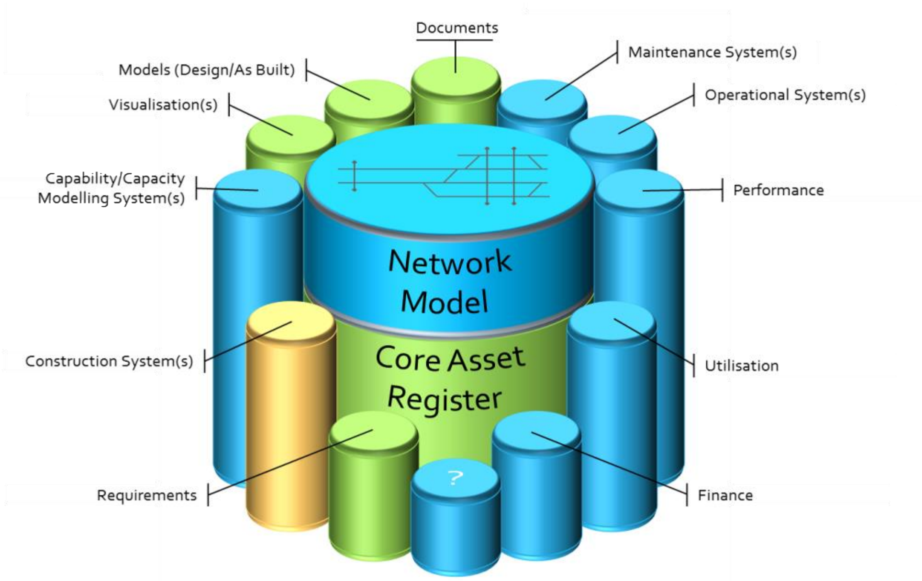



A typical set of hierarchical relationships is shown in this diagram. It is important to note that in such a scheme a Primary Asset could spawn further Primary Assets and Elements of Assets could spawn several Elements and so on.

Other relationships might be linking particular characteristics which give specific properties of an asset. For instance, taking our earlier example, a car might belong to a transport group and have different types such as saloon, sports, SUV etc. but each of these might have associated property classifications such as cost, colour, material, engine type etc. See Faceted Classification.

Both are essential to classifying infrastructure assets and are usually combined. See ISO 12006:2 2015.

Other relationships need to be established which stretch beyond characteristics and properties to include linking to many types of information. The diagram here illustrates some of those typical relationships for a railway, however, the principles are fully extendable to all types of assets.




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

This takes into account the current hybrid of analogue and digital information linking documents as well as full digital twin operation enabling linking of performance modelling to graphical models of intended or as built systems, to requirements, use in practice and construction processes.

As previously stated, this identification and linking provides for an extendable model based on federations of systems rather than one big monolithic model. Thus laying the foundation for future semantically linked data solutions.

### 7.11 Advice on what to store about things

If we can classify assets, then we can template what information/properties to capture and store about those assets related to the many user's requirements. See Information Users.

### 7.12 Enabling analysis of things

If we understand the components of our assets and their data, we can use the information to analyse and predict behaviour and performance carrying out capacity and sizing calculations.

Additionally, and perhaps the most powerful tool is the enabling of data analytics techniques which can reveal trends and metrics that would be lost in the mass of information. Predicting the results of deterioration, changes in utilisation and its impact on real time performance is an unexplored but much needed capability. Discovering why things happen and performing diagnostics, predicting what is likely to happen and suggesting courses of action are other powerful analytic tools that will be enabled by the right information collected and linked in a timely manner.

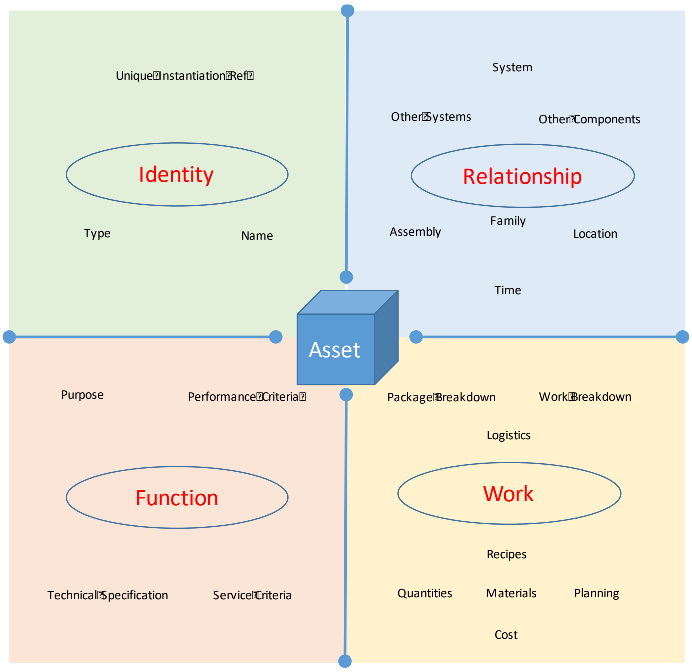
### 7.13 Understanding things

Having information classified in a recognisable form that can be understood by engineers, technicians and other human users is fundamental to making sense of the world we are creating and managing. This applies not only to understanding the form and technical details of the assets we manage but the timing of interventions be they planning, design, construction or operational management.

Furthermore, information that can be read electronically, understood, filtered and re-presented in an understandable form to users again helps in sense making. Human understanding and knowledge support are clear goals of our digitalisation process.

## 7.14 A holistic view

Taking those requirements together we can form a more holistic view of what we are trying to achieve by classification as shown in the diagram here.




If we view the objects we are trying to classify as an asset that resides in a virtual or in physical environment. In other words, in a digital twin or its physical reality. Then we need to fulfil information about it and its properties.

- **Identify** it uniquely firstly as what type of asset it is and what it is called then as it is instantiated in the virtual model and in the final physical model.
- Define its **Function** relating its purpose, its performance criteria, its technical specification and identify its service characteristics.
- Each asset will hold **relationships** to other assets and specific criteria.
    - What system does it belong to and what information does it inherit/provide for from that system?
    - How is related to other components/assets within that system?
    - What is its relationship to other systems within the chosen environment?
    - What if any assemblies/asset does it belong to or form part of and what information does it inherit/provide for that asset?
    - Does the asset have a specific location within the environment geographically, linearly or functionally such as space, section of road, within an area?
    - What are the time related aspects of the asset does it have specific properties that change with time?
- In order to plan, design, construct, implement, operate and maintain an asset, **work** must be carried out to create a series of **work** results.
    - Breaking down work into packages links the asset to the work package. Those work packages might be design domain teams for instance bridge design, specialist construction packages such as earthworks or piling, or operational maintenance packages such as condition monitoring, preventative maintenance, regular maintenance, damage repair, service sustaining.
    - Those packages will be broken down into work items or tasks.
    - Achieving those tasks will require recipes and resources.
    - The tasks will require planning and scheduling.
    - What material/products are being used.

- The quantities of those materials/products.
- How much each asset will cost to build.
- Getting the right components, materials and resources to the right place at the right time and ensuring nothing clashes both physically and logistically.

Whilst the above is not exhaustive it does indicate the hierarchical (what belongs to what and what inherits what) and faceted (what properties and outputs are associated with an asset) requirements for any asset related classification system.

Property attributes/requirements for any one asset will depend upon each of these elements will form unique combinations for each instantiation. For instance, a gabion may be used for many different purposes hence in any one model will require classification suitable to its circumstance.

It could be for part of an earthworks system used as a retaining wall. Where it would be classified as part of a retaining structure in this case earth retaining not water retaining.

It could be used as a revetment protecting against water scour on the banks of a water course. In which case it would be classified as water course embankment protection system which in turn could be part of a drainage system or canal transport system.

It could be a garden planter or as a boundary fence (perhaps a noise fence?) Each of which will be classified as part of a specific system and assemblies each with unique properties.

From the authors point of view it therefore does not make sense to build future classification on strings of references which make up a snapshot existence and properties at the time of that snapshot but rather on properties that relate to an asset/object type and describe its relationships to the many other facets of information associated with it.

Our current reliance upon such strings are purely a means to an end and the tools we have available during our interactions with assets.

# 8 Information Users

In order to understand the requirements for classification across the life cycle of an asset we should consider the wide range of users that are involved in the process.

To date many classification systems and their supporting standards have concentrated on the design and construction aspects of categorisation. In fact, that can often be more narrowed down to design, although standards such as ISO 12006:2 include construction processes these have rarely been developed to meet construction processes. Certainly, classifying for asset management has not been included except in principle.

For these reasons we summarise below classification requirements of life cycle players.

## 8.1 Functional Stakeholders

In this respect functional stakeholders are those that are involved in direct interaction with the assets being planned, designed, created and operationally managed.

### 8.1.1 Planners

Planning of a new asset or change to an existing asset considers a broad view of information. Initially it might look at the requirement for change and possible a variety of solutions. Once that is established then more detailed feasibility studies might take place. For a road or railway this might be corridor mapping, understanding the environment and broad range of structures that might be used. Balancing requirements against budgets and return on investment.

Planners therefore require classification on a broad scale with little reference to detail. Their outputs might be locations for development, outcome performance, functional requirements on a programme wide basis.

Those requirements establish the detail for all assets that will eventually comprise a project and final delivered total asset.

### 8.1.2 Cost Consultants

Many classification systems started their life as to support cost calculation rather than asset production and management. Hence classification breakdown was driven by how assets are measured, the material they are made of and work output.

There are two main drivers for cost centric classification:

- Estimation of the cost of facilities based on course granulation. Outputs include estimated cost of a road type per kilometre, cost of a bridge, tunnel etc. all based on historic and statistical information. To support this, assets need to be classified at a high granularity level and related to the facilities they support.
- Calculation of quantities and bills of materials. Driven methods of measurement that vary depending on domain discipline. Classification

therefore needs to be informed by how the components, materials and construction processes involved an asset are broken down.

Cost of acquisition and maintenance of assets should not be confused with value of asset which is covered in the asset owners and managers section below.

### 8.1.3 Designers

Designers take over from the initial planning and briefing for a new or renewed asset and develop the requirements from concept through to design models and specifications for building. It is their job to take output requirements and early plans to a state in which they can be built.

Current design process involves creating geometric models of new assets based on the designers' analysis of performance requirements to size and detail each element of the completed asset. This is communicated through a mixture of BIM Models, CAD models, drawings, documents and specifications. Each loosely linked to each other relying on indexing and cross referencing. Classification clearly plays a part in this indexing and referencing providing common points of relationship.

Future design process involves information models becoming the core of the design output and those models being linked to further information not necessarily held within that model but in separate data structures. In turn the models may be linked to other models in a system of systems thus forming a digital twin of facilities and assets ready for construction. Classification in this case provides the basis of intelligent linking of the different information sources and models.

In all cases the centre of the linking process is the classification of the asset being designed.

### 8.1.4 Construction Users

Construction users take the designed assets and break them into package and work breakdown structures. Planning how each will be constructed in sequence (commonly called 4D BIM). Linking these to procurement of materials, components, and skilled labour processes. Together with logistical planning (getting things in the right place and logically delivering them) they make recipes for construction.

Despite standards such as ISO 12006:2 including work processes this is a relatively unexplored area in digital engineering and practices are only just emerging.

Classification for constructors will link to the asset being built but also include spatial classification, materials, products, construction process, required skills, required plant and temporary works, timing, and cost.

### 8.1.5 Programme and Project Managers

Programme and project managers lead temporary organisations oversee the delivery of assets and as such are interested in ensuring that deliverables are clearly defined and programmed, that progress of delivery is monitored and paid for and that arising issues are mitigated and solved.

Classification for them again centres around asset but include the work breakdown structures, timing and payments for delivery.

ISO 22263:2008 Offers a more comprehensive list of necessary project information classes they include contract, objectives, activities such as resource plans, timetables, requirements on materials and components, procedures, management of risk, verification validation and inspection. Each of these related to specific deliveries and contribute to the Project Information delivery. Some may disappear at the end of the project but many will persist and hence are activities that need to be classified and related to the final delivery.

### 8.1.6 Asset Owners

Asset owners, those that have ownership and responsibility for the delivered asset will need to classify their assets at a granularity suitable for their responsibilities. These will include delivering the promised service outcomes, measuring performance, net present value of the asset, maintaining the value by timely intervention and predicting intervention costs.

### 8.1.7 Asset Managers

Asset managers hold similar requirements to asset owners but additionally will need to classify at a granularity suitable for preventative maintenance, condition monitoring, routine repair, dealing with emergencies and mitigating against predictable issues arising.

Categorisation will need therefore to be at component level and capable of linking back to functional design requirements.

### 8.1.8 Asset Users

Asset users, the ultimate reason why we have infrastructure assets are interested in finding information about journey times, disruptions, restrictions, future plans and feeding back information to the asset managers for action or response.

As such they are not interested in specific assets but rather the joined-up systems of asset and the location of specific incidents.

Granularity of classification therefore needs to be on a geographic and locational scale.

## 8.2 Smart Infrastructure

There is currently much talk of Smart Cities and Smart Infrastructure taking advantage of the capability of digital modelling to both plan and operate the overall system of systems that makes up our infrastructure. The capabilities of the Internet of Things (IoT) continuously monitoring and Digital Twins providing simulations and what if scenarios are enablers to this Smart World. However, the possibility of building huge databases to model the smart world, as discussed in the criteria section of this report, is neither practical nor desirable. Linking the different constituents of the various domains involved however is distinctly possible. Enabling trusted information to be exposed and linked between each different domain will form the bedrock of Smart Infrastructure. How information is classified will form the basis of those links between systems.

### 8.3 Social Interaction

Following on and as an important constituent of Smart Infrastructure is the capability of the general public being able to interact with the infrastructure that supports them. Enabling them to make real time decisions on when to travel, how to avoid incidents, manage their interactions with service providers.

# 9 Classification Uses

Classification has many uses and needs to cover at least the following facets:

- **Functional Breakdown**

Identifying the function of an asset, what it is designed to do and how it fulfils that function

- **System Breakdown**

Identification of the systems within an asset and a system of systems.

- **Component Breakdown**

Identifying the component assets and element parts with a system that comprise a system or an assembly.

- **Product Libraries**

Identifying products that fulfil functional requirements.

- **Quantities**

Identifying the units of measurement associated with an asset that define quantities of materials, elements and components. Provides link to separate quantities and bills of materials data set.

- **Cost**

Identifying the cost measurement unit of an asset, material, component and products. Provides link to separate cost data set.

- **Value**

Identifies the value measurement of an asset and its components. Usual a unit of net present value and not the cost of replacement.

- **Work Breakdown**

Identifies the package of work and work to be carried out to design, construct and maintain an asset and its components.

- **Asset Maintenance**

Identifies the breakdown of an asset required to measure condition, maintain, repair and update that asset or its components.

- **Asset Operation**

Identifies the breakdown of an asset that deliver service to its users.

- **Location**

Identifies the location of an asset.

- **Relationships & Connectivity**

Identifies relationship and connectivity between assets

- **Process**

Identifies and connects processes that might be carried out in relation to an asset.

# 10 Classification for Data Modelling

Most of this report has concentrated on the need for a transitional approach to classifying and identifying information thus being able to incorporate exist analogue information into a modelled asset. It is clear however, that the benefits of a more comprehensive digital modelling approach are significant and our aim should be to make the transition as fast and as practically as possible. To that end we need to turn to information modelling which incorporates and links beyond the traditional 3D CAD and BIM modelling that dominates existing practice. In such an approach we no longer try to build intelligence into our BIM model other than identifying an asset and its components but to provide a modelled approach that can link to multiple data sources and draw from them as and when required to not only define our assets but to make available properties and other faceted attributes.

It is at this point that the world of information technology and engineering start to overlap. Technically these should not conflict however the data modeller often introduces terms and techniques that are somehow confusing to the engineer. Often this relies on engineers and technicians relating requirements and processes to information technology specialist and those specialists turning those into models. A process that is open to misunderstanding, misinterpretation and mistakes.

There is requirement for information specialist and system architects to make their techniques more transparent and for engineers to understand modelling to the point of being more deeply involved rather than leaving it up to specialists.

Information modelling introduces a number of concepts and terms.

## 10.1 Ontologies

Earlier in this report we discussed Taxonomies as a way of describing and classifying and relating objects within a specific domain. Ontologies take the concept of Taxonomies a further step in describing an object. It encompasses representation, formal naming and definition of categories, properties and relations between the concepts, data and entities that make up one or many domains of knowledge. It is a way of describing objects and their behaviour with a system including properties, relationships and associated processes.

To many including the author of this report the concept is somewhat vague and hence a full understanding is difficult.

Ontologies are however the basis that information modelling is built on and as such classification provides some of the data required to describe an object.

## 10.2 Modelling Languages and Techniques

Approaches to modelling asset information through the lifecycle are essential to developing and understanding concepts and the data that complete those concepts. Describing an ontology and the information associated requires a language that can be written in clear and concise terms and understood by users.

Two such languages are commonly being used to provide this.

- Express which provides underpins modelling language that used by buildingSMART for development of their IFCs (Foundation Classes).
- UML Object Modelling Language which defines relationships and objects and associated information diagrammatically.

UML is the more recent approach and provides tools for conceptual modelling that can be expanded to meet the more detailed aspects of related content.

During the interviews with Nordic users we found that UML was being used in Norway extensively to understand and develop conceptual object types.
The UML model for road is based on LandInfra. The resulting information exchange requirements is then realized as the open object description GML (Geographic Markup Language).

The UML model can also be realized with other open object description when it supports UML, such as IFC.

More recently the conceptual modelling for extension of buildingSMART IFCs for Infrastructure are using UML to describe the Object Type Concepts required.

### 10.3 Object Type Libraries

Ontologies are closely associated with Object Type Libraries (OTL). An object described in an OTL will be described as an Ontology.

An object type library (OTL) is a library with standardised object-types names (e.g. road, viaduct) and properties or specifications. An object is described with its object-type data, geometry data and metadata, Metadata are data (or information) about the data of objects. Metadata are needed because each object type has its own properties. How the object types are grouped is called an ontology. The OTL can be linked to a data dictionary, with the definitions of object-types.

Within an OTL, assets are described with the standardised language, syntax and semantics required for a reliable information exchange.

Objects can carry or reference graphical data, non-graphical data and metadata.

The contents of an OTL apply to the entire lifecycle of an asset. The OTL defines the data structure and variables to be populated at different stages of an asset’s life, usually in the context of open data standards.

There are several OTLs being developed including at various levels in the industry. Some are nationally based such as the OTL in Rijkswaterstaat in the Netherlands and OKSTRA in Germany.

It is possible to use different OTLs from different sources by mapping between vocabularies and terms in each thus providing a translation layer.

Of course, classification of the object being described can be classified as part of its metadata.

A good classification system for OTL objects can provide a basis for essential links and mappings. However, this probably not related to the name or codification of the object but more likely the properties of the object.

## 10.4 Semantic Web

The concept of the semantic web is an extension of the current web in which information is given well defined meaning, better enabling computers and people to work in operation. Using the current web most of us search for specific document containing indexed information. The capability of the semantic web allows us to search for information about things, activities, processes and to use that information.

In a semantically enabled data source an engineer could search his/her project for a specific entity or asset and use information embedded in its description to describe all its attributes and perhaps select from a catalogue a ready-made solution or a previously constructed one.

The methods of describing an object are being embedded in the web by the World Wide Web Consortium as are the methods of information searching and retrieval.

It is worth read the report 'SKOS Simple Knowledge Organisation System Reference', referenced in Appendix 7 to understand further the concepts behind and the strengths of Semantic Linking.

## 10.5 Linked Data

Ontologies, object type libraries and sematic web technologies underpin the move towards the linked data approach to information modelling

Linked data recognises the fact that information is drawn from many sources some within a particular asset set or project others from outside sources such as mapping agencies, utility companies, weather, environmental agencies, panning authorities and many more.

Whilst use of linked data is in its infancy within the infrastructure industry there is little doubt that it has a significant role to play in future modelling and smart infrastructure.

## 10.6 Is infrastructure industry ready for semantically linked data?

Considerable work has been done on proving and promoting the potential of 'Linked' data. Unfortunately, the concept and its implementation are somewhat opaque to the architectural and engineering profession its language being hidden in terms that are academic and technologies that are deeply embedded information technology theory. The concept is simple but finding someone or some reference that can explain 'Ontology' or 'Semantic Web' in simple terms is proving a barrier to its uptake and development. We have an engineering profession that has profound knowledge of its subject and its intricacies and the need to interpret that knowledge into modern knowledge handling technologies.

The concept of a simple 'Object Type' that can be referenced and its properties linked in other data sets to uniquely describe its use takes classification to a new level beyond the naming reference string.

Semantically linked data is about describing objects, concepts and relationships in a language that can be coded just like an internet page in hypertext so that the data embedded can be read and used by others. It is about making intelligent links that can be read and interpreted by machine. Without trying to trivialise it too much a link can be likened to a QR code which embeds intelligent information that links it to information in a reference system. The QR Code here, for instance, references the internet pages from the CEDR Interlink Research Project (Referred to in Section 13 Related Research Reports) report pages discussing a basic European Road Object Type Language (OTL) which turn are interactive enabling further drilling down and embedding further information.

## 10.7 Object Type Libraries under Development

Recognising the power and need for a more modelled approach to information and the possibilities of sharing across domains a number of international efforts are underway to create Object Type Libraries (Ontologies)

### 10.7.1 Netherlands

Research and development effort is being made in developing an industry – CB-NL. The transport Authority of the Netherlands RWS has worked on RWS-OTL.

### 10.7.2 Germany

Germany has developed a road base OTL known as OKSTRA

### 10.7.3 European OTL

In the CEDR based research project Interlink a proposed European Road OTL was introduced. Details of this work can be found in the output to the project 'CEDR-INTERLINK Project Report' referenced in Appendix 7 and discussed in Section 13 of this report.

## 10.8 The need for consistency

The strength of Object Type Libraries lies in its possibility to be linked and mapped across domains and users. However, to achieve this linking and mapping a consistent modelling approach is essential. There is a need for cross industry, cross nation cooperation in developing that approach.

CEN 442/WG4/TG3 is currently developing standards to help in applying this consistency.

# 11 Classification Standards

## 11.1 Baseline Standards

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

The table in appendix A - 3 sets out the most significant of these together with some brief notes on their application.

It is not the intention of this report to carry out a detailed analysis of those standards but rather to outline the principles behind them and to perhaps point out potential issues in their currency in the emerging digital engineering world.

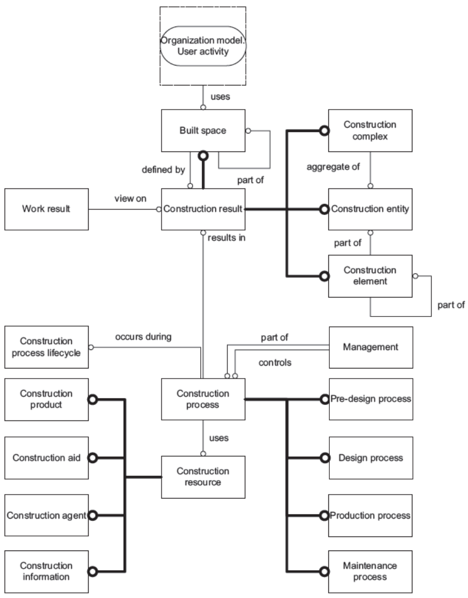
## 11.2 ISO 12006-2:2015 Building construction

Organisation of Information about construction works- Part 2: Framework for Classification.

This standard and its predecessors has been the bedrock of most classification systems over the past 15 years or so. Originally aimed at the construction process and its products its 2015 update widened its scope to include a life cycle approach to information and incorporate the emerging requirements of digital information (specifically BIM).

It still however is construction related in its content with only reference to operational use and maintenance.

It establishes the principles of classes of objects that define physical things and their function (which it terms construction result), the hierarchical makeup of those things, the space they relate to and the construction processes and resources used in making those things. The diagram here (using Express modelling language), extracted from the standard, give a simplified diagrammatic view of the relationships between the facets of classification of those things.




It provides a set recommended of tables reflecting those facets which used together can describe the different facets and the related properties that not only define it but its relationship to other things, how its built, what is made from and the design construction processes associated with it.

The standard recognises the need for an Object Type and for that object type to be unique. It also recognises the concept of being part of a system that related to other systems (system of systems).

Critically, despite its references to asset and lifecycle it does not explicitly incorporate operational management processes.

It is somewhat of a mixture of tables and process with the beginnings of recognition of information objects and process.

It does however provide a sensible framework for expansion in to the processes of planning design and operational management and as

### 11.3 ISO 12006:3 Building construction – Organisation of information about construction works.

Part 3 Framework for object orientated information.

Provides a taxonomy model, which provides the ability to define concepts by means of properties, to group concepts, and define relationships between concepts.

The role that on object plays in an overall environment can designated through the model and provides the capability to define the context and relationships within which the object is used.

Using the same language that buildingSMART IFC construction uses it fits the need for open information exchange.

As such it provides an approach to classification closer to modelling techniques and the surrounding processes. It therefore provides an approach to classification that more closely meets the needs of digital engineering and digital twins.

The ISO drafting committee TC 59 is currently reviewing the standard. The author believes that the UML approach to modelling is being used at least for the original concept modelling. How that will be represented in the standard is not yet settled. This alongside other research being carried out to update the representation of IFC concepts should be kept in mind as the understanding of digital classification evolves.

### 11.4 ISO 22274:2013 – Systems to manage terminology, knowledge and content

Concept related aspects for developing and internationalising classification systems.

Establishes basic principles and requirements to ensure classification systems are suitable for worldwide application. Addresses the need for domain centric concept centric classification. Provides guidelines on information content, terminological principles and requirements for internationalisation. Is referred to in ISO 12006-2:2015 to elucidate structure in classification.

### 11.5 EN 81346-2:2009 Industrial systems, installations and equipment and industrial products – Structural principles and reference designations

Part of a series of standards that introduces the idea of Reference Designations System and integrates a system of systems lifecycle approach to classification. It attempts to provide a common identification language across object types and their classification.

At a high level it creates Tags for objects which may be systems or elements of systems or components within those systems. These are constructed with a series of concatenated letter and numbers that link the object to its Aspect (how the system/object is viewed) – Structure (how system elements are related – Classification – (what kind/type of the system elements). As such it creates a unique identifier for each object which includes its function, how it is constructed (what elements), where it is located and its type.

The consequent Tag reflects the system breakdown structure of instantiated objects. Whilst this allows the user both human and machine to understand how things fit together it has dangers when applied to the full life cycle. If for instance an existing element is connected differently or a new element introduced above an existing one in a system or a new subsystem added at some point in the lifecycle the current string becomes redundant and will require change. Relationships get locked into the string and future change management, an essential of asset management, becomes difficult.

In many ways, it formalises the relationships implied in the table-based solutions based on ISO 12006:2 and as such is step towards a more digital view of assets.

Its tagging approach may be a good basis for bridging between current systems and the more formal modelling approach that digital engineering requires.

This standard forms the basis of a number of Nordic classification systems including the Danish CCS and its principles are embedded in the Swedish CoClass System.

The approach has received some criticism regarding its concentration on function as the base for sub-division. Reference 9 in the Appendix presents a detailed critique of the approach in relation to the Swedish CoClass. The author of this report is not qualified to present a detailed opinion of this discussion.

### 11.6 Related Standards

There are a number of other standards that provide background and extra knowledge for our examination of classification. Their headline relevance is summarised below:

### 11.6.1 ISO 29481 Parts 1 & 2 Building Information models – information delivery manuals

Provide a methodology for creating information delivery process manuals. Specifically related to buildingSMART IFC delivery they do however provide a good background to the process of information delivery and hence have bearing on classification.

### 11.6.2 ISO 22263:2008 Organisation of information about construction works – Framework for the management of projects

This standard look more at project delivery than results of projects (assets) however it does indicate the information needs during the delivery of a project.

### 11.6.3 ISO 15926: Integration of lifecycle data for process plants including oil and gas production facilities.

Whilst not strictly infrastructure related the standard and its subsequent recommendations have embodied the use of Semantically Linked Data and as such are a useful in understanding its potential.

### 11.6.4 ISO 19650 Suite of standards for the organisation and digitisation of information about buildings and civil engineering works.

These standards specify the delivery process for information across the stages of lifecycle. Embedding coordination, collaboration, verification of information. They do not specifically define classification but do specify the need for information requirements at all stages. Hence, they have a bearing on how we classify and recognise information.

### 11.6.5 ISO 14224 - Petroleum, petrochemical and natural gas industries – Collection and exchange of reliability and maintenance data for equipment

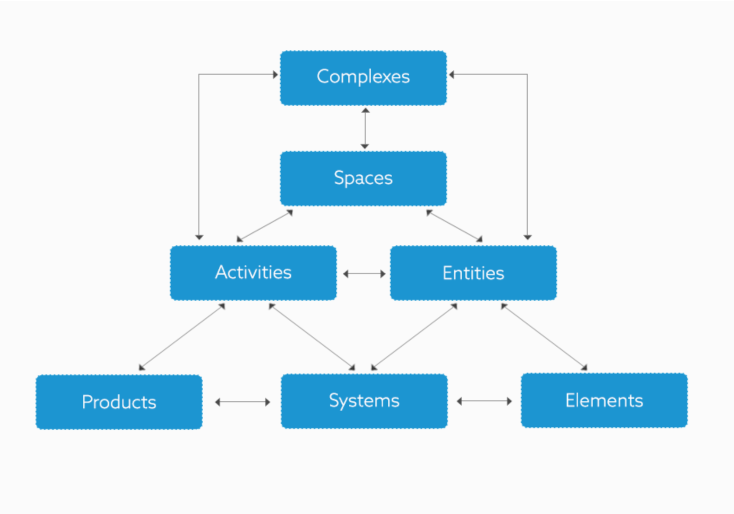
Provide principles for the collection and exchange of maintenance and reliability data for assets. It incorporates an asset Hierarchy based on ISO 14224 and as such logically creates a basic function which is satisfied by a technical solution. Trafikverket is using this standard for their asset hierarchy that they use for asset management purposes.

# 12 Existing Classification Systems

Several classification systems have been developed mostly based on the ISO 12006 standards and more recently on ISO 81436. Most have been adapted to meet the needs of digital engineering (BIM) across the built environment and are still being evolved and developed as requirements and capabilities emerge.

This report is not designed to be a comparison of existing systems but rather to understand their potential and how they fit in to the digital engineering future.

Understandably most have been developed from a national viewpoint considering the needs of local supply chains, procurement methods, contracts and traditions. There is a recognition that the industry is becoming more international and hence a need for a more global perspective. Naturally there is a degree of competition between these and the bodies that represent their development. That is understandable as many hours of personal investment has gone into them. It is encouraging that the commissioning of this report demonstrates a desire for wider cooperation across at least one region.




## 12.1 Uniclass 2015

Uniclass is a UK based classification system which was first published 1997. Revised several times most recently as part of the UK BIM Strategy to be better fitted to the world of BIM and as part of a BIM Toolkit for what has been called BIM Level 2

It is based on the principles of ISO 12006:2 and is designed to be mapped to other classification systems. It takes a unified approach to the construction industry including buildings, landscape, engineering services and infrastructure in its composition.

Made up of a broadly hierarchical suite of tables based on ISO 12006: it centres on the physical objects ranging from Complexes to detailed components. More recently it has been extended to include information form, roles, tools and equipment, & project management information.

Coding for objects are constructed as concatenated numbers from the tables and as such the system can be regarded as a tagging system.

It provides a simple extendable set of objects and relationships which has its feet in the analogue era but is evolving to meet the digital world of objects. As such it has much to recommend its use and the author understands that other countries are considering its adoption rather than creating systems of their own.

The system is freely available and is managed and actively developed introducing new tables and objects over time to further meet the needs of industry.

## 12.2 CCS

CCS is a Danish Classification system funded by the Danish Government and Private Contributors, developed between 2011 and 2015. It is based on the principles set out in ISO 81346 Standard and as such supports a 'systems' engineering approach to classification. Using a 'Reference Designation System' it builds information about specific objects from a set of object types that can be seen/filtered by functional, location and product aspects.

Initially designed to cover buildings recent efforts have been made to extend its use for infrastructure.
It has much the same foundation as the Swedish CoClass System but unlike that system has not been extended to cover asset management requirements.

Designed to create a common language for all models it has five tools for structuring building information.

- What kind of object am I? (Classification)
- Which specific object am I? (Identification)
- What properties do I have? (Properties)
- What information do I need when? (Level of Information)
- Measuring Rules

It breaks object types into similar groupings to the suggested tables in ISO 12006:2 Namely Elements, location (spaces) etc.

The result is a generated code unique for the object that describes it and its instantiation in a project. Thus, a human and machine-readable tag is generated.

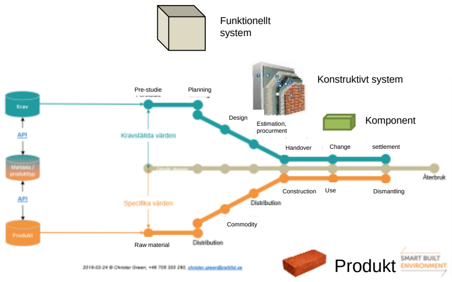
The resulting system has good support for a digital systems approach to delivering assets and is suitable for mapping to modelling systems.

## 12.3 CoClass

CoClass has been developed and sponsored by Trafikverket and other industry groups.

It takes a life cycle view of information and is designed to be incorporated across the lifecycle of assets and eventual use in asset management systems. By doing so it follows the asset through from project delivery to management and change in operation.

”Lifecycle for the product – CoClass 2019”




The development is based on ISO 81346 principles and draws heavily on the work carried out by the Danish CCS system. So similar comments apply.

There has been some criticism of the ISO 81346-2 approach during the development of the system. See comments on ISO 81346 above and reference 9 in the Appendix 7 of this report.

In test cases users has experienced issues when implementing the parts of CoClass that is based up on the principles of 81346-2:2019. The 2019 version of the 81346-2 has a different approach when it comes to the classes for basic functions, which changes the usability of the standard compared to the 81346-2:2009 version.

User comments are that CoClass has become too product-oriented and is difficult to apply with breakdown structures as 14224.

Recent developments have been made to overcome these issues.

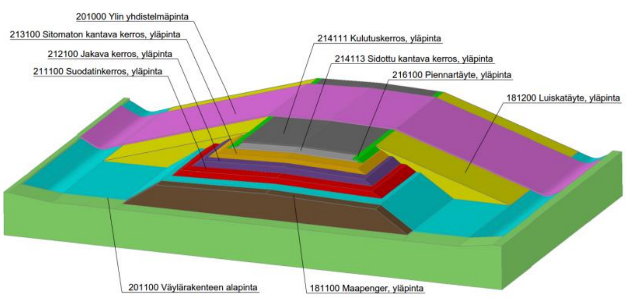
As mentioned before the author is not qualified to comment on these issues other than he feels that the approach taken in both CCS and CoClass has potential to incorporate and use modelling systems if the issues can be resolved.

## 12.4 Finnish Talo 2000

Made for buildings the classification is ISO 12006:2 table based classification but with the added capability of sub division by activity.

## 12.5 Finnish Infra 2015

An extension of the Building System to introduce Infra objects. Is closely aligned with the Finnish Infra Model which uses an expanded version Land XML to exchange design and construction information in an open non-proprietary format.




Infra Model has some maturity and in its 3rd generation of its evolution. Its use is mandated by the Finnish Transport authority for project delivery. It is intended to eventually migrate the Infra Model to be buildingSMART IFC as the Infra extensions become available and useful. The codes generated by the classification are used to label the objects in Infra Model and give each an intelligence.

### 12.6 Others

This report is not an extensive survey of the many current efforts to classify the built environment. There are a number of ISO 12006:2 based tabular systems available most notably the OmniClass system which is largely USA based. It has strong resemblance to the Uniclass 2015 system.

# 13 Related Documents, Projects and Research

During the research for this report several useful reports and research projects were discovered. It is worth reading these as background context to this report. They are, where published, referenced in Appendix A-7.

Of particular relevance are the following: -

## 13.1 ICIS Project – Classification, Identification and BIM

The output for this work is worth reading in the context of this current report and will fill in many of the gaps not discussed here. It discusses the issues surrounding the requirements for moving from existing systems to those that support BIM. It specifically addresses the issue of objects and their relationship to classification drawing on ISO 12006-2:2015 revision experience. It brings in the need for managing terminology referring to ISO 22274:2013 plus introduces the concept of Reference Designation from ISO 81346:2013.

## 13.2 CEDR-INTERLINK Project

In September 2016, INTERLINK commenced a two-year research project which resulted in a validated basic European Road Object Type Library (EUROTL), using semantic web technology.
In 2018 INTERLINK published their CEDR-INTERLINK Approach and the first basic EUROTL, which NRAs can use to improve their Asset Information Management.

The results of the project demonstrate the potential of Semantically Linked data across a wide variety of information sources with a number of practical use cases.

The resulting interactive report referenced in Appendix A -7 Ref 4 is worth reading as background to the possibilities for cloud-based information sharing in the context of infrastructure assets.

## 13.3 buildingSMART Infrastructure Extension to IFC Workshops

Over the past few years buildingSMART have been working on projects to extend their Industry Foundation Classes (IFC) to include the requirements of infrastructure. These include Bridges, Roads, Railways and Ports and Waterways and more recently work has started on Tunnels. Alongside this they have been working on harmonising the requirements that have emerged from those projects into a common approach and set of IFC extensions.

The significant benefit of this work beyond the production of IFCs is the fact that the effort has included practical engineering expertise and domain knowledge in the development process.

In many cases the output has been modelled conceptually before coding. Whilst this work is not about classification its output has bearing on the overall information needs and relationships between information of assets and therefore the output should be considered when developing future classification.

The work is ongoing so full reports are not yet available however they are being published on the buildingSMART websites and are worth reviewing.

# 14 Interview Summaries

In order to discover the context and background to this report a number of interviews/discussions were carried out with the organisations involved.

The table in Appendix A - 2 identifies each of the discovery sessions and their participants.

The author would like to thank all of those who participated in the discussions for the open and frank way issues were viewed and for the undoubted expertise that was shared. It is clear that there is a strong desire to cooperate in achieving the potential of digital engineering across the group.

Discussions were wide ranging and covered many subjects and current issues related to digital engineering and BIM. It is not the intention to report on these interviews in detail, nor to compare each organisation’s implementations and their progress. The discussions were used to understand, extract and discuss the current state of knowledge, use of classification, specific issues, future requirements and predictions.  This report is the result of those discussion and the supporting research carried out.

The following are extracted as specific highlights and observations from the interviews: -

- Most organisation rely on classification to create a coded tag to add intelligence to and identify objects, lines and polygons in their design tools. This may be to give a label to an object/line in a CAD model or to label the object in a BIM model such as in the Finnish Infra Model.
- Those tag labels are created as a concatenated string drawn from classification tables which identify objects and relationships.
- The origins of most classification systems have some roots in the ISO 12006:205 table suggestions.
- The Reference Designation System (RDS) in ISO 81346 forms the base of systems in the majority of classification systems. Recognising the systems approach it provides a basis for modelling relationships and a common language across projects.
- In Norway a step towards a modelled approach to object relationships is being developed based on models according to the Unified Modelling Language (UML) and standards from ISO/TC 211 and the Open Geospatial Consortium (OGC). The resulting objects are then expressed in GML or IFC.
- Similarly, in Finland a modelling approach is evolving based on their Infra Model moving towards buildingSMART IFC.
- In all cases there are many stakeholders across the life cycle which need to be taken into account and the needs of these stakeholder need to considered as classification is evolved from its current narrow design and costing base.

# 15 Appendix

## 15.1 A - 1 Original Brief

### Proposal for a Nordic study about classification systems

The digital transformation in building and infrastructure industry is dependent on implementation of BIM for the whole lifecycle. The public sector within road and railway in the Nordic countries identified vital reasons for a common approach to BIM particularly since BIM is a subject under development, with major consequences for our organizations. Supporting the flow of information between different systems through the different stages of the lifecycle requires a common approach to organize data in standard way in the different systems.

Over some time, infrastructure organizations have been working with classification of the information digitally. Different ISO standards have been published to define the principals for organizing information. Based on them different classification systems are prepared in different countries. Digitalization of asset information and use of different type of data has challenged the traditional classification systems. New technologies as Internet of Things (IoT) and using information from sensors creates the need for more flexibility classifying information. Successful pilot projects using linked data open up a new approach to organize information.

Assets and information about them are generated and updated by design and building processes, handed over to the organization maintaining the assets. The information is being stored in asset management systems and updated through operation and maintenance. By using the same classification system through the whole processes, the flow of data becomes more effective and reliable. Within the last decades the supply chain has become more and more international. It is even more visible within Nordic countries where the same suppliers work across the countries. Having the same approach to classifying the information gives better odds to implement the classification in the used software, which is important for all parties.

To understand the capacity of the different classification systems and their approach to digitalization of asset data supporting BIM in lifecycle, it is recommended to make a study within the most used systems, compare them based on the need for information through the whole lifecycle and towards linear assets as road and railroad systems.

The product of the study should be a 10-20-page report. The report must clarify:

- What is classification system?
- Why it is important to have a classification system?
- Which major classification systems are available?
- Which ISO standards are behind the major classification systems?
- What are the differences between the major classification systems?

- What is linked data?
- Is the construction business ready for linked data? How do we secure the information flow before linked data is in place?
- Is there any conflict using classification systems and linking data at same time?
- What are the tendencies for development of classification systems?
- Comparing different classification systems are there any of them better covering linear assets?
- Comparing different classification systems are there any of them better covering lifecycle including asset management?
- Comparing the classifications system if they allow to split up and follow the asset as a function and the physical element that realizes the function.
- What are the challenges and benefits implementing the compared classification systems?
- Which criteria are important when evaluating classification systems?
- What other standards are needed to describe linear assets?
- What other standards are needed to describe the different aspects from PIM and AIM

The NBC organizations must assist the study by giving input about their approach to asset management to get a consensus about whether we can get agreement on a common approach. The report can be facilitated by buildingSMART Nordic to ease the procurement process. The Nordic BIM group are to be interviewed to cover the vital needs for information for the study. NBC supports the report by delivering the relevant studies within the classification to the author of the report. Suggested start 1st March 2019; deadline 31st May 2019.

## 15.2 A - 2 Participating Organisations & Interview Participants

| Country | Organisation | Attendees |
|---|---|---|
| **Denmark** | Banedanmark | Gita Monshizadeh - Head of BIM & Digital Innovation department<br>Jørgen Eigil Hammer – Application Architect<br>Libeth Frausing - Project manager, Data & Documentation<br>Henrik Juell-Sundbye - Digitalization consultant, Data & Digitalization<br>Reza Barati - BIM specialist, Construction division |
| | Vejdirektorat | Helle Nedergaard Johanson – Surveying Technician<br>Kaj Storustovu – IT<br>Neel Kallehave-Rolland – Contract Manager<br>Soren Fogh – Asset Manager |
| **Finland** | Väylä | Tarmo Savolainen – Chief Specialist InfraBIM<br>Teea Kantojarvi, Specialist Railway Information<br>Ari-Pekka Manninen, Development Manager<br>Heidi Kotiranta, Project Secretary<br>Ari Huomo, Development Manager<br>Tiina Pertula, Ramboll, Director InfraBIM<br>Juha Liukas, Sitowise, Leading Consultant |
| **Norway** | Bane NOR | Kristin Lysebo – BIM Manager<br>Adis Delalic – IT Architect |
| | Vegvesen | Thor-Sigurd Thorsen – BIM Manager<br>Ingar Skogli – Geomatic Classification |
| **Sweden** | Trafikverket | Mikael Tornkvist<br>Matts Karslsson<br>Peter Axelsson<br>Rae White |

## 15.3 A - 3 Organisation Contacts

| Country | Organisation | Contact | email |
|---|---|---|---|
| **Denmark** | Banedanmark | Gita Mohshizadeh | gimo@bane.dk |
| | Vejdirektorat | Rasmus Lynge Fuglsang | rfj@vd.dk |
| **Finland** | Väylä | Tarmo Savolainen | Tarmo.savolainen@vayla.fi |
| **Norway** | Bane NOR | Kristin Lysebo | Kristin.lysebo@banenor.no |
| | Nye Veier AS | Per Qvalben | Per.qvalben@nyeveier.no |
| | Vegvesen | Thor-Sigurd Thorsen | thor-sigurd.thorsen@vegvesen.no |
| **Sweden** | Trafikverket | Ingemar Lewen | Ingemar.lewen@trafikverket.se |

## 15.4 A - 4 Baseline Standards

| Publication | Publisher | Notes |
|---|---|---|
| **ISO 12006-2:2015**<br>**Building construction – Organization of information about construction works-**<br>**Part 2: Framework for classification** | ISO International Organization for Standards | Defines a framework for construction sector classification systems and identifies a set of recommended classification tables and their titles for a range of construction objects.<br>Has been revised to include full life cycle and the basic principles of building information modelling.<br>Is the base of most of the classification systems in current use or development? |
| **ISO 12006-3:2007**<br>**Building construction – Organization of information about construction works-**<br>**Part 3: Framework for object orientated information** | ISO International Organization for Standards | Provides a basis of a modelling approach to information.<br>Specifies a language independent information model which can be used for the development of dictionaries used to store or provide information about construction works. It enables classification systems, information models, object models and process models to be referenced within a common framework. |
| **ISO 22274:2013**<br>**Systems to manage terminology, knowledge and content – Concept-related aspects for developing and internationalising classification systems.** | ISO International Organization for Standards | Establishes basic principles and requirements to ensure classification systems are suitable for worldwide application. Addresses the need for domain centric concept centric classification. Provides guidelines on information content, terminological principles and requirements for internationalisation. Is referred to in ISO 12006-2:2015 to elucidate structure in classification. |
| **EN 813346-2:2009**<br>**Industrial systems, installations and equipment and industrial products – Structuring principles and referencing designations**<br>**Part 2: Classification of objects and codes for classes** | ISO International Organization for Standards | This and its accompanying suite of parts establishes principles for structuring objects and associated information and rules on forming reference designations of objects. It recognises the need for systems approach to classification and attempts to provide a common language for referencing objects within those systems and their derivatives. |
| **Geographic information/Geomatics, ISO/TC 211:**<br>About: https://committee.iso.org/home/tc211<br>General information: https://www.iso.org/committee/54904.html<br>Standards: https://www.iso.org/committee/54904/x/catalogue/p/1/u/0/w/0/d/0<br>Standard models & schemas: https://www.isotc211.org/<br>Members: https://www.iso.org/committee/54904.html?view=participation | | |

| |
|---|
| **Open Geospatial Group (OGC):**<br>General information: https://www.opengeospatial.org/<br>Standards: https://www.opengeospatial.org/standards<br>Members: https://www.opengeospatial.org/ogc/members |
| **Unified Modelling Language (UML):**<br>General information: https://www.uml.org/index.htm<br>Rules for UML-modelling of geographic information, ISO 19103:2015 :<br>https://www.iso.org/standard/56734.html<br>National standard for UML-modelling of geographic information based on ISO 19103:2015:<br>https://www.kartverket.no/globalassets/standard/sosi-standarden-del-1-og-2/sosi-standard-del-1/5.0/regler_for_uml-modellering_5.0.pdf |
| **SOSI – national standards for organization of geographic information/Geomatics:**<br>https://www.kartverket.no/geodataarbeid/Standarder/SOSI/ |

## 15.5 A - 5 Related & Supporting Standards

| Publication | Publisher | Notes |
|---|---|---|
| **ISO 29481 – 1:2017**<br>**Building information models – information delivery manual** | ISO International Organization for Standards | This part of the standard provides a methodology for creating delivery manuals for information that links the business process of constructing and managing facilities and their constituent object.<br>Although it does not specifically mention classification the processes that it links are key to the information about assets and hence help in understanding facets of classification. |
| **ISO 29481 – 2:2016**<br>**Building information models – information delivery manual**<br>**Part 2: Interaction framework** | ISO International Organization for Standards | This part of the standard provides a methodology for an interaction framework between actors and the information that links the business process of constructing and managing facilities and their constituent object.<br>Like Part 1 it does not specifically mention classification the processes that it links are key to the information about assets and hence help in understanding facets of classification. |

| Publication | Publisher | Notes |
|---|---|---|
| **ISO 22263:2008**<br>**Organization of information about construction works – Framework for the management of projects** | ISO International Organization for Standards | This standard specifies a framework for the organisation of project information in construction projects. It includes both process related and output product related information. Whilst not a classification standard it is helpful in understanding the wide range of information handled by projects and how it is related and linked to the eventual assets and their requirements. |
| **ISO 15926: Integration of lifecycle data for process plants including oil and gas production facilities.** | ISO International Organization for Standards | Although pointing at the process industry this standard has much content that could be offered to the wider construction industry. It takes a conceptual model approach to data representation describing ontologies of objects. It is particularly useful in understanding a semantic linked data approach to information exchange. |
| **ISO 19650 Suite of Standards**<br>**Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling** | ISO International Organization for Standards | The set of standards that specify the requirements for delivery of assets including the defining of information requirements and the processes for information delivery, coordination, validation and verification. |

## 15.6 A - 6 Existing Classification Systems

| Publication | Publisher | Notes |
|---|---|---|
| **CoClass** | A consortium of Swedish organisations including Trafikverket and other industry bodies. | A classification system built on the principles outlined in ISO 12006:2015 and the ISO 81346 suite of standards. Designed to cover the whole life cycle of assets. It is designed to support all the tables in ISO 12006 and hence covers the full life cycle process.<br>It creates labels for assets based on the ISO 81346 Reference Design standard. These labels build strings of letter codes that create an intelligent description of the asset and its identity. By doing so it creates a common asset terminology aiding interoperability.<br>It is designed with APIs to work in a digital environment but to also be able to humanly understandable.<br>It is available for use via paid licence. |
| **Omniclass** | CSI and CSC in the USA and Canada | A classification system built on the principles of ISO 12006:2015. It is a North American interpretation of that standard. Like Uniclass creates classifications by joining together tables as facets.<br>It is maintained |
| **Uniclass 2015** | Published and managed by NBS in the UK | A classification system built on the principles of ISO 12006:2015. It is a UK interpretation of that standard. Designed to cover the life cycle of an asset. Has expanded tables that cover both buildings and infrastructure aspects of construction. It creates a classification for assets by joining tables as facets.<br>It is currently maintained and is free at the point of use. |
| **CCS** | Danish Government cuneco project | Implements and embeds the principles of ISO 81346 series of standards.<br>Is currently being updated to extend beyond its early electrical systems and building related systems content to include infrastructure.<br>Bears close relation to Swedish CoClass without its reference to asset management content.<br>Creates a unique concatenated string of numbers and letters based on references to identify an object. |
| **Finnish InfraBIM** | Building Information Foundation RTS | A series of object type codes covering most of the objects encountered in transport assets along with codes to describe resources and work carried out.<br>Is designed to support the Finnish Infra Model standardisation for delivering information about infra assets. |

| | | |
|---|---|---|
| **Finnish Construction Talo 2000** | Building Information Foundation RTS | A system for buildings based on ISO 12006 table approach but including a series of methods for breakdown structures to be used for BIM, specifying, cost management and production planning |

## 15.7 A - 7 References and Further Reading


1. ICIS (International Construction Information Society) Project 3 Report – Classification, Identification and BIM, October 2017
2. OGC Project Document 16-000r1 – Landinfra executive summary Paul Scarponcini. - Linear Referencing
3. Implementing Model Semantics and a (MB)SE Ontology in the Civil Engineering and Construction Sector - http://81346.com/english/wp-content/uploads/Presentation-of-RDS-ccs-NOSE-2015-Tour-for-www-publication-2015-05-31-c.pdf
4. CEDR-INTERLINK Project Report – Results of CEDR Project introducing the concepts of semantically linked data and the proposal of a Euro Object Type Library (EUROTL) for roads. https://rhk.maps.arcgis.com/apps/MapSeries/index.html?appid=f4ae8c1686554521bfef818efa0bab06
5. SKOS Simple Knowledge Organisation System Reference – https://www.w3.org/TR/skos-reference
6. NATSPEC – ICIS – National BIM Object Type Library Survey – Summary Report.
7. Classification made simple – An introduction to knowledge organisation and information retrieval – Eric J Hunter – Third Edition – Ashgate publishing Ltd ISBN 978-0-7546-7558-7
8. Organising knowledge – Taxonomies, knowledge and organisational effectiveness – Patrick Lambe – Chandos Publishing – ISBN 1-84334-227-8
9. A Critical analysis of international standards for construction classification – results from the development of a new Swedish construction classification system. Anders Ekholm – Lund University - https://portal.research.lu.se/portal/files/16339424/2016_10_31_Ekholm_CIB_W78_paper.pdf