ICIS PROJECT #3 - CLASSIFICATION, IDENTIFICATION, AND BIM

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Executive summary

This ICIS report states that a number of existing national classification systems today are useful in order to organize various types of information for certain parties in some of the processes in the construction lifecycle. But it also questions if currently used classification is optimal for supporting the collaborative process with BIM and all parties involved.

With the 2012 international survey of the implementation and use of construction classification systems worldwide, the revision of the classification standard ISO 12006-2, and the experiences from current nationally based classification work, several issues were addressed and questions raised about the use of classification in construction as we know it today.

With the revision of ISO 12006-2, the focus changed from not only classification according to purpose but also creating common language and structuring of information referencing project-specific objects working with BIM.

In this report, these issues are explained and discussed in order to generate a debate of what will be necessary to support a fast-developing BIM practice that combines information from several sources and software platforms. Much adaption of existing classification systems to BIM is going on. Though the classification for BIM potential of the revised ISO 12006-2:2015 edition, in combination with other relevant international standards, has still to be released.

This report is written for persons and individuals in the construction sector. On expert level, it is occupied with and discusses the use, the importance, and the nature of classification and identification in and with BIM.

Introduction - The challenge of BIM to classification

Building Information Modelling (BIM) is changing the way we deal with information in the construction sector, transferring information contained in traditional documentation to ICT-handled data objects with attached information representing the construction complexes and entities, the spaces, and the elements. The same change is affecting all of the resources and processes used to program, design, produce, and maintain these construction results and their related information to be used in a more collaborative, integrated, and sharing manner than ever.

Classifying construction information is thereby challenged in order to support these changes and new ways of working and to provide common language, structure, and ways of handling information in a more uniform way than before. Therefore, in this report classification, defined language, and structuring of information will be seen as integrated parts of the same context and can be seen as dealing with the "I" in BIM. The scope of this report is thus broader than the use of classification in itself.

For some years, there has been an ongoing discussion within ICIS and other international forums about these issues. This report tries to outline the most essential topics of these discussions and refer to the work being done nationally and internationally about redefining construction classification itself, and the way of using it to support BIM. Also, globalization sets an agenda for more international standards to be developed within these areas.

Because we are in the middle of change, this report will reflect the mixed situation of a journey from an analogue to a gradually increasing digital practice. However, in order to not only refer to the current state of the art, it is intended also to list debatable demands and possible solutions/actions for the future use of classification in a BIM context.

1. BIM

1.1 Definitions of BIM

There are many definitions of BIM; for example, the following four definitions or explanations were taken from websites of different organizations.

> NIBS: "A BIM is a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward."
>
> NBS: "…it is simply the means by which everyone can understand a building through the use of a digital model. Modeling an asset in digital form enables those who interact with the building to optimize their actions, resulting in a greater whole life value for the asset."
>
> Autodesk: BIM is an intelligent model-based process that provides insight to help you plan, design, construct, and manage buildings and infrastructure.

BuildingSMART: "BIM is an acronym, which represents three separate but linked functions:

> Building Information Modelling: Is a BUSINESS PROCESS for generating and leveraging building data to design, construct and operate the building during its lifecycle. BIM allows all stakeholders to have access to the same information at the same time through interoperability between technology platforms.
>
> Building Information Model: Is the DIGITAL REPRESENTATION of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its lifecycle from inception onwards.
>
> Building Information Management: Is the ORGANIZATION & CONTROL of the business process by utilizing the information in the digital prototype to effect the sharing of information over the entire lifecycle of an asset. The benefits include centralized and visual communication, early exploration of options, sustainability, efficient design, integration of disciplines, site control, as built documentation, etc. - effectively developing an asset lifecycle process and model from conception to final retirement."

In summary:
BIM is about constructing and maintaining the building twice, first digitally then physically. BIM is then a digital representation of a building made of objects that are related: the building itself, the spaces, and the systems (construction elements) that make up the spaces. But it is also about the processes of capturing all of the structured information, bringing everything together, coordinating different systems and platforms, supporting collaboration and knowledge sharing, and being efficient and productive in a standardized and digitalized manner. This process is where classification, defined language, and structuring of information come into perspective of BIM.

1.2 Objects and ISO 12006-2

BIM involves the definition of a building as a composed set of objects (*BIM Handbook*).
A virtual model of a building, therefore, consists of objects representing the building and its constituents, the Construction results. But other types of construction objects are just as relevant according to ISO 12006-2:2015 - *Building Construction - Organization of Information about Construction Works - Part 2: Framework for Classification*. This framework defines the overall conceptual model divided into four domains (see figure 1).

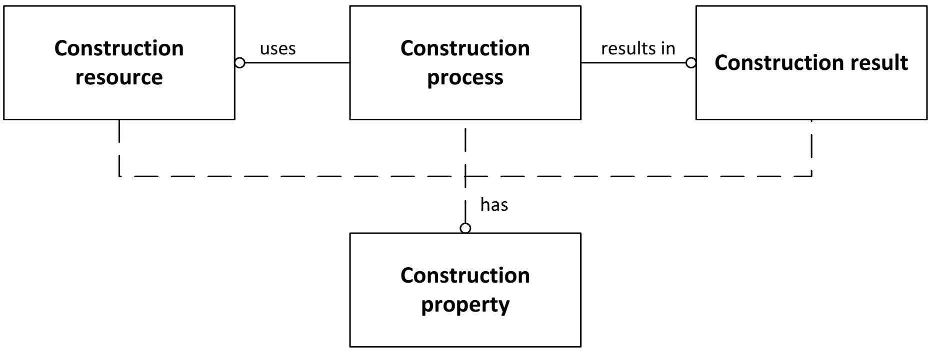

Figure 1 - Grouping of object classes are according to ISO 12006-2 divided into four superior domains of the conceptual model

The construction resources and the construction processes are important objects for collaboration, producing, and managing construction; the construction properties are the data-bearing constituents of the collected information about the building and its design and maintenance.

The focus on data objects for the last 20 years is successively emphasized by the more extended use and functionality of the 3D object-oriented model. However, both geometrical and alphanumerical data still make up the collected virtual representation of a building - the "I" in BIM. Classification and structuring of information have the potential to be the glue that brings all this together if it is designed to support the BIM processes and handling of objects and all their information.

1.3 Databases

The extended use of databases has technologically made it possible to create and handle object-oriented information, and to exchange and remodel it. It is a movement from data embedded in analogue documents and office package tools to accessible and reusable data in databases.
What has happened to the geometrically based building model tools in order to make more intelligent models will also have to happen to the handling of alphanumerical data outside the geometrical models in order to relate and converge the two areas of data. There is a need to bring these data together and use and reuse the respective sets of data in order to be able to simulate scenarios and extract useful information in the design, the execution, and the maintenance processes.

Object libraries with shared objects and contained data sets will be future placeholders for important information in the construction industry.

2. Classification, defined language, and structuring of information

2.1 The revision of ISO 12006-2 (released 2015)

Since 2001, ISO 12006-2 - *Building Construction - Organization of Information about Construction Works - Part 2: Framework for Classification* has been the standard for national construction classification systems to be based upon. The standard defines the scope of construction classification, defines the overall conceptual model (see figures 1 and 5), and points out relevant classification tables for the construction industry to use (see chapter 2.5, Object classes and classification tables). ISO-12006-2 does not specify any principles on precisely how to classify or how to define concepts and classes. One of the general goals of revising the standard was to move it from the area of merely classifying document-oriented information to make it more BIM- and object-focused, aligning it more with the object-oriented information standard ISO 12006-3:2007 - *Building Construction - Organization of Information about Construction Works - Part 3: Framework for Object-Oriented Information*, and thus bring it closer to the use of the buildingSMART standards for Industry Foundation Classes (IFC) and buildingSMART Data Dictionary (bSDD).

Other improvements of ISO 12006-2 were also taken in as a part of the scope for the revision, such as follows:

- The need for inclusion and acceptance of system awareness in general to be applied to solve problems of understanding the complexity of construction and to support systems engineering and systems delivery in an industrialized manner
- To clearly distinguish between part-of relations (system-of-systems) and type-of relations (classification)
- To clearly specify how part-of relations and type-of relations can be combined to an unambiguous identifier for systems and their constituents to respond to the need for structuring of information and for supporting the coordination of platforms handling this information

2.2 The international classification survey and end-user comments

Before the finished revision of the standard, now ISO 12006-2:2015, an international classification survey was planned and executed to provide the workgroup with relevant information about the actual state and use of classification in construction worldwide in general and related to ISO 12006-2 as a framework standard specifically. Primary participants were from the national classification bodies, the buildingSMART community, the observing and participating member countries from ISO TC/59/SC13, and members of ICIS - in all, 51 participants from 19 countries (Europe, North America, Asia, and Australia); 27 of which fully completed the thorough survey. The survey was attended by a great deal of well-known BIM-oriented participants and spokespersons.

The detailed Q&A of the survey and other end-user comments appear in detail in Annex A - The international classification survey and end-user comments.

2.3 Demands for classification and structuring of information summarized

Referring to Annex A, an extract of the survey and the end-user comments to summarize demands for a standardized construction classification and information structuring system with BIM could be as follows:

1. It is important to engage the whole value chain in classifying and structuring information in order to get the collaborative BIM process to work smoothly - general industry implementation is needed.
2. It is important that classification systems support the generation and exchange of all types of information and for all parties involved - also in the areas of execution and facilities management.
3. There is a need for classifying the object unambiguously (to know what kind of object, the type-of relations).
4. There is a need to be able to structure systems and their information and to generate reference designations in order to identify project-specific objects (to know which specific object and/or in which context, the part-of relations).
5. There is, in the near future, still a need to support both classification of traditional document-based and BIM object-based information.
6. The end user will prefer fewer and more stable classification codes throughout the lifecycle of an object - mapping is optional if needed, but it can also be complicated and difficult. Advantages, disadvantages, and consequences of mapping of concepts and classification codes remain to be discussed.
7. Maybe a more simplified classification of objects is needed supplemented by the use of classified properties.
8. Machine-readable codes being implemented in software-systems to support the end-user’s needs will be preferred - also including the classification notation part of IFC to be implemented in software to ensure the exchange of information between platforms.
9. Some important criteria could be to base classification and structuring on well-known international standards in order to achieve higher compatibility and more likely software implementation.

2.4 Terms and definitions for concepts and classes

Some problems with construction classification systems today will now be mentioned in relation to the revision of ISO 12006-2, in relation to BIM, and for working with classification in general.

It is often seen in construction classification that there in the same tables is a mix of concepts, terms, and synonyms maybe because of a lack of (proper) definitions for concepts and sometimes also for the classes they belong to. This mix results in what is termed *enumerative classification*, uneven lists that are even placeholders for "miscellaneous" and "others" classes. These categories will make it hard to place or find some objects, which in itself is a problem but also is extremely critical to BIM.

Enumerative classification tables often result in unclear classification and doubtful placing of objects in the right classes. A typical example could be walls - will they be put in the class for loadbearing walls or in the class for space dividing walls? And what if a wall is changed from being loadbearing to just being space dividing? Will it then have to change class and classification code? In these situations, the placing in the table is typically handled by individual interpretation that focuses on what should be the most important characteristic according to agent, process, or purpose.

Another problem often seen in many of these classification tables is Column, Pole, Post, and others are put in different classes although they have the same characteristic function. Actually, they are synonyms, often material- or discipline-specific occurrences, that have many of the same characteristic properties. Nevertheless, they are often listed individually with the risk of misinterpretation. Enumerative lists, though, are better than no lists at all.

Some basic principles must be followed in order to achieve unambiguous and well-defined classification tables. As a consequence of a somewhat unclear and uneven classification practice in the construction industry worldwide, three standards were brought into the work during the revision of ISO 12006-2:2015.

The basic and widely accepted principles of relations (part-of relations, type-of relations, and associative relations) are defined in ISO 704:2009 - *Terminology Work - Principles and Methods*, which subsequently has become a normative reference in ISO 12006-2. ISO 704:2009 is about using:

- A preferred term together with other terms as synonyms, all designating the same concept,
- Intentional definitions of concepts and classes (an intentional definition is a concise statement of what the concept is),
- A distinguishing between concept relations as generic, partitive, and associative relations,
- Terminological analysis for creating classes,
- A description of the theoretical relations between objects, concepts, properties, and characteristics.

ISO 1087-1:2000 - *Terminology Work - Vocabulary – Part 1: Theory and Application* is about terminology in order to provide a systemic description of the concepts in the field of terminology and to clarify the use of terms in this field. ISO 1087-1:2000 has become a normative standard in ISO 12006-2 and deals with:

- Concept relations - superior and subordinate concepts,
- Terminological ontologies and relations to classification,
- Intentional definition principles,
- Characteristics and criteria for division of classes.

Rules for creating classification systems in general are described in ISO 22274:2013 - *Systems to Manage Terminology, Knowledge and Content - Concept-Related Aspects for Developing and Internationalizing Classification Systems*, which was published during the revision work of ISO 12006-2 and was adapted during the finalization of the standard as a general rule of creating classes (not previously described in the standard). ISO 22274:2013 also became a normative standard in ISO 12006-2 and deals with:

- Fundamental development considerations for classification systems,
- Terminological principles related to classification systems,

- Concept systems and classification systems,
- Requirements for an internationalized classification,
- Internationalization aspects,
- Localization aspects.

ISO 704:2009, ISO 1087-1:2000, and 22274:2013 together add supplementary principles to the framework of ISO 12006-2:2015 for use of classification in construction. These standards could also greatly benefit the work in bSDD.

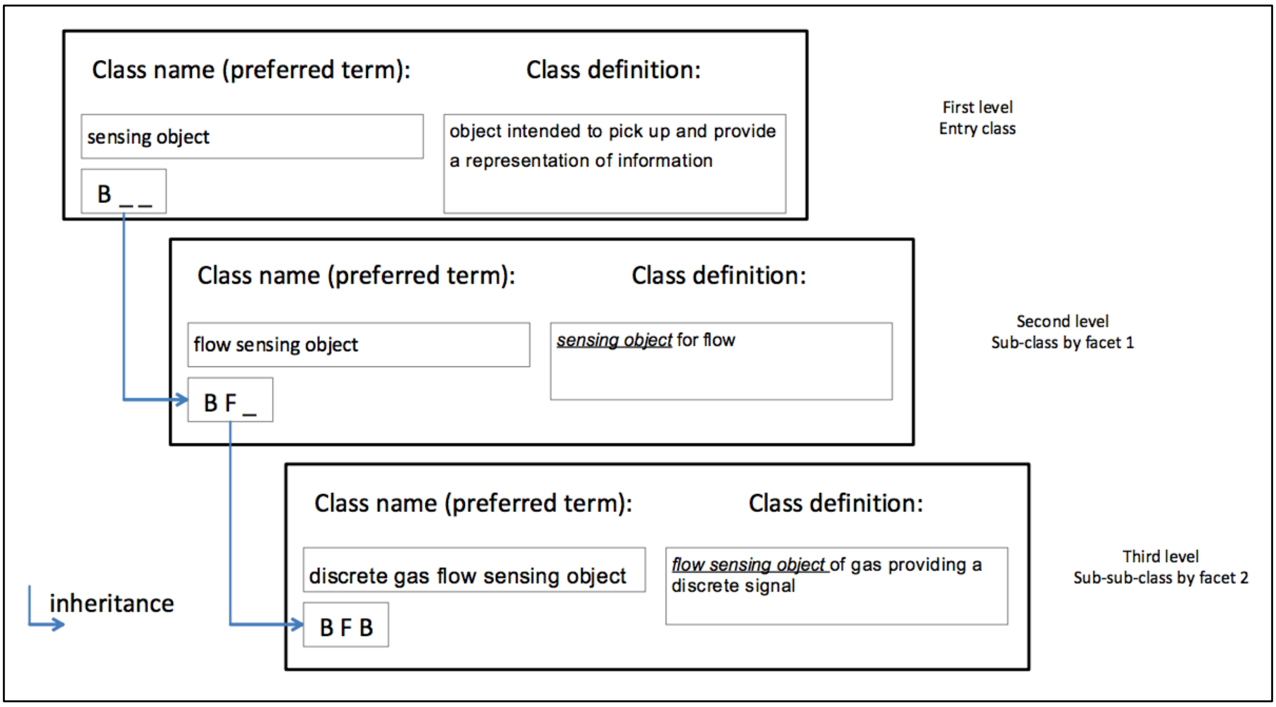

Figure 2 - Illustration of a definition of classes [ISO/IEC81346-2 under revision, CD version 2016]

In figure 2, according to ISO 704:2009, is an example of how a definition begins with a predicate noun stating the border generic (superordinate) concept associated with the concept being defined, together with delimiters indicating the characteristics that delimit the concept being defined from coordinate concepts.

Classification theory is thus well defined and can be readily applied for assessing how soundly constructed a classification system is, e.g., subdivision by a consistently applied characteristic or ordering principle, expressive notation.

No further detailed description about the methods and principles mentioned in these standards will be discussed in this report. Doing so will take the report too far and into the standards as well. The standards mentioned might instead be seen as important references for the professionalization of classification in construction and could be useful for improving many classification systems already in use. In this report though, some issues from the standards will be mentioned according to difficulties in making more common and BIM-oriented classification systems easier to handle for end users.

2.5 Object classes and classification tables

ISO 12006-2 recommends the following items for tables grouped by the four domains (see figure 1) and listed by table name and what to be classified by.

CLASSES RELATED TO RESOURCE:
A.1 Construction information - by content
A.2 Construction product - by function or form or material or any combination of these
A.3 Construction agent - by discipline or role or any combination of these
A.4 Construction aid - by function or form or material or any combination of these

CLASSES RELATED TO PROCESS:
A.5 Management - by management activity
A.6 Construction process - by construction activity or construction process lifecycle stage or any combination of these

CLASSES RELATED TO RESULT:
A.7 Construction complex - by form or function or user activity or any combination of these
A.8 Construction entity - by form or function or user activity or any combination of these
A.9 Built space - by form or function or user activity or any combination of these
A.10 Construction element - by function or form or position or any combination of these
A.11 Work result - by work activity and resources used

CLASSES RELATED TO PROPERTY:
A.12 Construction property - by property type

In many classification systems, there are tables for Element (generic), Designed element (for drawings and models), Work section/Work result/Production result (for calculation and execution), and Maintenance result (for operation purposes). These tables are in a historical context also focused on classifying the document-based information and serve these purposes well.

Many countries having classification systems for construction have several of the listed tables, and some have only a few.

The classification tables typically describe type-of relations of concepts and classes.

2.6 Type-of relations and the desired level of classification

The principles for defined criteria for superior and subordinate classes are thoroughly described in the four ISO standards mentioned in chapter 2.4. In figure 3, two examples are given. The figure shows that types of generic elements, such as wall, roof, floor, insulation, valve, slab, duct, etc., are listed in the Construction elements table.

It is also possible to make the subtypes of these according to material or location as shown. The generic class insulation is here divided into subclasses as wall batts, duct insulation, etc.

This action can be handled as two separate classification tables or combined into one. Numerous construction classification systems make the combination of the generic and the subtype classes.

Different participants are interested in different properties because they have an interest in information for different purposes and processes. All classification is based on characteristic properties. The choice of characteristic properties is, therefore, closely connected to the purpose of the classification and the target group for the use of this classification.

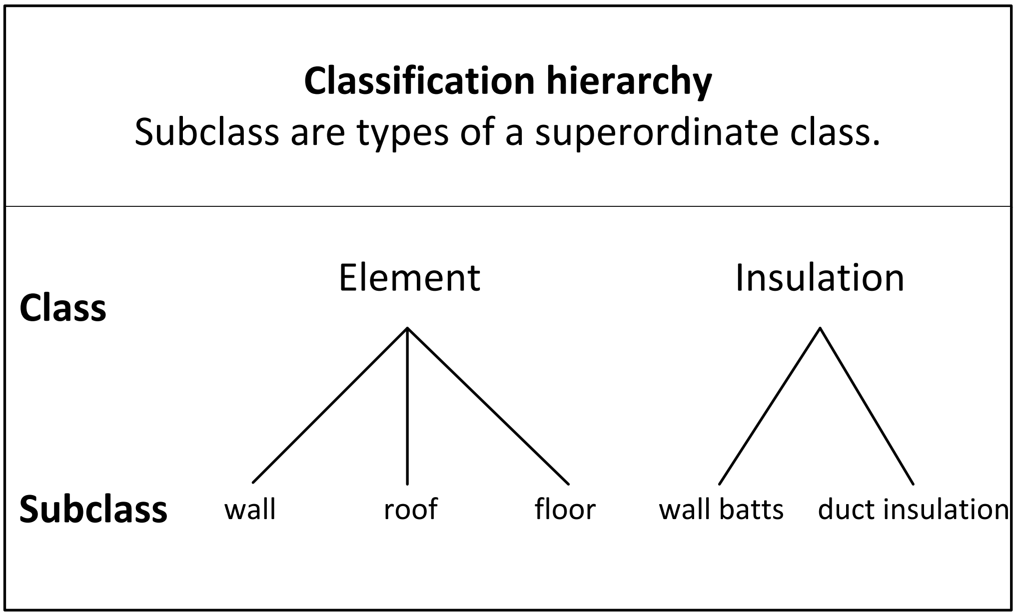

Figure 3 - Illustration of a classification hierarchy as type-of relations [ISO 12006-2, part of figure 2]

There is a built-in conflict in that the more type specific a classification will be, based on a certain combination of properties, the more useful it will be for a specific purpose of a specific participant in the construction process and the less useful it will typically be for others. An object, such as a window, can easily have over 200 properties; some of them will be of interest for:

- The client (e.g., functionality, light transparency, sustainability, color, and reflection),
- The architect (e.g., hung type, material, glass area, color, transparency, solar transmittance, dimension, and profiling type),
- The engineer (e.g., glass area, thermal transmittance, insulation factor, fire protection, security rate, safety, and thermal stress cracking),
- The manufacturer (e.g., number of glass panes, dimensions, material, type, production cost, production time, and CE-marking),
- The contractor (e.g., window type, quantity, quality marking, mounting information, mounting time, and tendering price),
- The maintenance organization (e.g., manufacturer name, fabrication name, longevity, service interval, location, accessibility, and service cost).

A few of these properties will be of mutual interest for nearly all parties, and specific properties will frequently only occur in a certain stage of the lifecycle. Consequently, a lot of properties will only be of interest for one or a few parties throughout the lifecycle of a window. Classifying a subtype of a window by using two, three or four properties can only serve a few purposes; however, it can do that specifically and very well.

This problem was addressed by the classification survey made in relation to the revision of ISO 12006-2:2015, initiated in 2013. From the survey, it was clear that loads of actual classified information in construction is related to the practice of consultants and is used mainly by this group for specification and calculation purposes. The same information and its classification is only used by contractors and maintenance organizations to some extent and is due to a consequence of stated demands or possible information deliveries, if at all usable. Examples were given that contractors and maintenance organizations had to change the classification of information to a more useful purpose. Renaming and recoding elements can thus be a huge maintenance task for the parties all through the construction lifecycle.

With BIM, multiple levels of object definition and specification are needed - from early stage design using generic objects, to fabrication level detailing the implemented object. But a door will still be a door. Only the amount and precision of information will increase throughout the process, from a few initial and maybe temporary data (properties), to countless detailed and finally decided data (more properties with specified values).

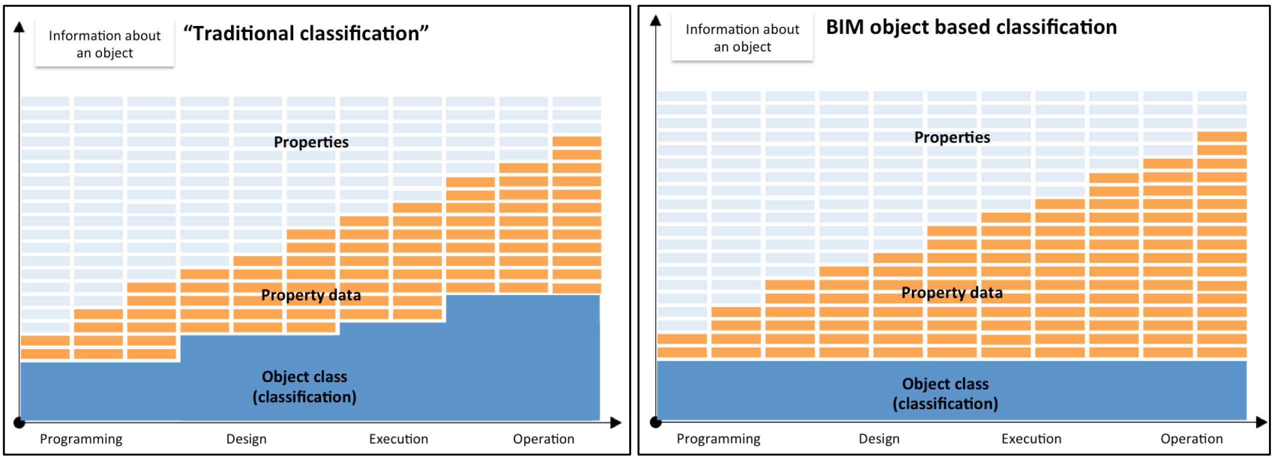

Figure 4 – Illustration of two possible types of classification systems:
To the left, a typical or "traditional" classification with different classification tables for different participants and purposes and specialized subtype classes incorporating more and more properties.
To the right, a generic and stable classification with one entry class that is used all through the lifecycle combined with an increasing number of properties that might be selected, searched, or sorted as property sets through defined information levels according to specific purposes.

The fundamental questions for any construction classification in relation to BIM will be:

- Will we find value in giving the same object different codes of (sub)type classification according to the amount of properties successively specifying the object further?
- Or will we generally classify the object as a door and derive the subtypes of it from the properties most wanted by any participants in any stage of the lifecycle?

- Will we name the object differently according to change of classification codes or according to change of properties?
- Or will we want to use the preferred generic term for classifying the construction element and add a type name as a property?
- And/or will we do or have to do all of this in combination for a lot of good reasons, especially considering the amount of already classified information available?

Types of elements and the related naming and classification are due to change continuously as a result of:

- Development of new materials
- New ways of working
- Time-specific architectural design
- And so forth

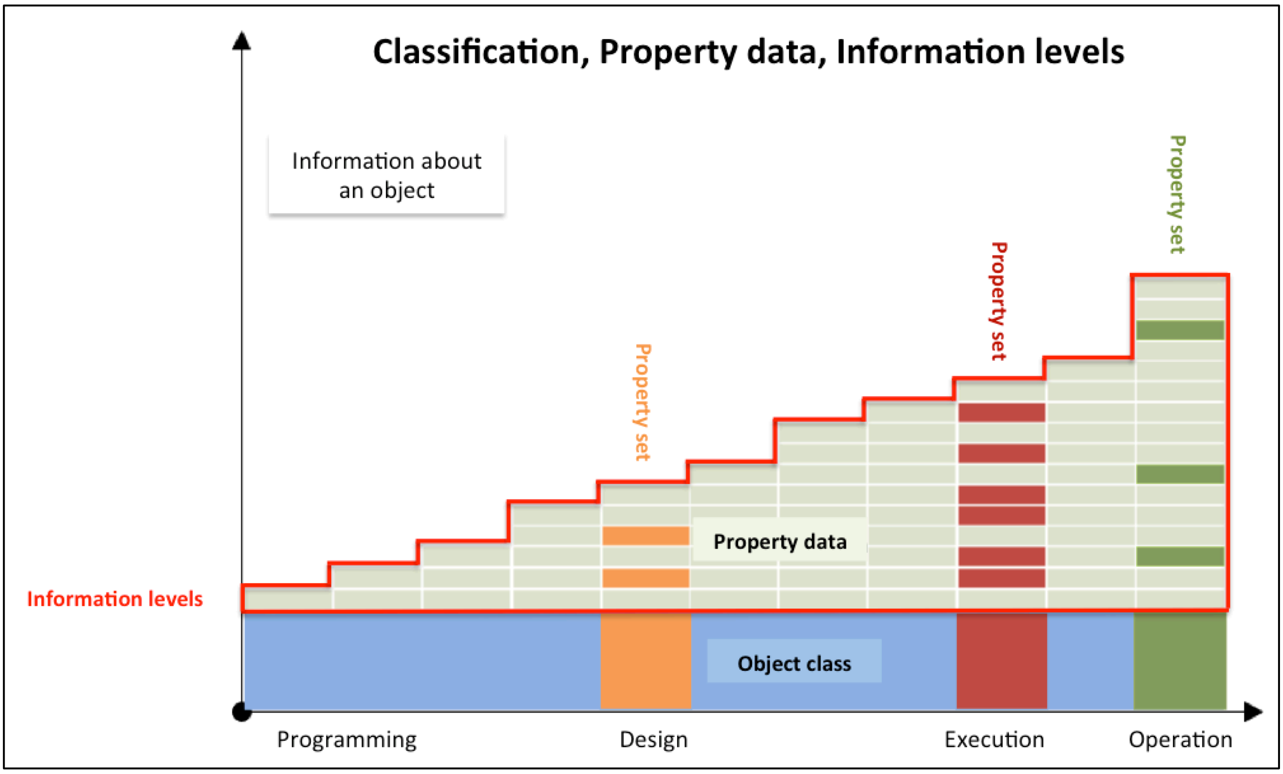

Figure 5 - Illustration of a generic and stable classification that is used all through the lifecycle combined with an increasing number of properties that might be selected as property sets through defined information levels according to a specific purpose, e.g. an IDM.

Another difficult task is mapping one national classification's codes and class names made up by different combined properties to another national classification's codes and class names. Without proper concept and class definitions, and precise knowledge of the combined properties that make up the characteristic of the class, mapping between two classification tables with detailed subtypes can be a very difficult task. This mapping is also of concern for the bSDD-work. Earlier-mentioned international standards such as ISO 704, ISO 1087-1, and ISO 22274 might be of valuable help here.

As already discussed, ISO 12006-2 does not provide guidelines for the definition of concepts and classes. Principles for generating classification systems with classes and letter codes to determine the classes can be found in ISO/IEC 81346-2. This standard could be the basis for a more international standardized way of creating classification systems, for construction as already used in other sectors.

2.7 Part-of relations, structure, and identification

BIM involves the definition of a building as a composed set of objects (*BIM Handbook*). As shown in figure 6, a section taken from the conceptual model in ISO 12006-2:2015, built space can be parts of other spaces, and construction elements can be composed of other elements that together are parts of the construction entity. Again, two or more construction entities can be parts of the construction complex.

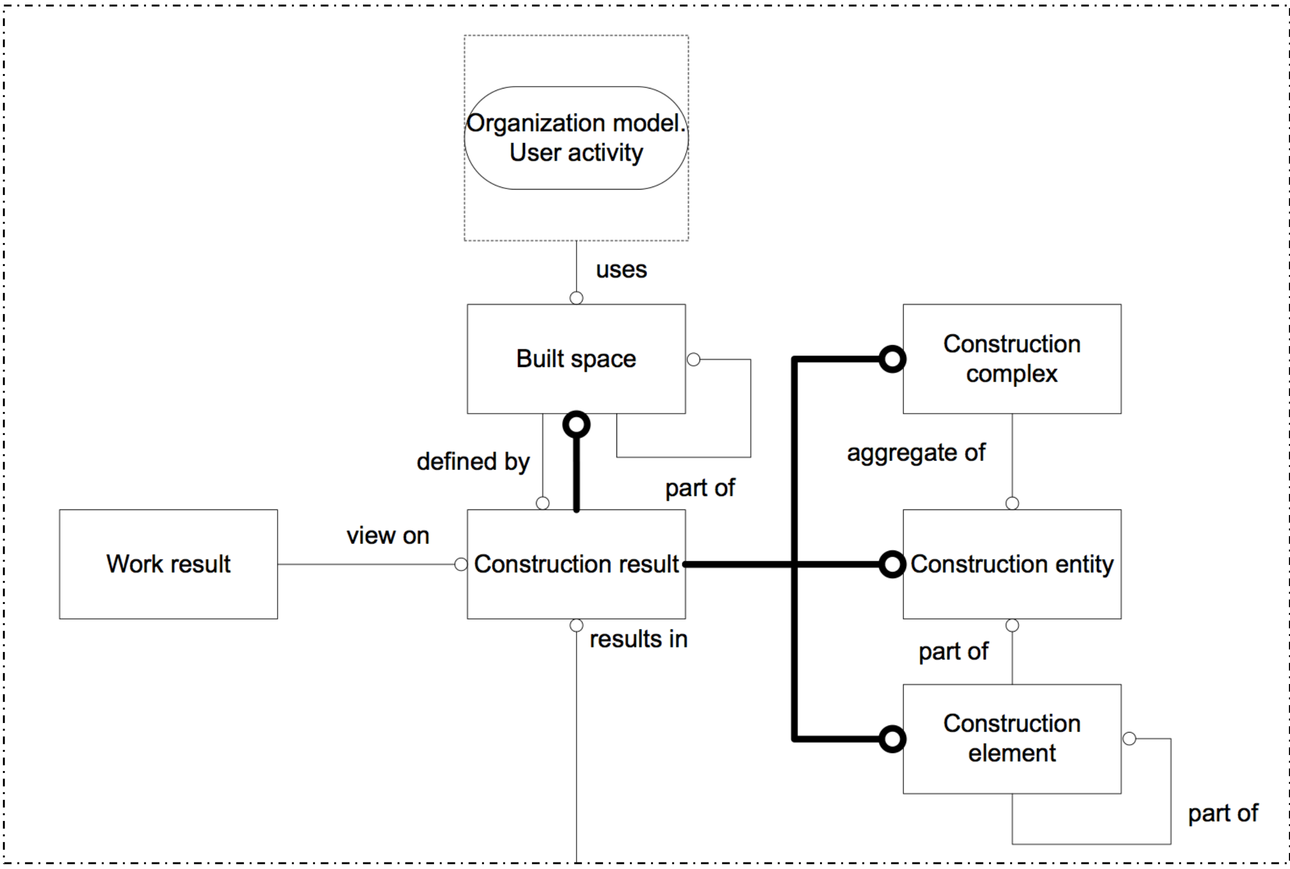

Figure 6 –A section of the illustration of classes and the general relationship between them [ISO 12006-2, figure 1]

In the conceptual model, the compositional aspect thus has already been introduced not only in the revised 2015 edition but also in the earlier 2001 edition of ISO 12006-2. And it is therefore of interest how composition is handled through the use of building models and structuring of information supporting BIM.

In ISO 12006-2:2015, it is stated:

"In the context of this International Standard, all objects can be seen as systems."

"The concept of system is not linked to any specific domain, but is to be used in a broad sense."
"The system approach allows a designer to handle wholes (as distinct from parts). By identifying related systems, the relationships among these can be determined, and monitored, e.g. to ensure that all systems operate correctly. Examples of relationships are input to or output from a system to its environment."
Further explanations and examples are given in the standard.

The compositional hierarchy resembles the one of the building model and can be supported by, but is not limited to, software-specific features or capacities. Composition involves structure and order and is often useful to:
- Overview if everything is at its place,
- Identify project-specific occurrences of objects in a building or any other facility, etc.
- Group objects in an overlaying systems structure,
- Identify possible interfaces between systems and their parts,
- Be able to configure a composition of elements to a whole.

In figure 7, two examples are given. The figure shows that stud, insulation, and plate are parts of a wall system, and that fan, insulation, and ventilator are parts of a ventilation system.

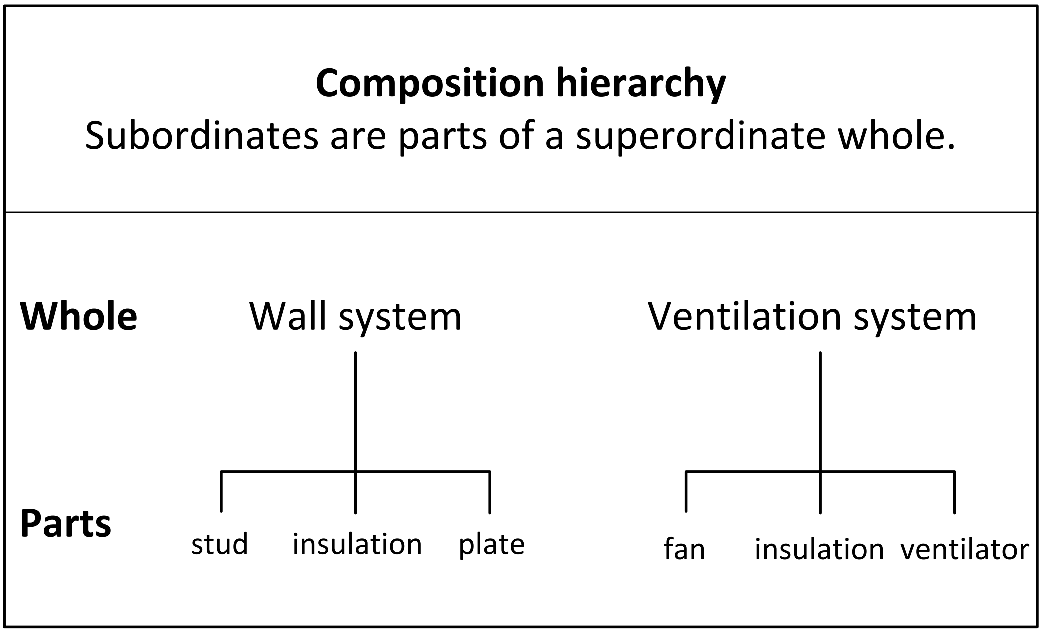

Figure 7 - Illustration of a compositional hierarchy as part-of relations [ISO 12006-2, part of figure 2]

This is not classification because insulation can be found as a constituent several times in the structure. But handling these part-whole relations is very useful to support systems delivery, execution planning, markup and identifying parts of systems, maintenance of complex systems, linking objects and their information together, etc.

This can also be based on international standards:
- The basic and well-known principles of part-of relations are defined in ISO 704,
- Rules and description of designation of systems and their constituents are given in the ISO/IEC 81346 standard series about Reference Designation Systems (RDS).

With the scope of applying the use of RDS, ISO/IEC 81346-1 describes the basic rules of structuring (system-of-systems) and the creation of reference designations based on three defined aspects: The functional aspect (prefix "="), the product aspect (prefix "-") and the location aspect (prefix "+"). These or further needed aspects will always have to be defined.

Examples of the use of compositional view in the product aspect (-) and in the functional aspect (=) on systems of construction elements for architecture, structuring, and building services can be seen in figure 8, applying to the rules given in ISO/IEC 81346-2.

Object (system)	**Reference designation**
Stairway construction no. 1	-AF01
Door no. 5	-QQC5
Wall system no. 1 Wall construction no. 1	-B1.AD1
Wall system no. 1 Wall construction no. 3 Door no. 2	-B1.AD3.QQC2
Ventilation system no. 1 Ventilation plant no. 4	=J1.HF4
Ventilation system no. 2 Ventilation plant no. 3 Filter system no. 1 Pressure switch no. 21	=J2.HF3.KC1.BPB21
Electrical system no. 2 Power supply system no. 1 Lighting system no. 2 Switch no. 6	=K1.HG1.HH2.SFA6
Access control system no. 4 Card reader no. 3	=KL4.BZC3

Figure 8 - Illustration of various reference designations [ISO 81346-12, CD version 2015] based on CCS.

2.8 Combining classification and structuring

As shown in figure 8, a classification code with letters and identification code of parts with digits are combined to make up a reference designation. Figure 9 illustrates the principle for this. Generic construction elements make up a model like part-of structure, and to every generic element there could be a classified subtype where the dividing criteria as shown are the materials used.

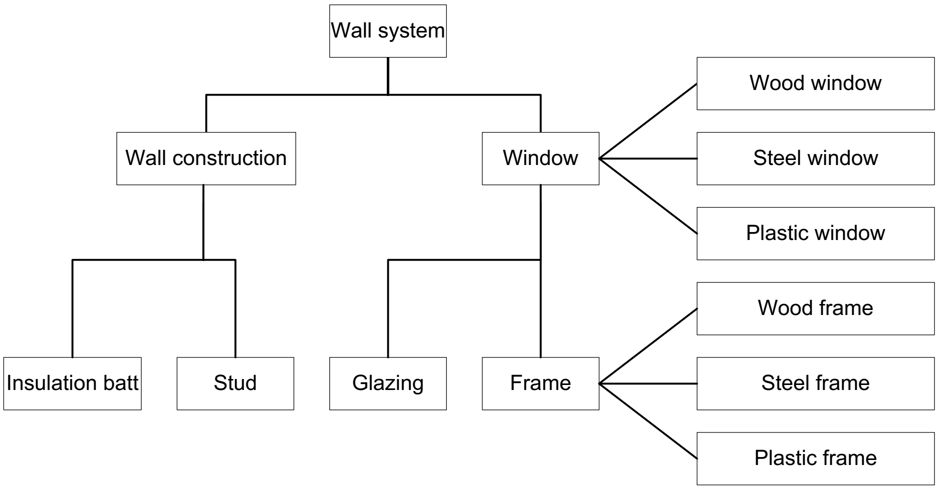

Figure 9 - Illustration of a combination of composition and classification [ISO 12006-2, figure 3]

Aided by basic systems engineering methods, the system-of-systems approach combined with rules for creation of internationally defined classification and unambiguous identification could create new standards for structuring of information for the building construction area. The unambiguous identification RDS is used to create links among various models of the systems that are designed and engineered by a range of actors, thereby creating both a common language among humans and the various computer systems being used.

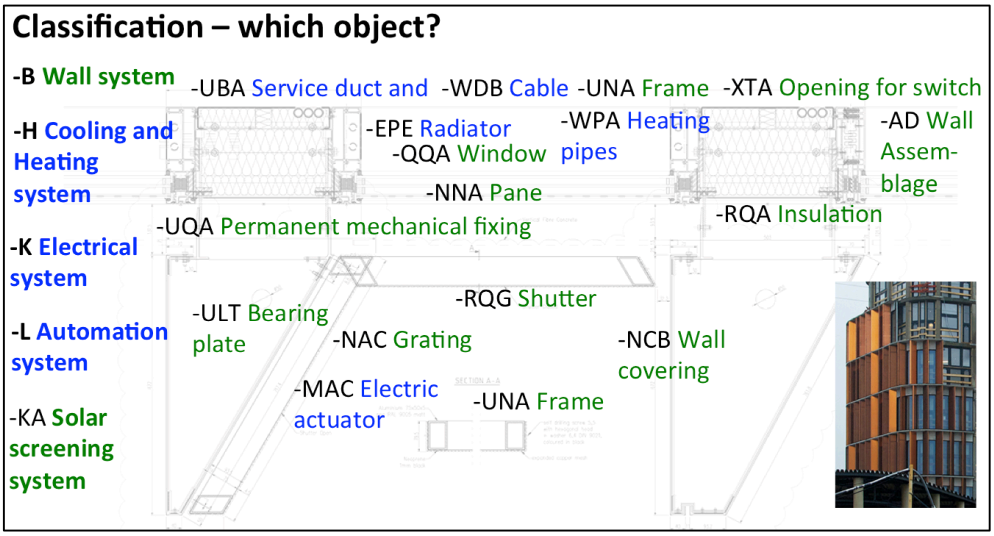

Figure 10 - Illustration of a complex curtain wall system combined with heating and solar screening systems with all construction elements classified (green colour used for architecture and construction, blue for building services elements) [**CCS-example with The Panum tower by C.F. Moller architects**]

This way of combining classification with reference designation in order to handle objects as part-of systems will be extremely useful with BIM and new ways of designing and executing buildings. The complexity of composition is increasing. Installations become integrated in structural and architectural construction elements, and many systems interact with each other. The complexity, interface challenges, and quality management will be difficult to handle without using these tools derived from the standardized and industrialized fabrication of advanced products.

An example of complexity is shown below. It is clear in figure 10 that it is useful to have classification, to know what kind of objects (construction elements) are put together.

But it is only as shown in figure 11 that one can actually see how the same construction elements are organized as systems and interact with each other, and how it will be possible to define interfaces between them and organize them for calculation purposes, etc.

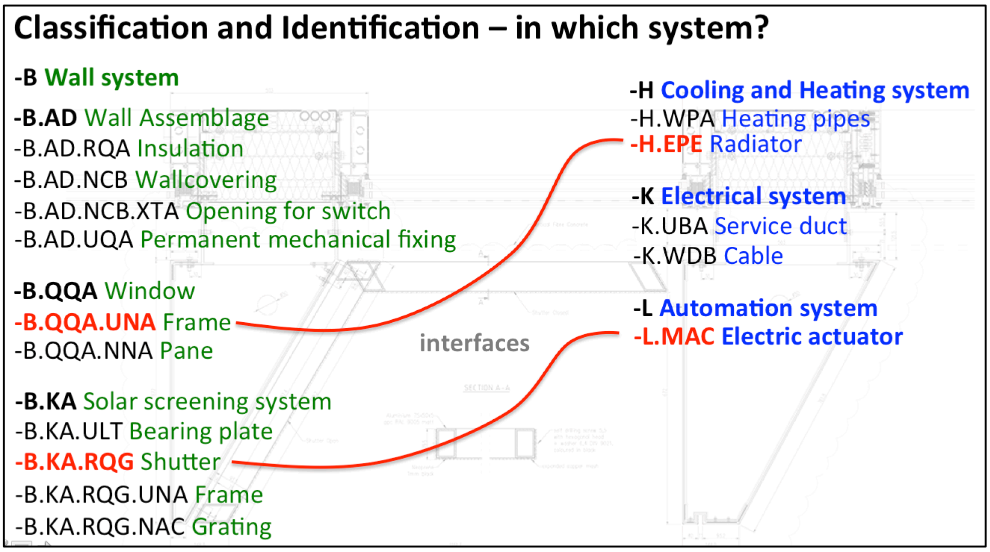

Figure 11 - Illustration of a complex curtain wall system combined with heating and solar screening systems organized in seven systems with part-of structuring and reference designation (RDS) and with possibility to identify interfaces and organizing construction elements for calculation, bidding, and summarizing on the tender list [**CCS-example with The Panum tower by C.F. Moller architects**]

2.9 Object occurrences, types, instances, and identifiers

According to the *Oxford Advanced Dictionary*:

- An occurrence is something being found in a place.
- An instance is a single occurrence of something.
- An individual is a single member of a class.
- A type is a category of things having common characteristics and, therefore, typically belonging to a class.

According to ISO/IEC 81346-1:

- A type is a class of objects having the same set of characteristics.
- A type can be from very generic to very specific depending on the number of common characteristics.
- An individual is one specimen of a type irrespective of where it is being used.
- An occurrence is the use of a type object for a specific function, as a specific component, or in a specific location within a building or a system.

The identifier of a generic object type can be described by a classification code expressed by letters or digits.

Occurrences can be identified by an RDS-code, related to the system context in which they occur, as seen in figure 12. The objects in a structure are occurrences of object types. Each occurrence is related to an individual that may be replaced by another individual (e.g., when it is broken or the type has been changed) without changing the occurrence designation.

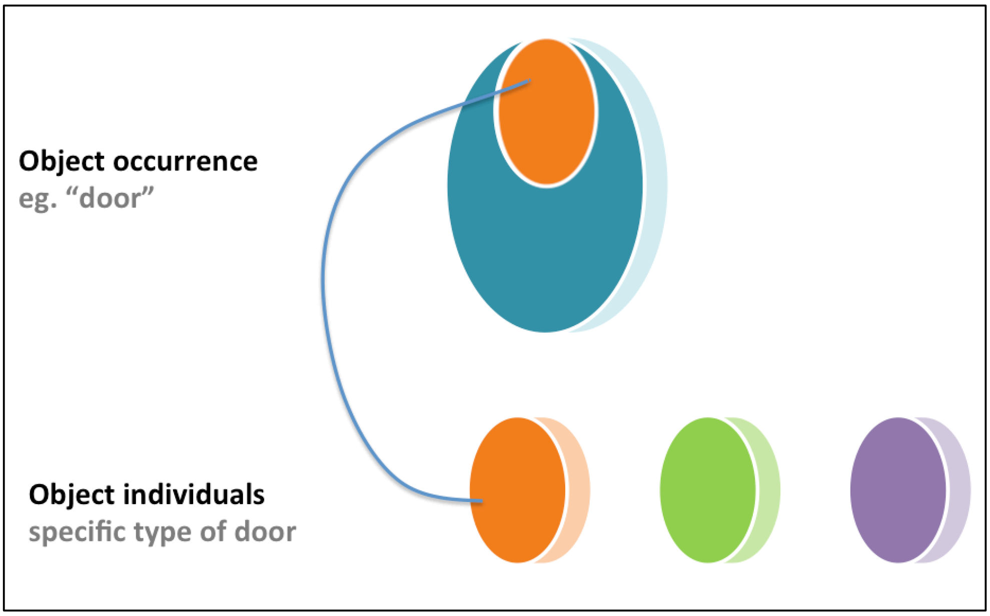

Figure 12 - The illustration shows how object occurrences, e.g., a door, can be instantiated by different object individuals; e.g., specific product types of a door

It is normal practice today to impose some coding logic to the types or subtypes; often, a coding logic that is company or project specific. Consequently, the logic changes with different construction organizations, companies, and projects and thus is non-standardized.

Figure 13 gives examples of differentiated types according to classification, instance, and types.

Classification code	Instance code	Dimension type	Door, shutter, and hatch system	Door, shutter, and hatch type	Instance variants; e.g., color
Ss-25-30-20-30-A-G01	DG01	A	Frame and door leaf system	A	Blue
Ss-25-30-20-30-A-G02	DG02	B	Frame and door leaf system	A	Green
Ss-25-30-20-30-B-G03	DG03	B	Frame and door leaf system	B	Green
Ss-25-30-20-30-C-G04	DG04	C	Frame and door leaf system	C	Pink
Ss-25-30-20-62-A-G05	DG05	D	Pivot doorset system	A	Blue

Ss-25-30-20-30-B-G06	DG06	A	Frame and door leaf system	B	Cerise
Ss-25-30-20-93-A-G07	DG07	E	Up-and-over doorset system	A	Beige
Source of information:	Geometry		Specification		Schedule

Figure 13 - Illustration of combined classes, instances, and types [Uniclass2 notation example].

It is greatly important that all participants in a project, and even better across projects and changing collaboration teams, have agreed upon and use the same types of identifiers, classification codes, and numbering codes. The best way is then to use common agreed classification standards and referencing standards; e.g., RDS.

There are two main issues for the use of identifiers to make the match:
- To classify objects uniquely - having the same characteristic properties,
- To identify objects specifically - recognizing the instance of the object.

2.10 Properties

Members of classes have properties. These properties can be used to define and subdivide the classes to finer levels of detail, for a detailed classification, and end users can agree upon the purpose of the classification and the criteria for dividing the classes.

If having a more generic classification, properties will be useful for searching and organizing information regarding specific purposes. The buildingSMART property sets are examples of grouping agreed properties to objects; e.g., a wall or a window. This classification could be a selection of properties according to a purpose; e.g., an IDM (Information Delivery Manual, buildingSMART) - see figure 5.

Properties are objects in their own right, and thus need to be treated as a special class, which pervades results, processes, and resources. Properties have values. Some of these values are classified values according to legislation or standards; others will have to be defined according to common practice or project-specific purposes. See chapter 2.6, Type-of relations and the desired level of classification for properties and classifying subtypes.

3. BIM and Classification - implementing ISO 12006-2

3.1 General requirements for BIM-ready classification systems

Looking at other industries, it is obvious that being able to control processes and increase productivity, to handle information not only in the design stage but also in the whole lifecycle, is vital. These industries use a range of working methods spanning from modeling to systems engineering, and many of these are based on international standards. Important tools are 3D models, classification and reference designation to support collaboration and document processes, and data-based structured and stored information about production results and the maintenance of these. These industries fabricate cars, trains, airplanes, cruise ships, and other complex products typically with a whole supply chain involved. Everyone in that chain has to have the right information and needs to understand what, which, how, and where to deliver. There is every reason to believe that the construction industry will also be able to benefit from this palette of tools. The challenge for the industry is to make these tools work together smoothly and coordinated. Getting classification and reference designation to fit the modeling process is an important issue in order to make the "I" in BIM work and secure the use of integrated and interoperable data.

As earlier mentioned, BIM is changing on the basis of digitalization of information the way we have been producing, using, and sharing information in the Construction Industry.

BIM is a collaborative process where every participant in the construction process is going to provide information that can be shared and used by others. It causes new ways of working and the need for standardized working methods, standardized information structures, and common data formats in order to gain the benefits of BIM's true potential.

Demands and benefits of using BIM are already setting new standards for design processes, use of classification, handling of building models, coordinated specification, searching for products, digital tendering, automating cost estimation, and ways of planning production, operation, and maintenance.

One of the significant changes is the change of focus from paper-based document handling of information to a more object-oriented approach to information as data. The focus is on data that can be exchanged, be used directly in the next process, or be automated to create new process results. In BIM, every object is the bearer of information in the form of property data.

Until now, the biggest changes have been in the development of applications and working methods for creating and handling geometrical information through the 3D modeling and the use of the building model as an information bearer. Also, to be recognized in this area is the development of common data formats like the IFC to secure proper exchange of data between applications.

The next big change will be to make data in specification, product specification, calculation, and maintenance systems more interoperable to all participants and to coordinate specified objects seamlessly with the geometrical objects of the building model. This development in handling of writeable and countable information is an important step towards an integrated use of information that has to be based on commonly accepted standards and working methods to be successful. Some of these standards will be classification and identification methods that support this new way of working.

The focus of this project has been to make an outline of how systems for classification and identification can contribute to these efforts, creating standards and tools for information structure and handling of information between participants and applications throughout the construction lifecycle processes.

In order to determine if a classification and the way of information structuring is useful to BIM, it will be appropriate to examine what the classification as such can support. Will it be able to:

Reduce or remove:

- Repeated labor with creating, handling, and exchange of information
- Inconsistency in data, specifically redundant data and data without integration
- Data separation by use of proprietary systems and not standardized information structure

Optimize:

- Automated handling of information - making data computing possible
- The making of objects in databases intelligent by rules to respond to changes and relations
- Defining and handling of objects at any aggregated level
- Collaboration supporting all participants in their work through all processes
- Traceability of objects and their information throughout the lifecycle

The revision and edition of ISO 12006-2:2015 was made to support and point out in general principles and means of structures and rules to meet these challenges and requirements. Also, the revised standard points out other standards that will support this task.

4. Applying classification in BIM

4.1 In general

In order to apply classification in BIM, it will be of absolute necessity that the ICT tools are able to handle the codes in a standardized way and with appointed placeholders. In relation to exchange of information through IFC, it is also vital that ICT tools have implemented the IFC Classification Notation. Unfortunately, this is seldom the situation for many tools, which causes abundant loss of data in the exchange situations.

The end users and their organizations and national construction authorities will have to put pressure on ICT vendors to make this implementation of classification notation happen.

It is essential for ease of use that a classification system be consistent throughout all phases of the documentation development process. Classification needs to be general, flexible, and adaptable to many areas:

- Classifying documents with metadata
- Classifying and providing naming conventions for drawings and specifications
- Organizing, accessing, and extracting data within every information platform
- Cross referencing between graphic information and written data
- Specifications
- Estimating, bills, and tender
- Organization of maintenance manuals
- And so forth

In the following, important topics and challenges of applying classification in BIM will be listed and examples given.

4.2 Geometry and modeling

Compositional modeling also applies to geometries. It is essential to BIM that the classification and mapping of object geometries and non-geometries be identical, so they can be linked to each other. It is important for modeling that the same object has the same code and name in the geometry and in the textual parts of the information model, so these two parts can integrate and be linked together. Geometrical objects shall be coded so they match the specifications of the construction elements, etc. This action can be done by classification codes, type codes, and RDS codes.

Instance schedules can be the means whereby the project geometry and the project specification are mapped to each other - each instance of an object is mapped to its type.

For example, layered elements such as external walls are modeled in Revit such that each layer is a system, more or less (dry lining is one system but two layers). This alignment is not perfect - Revit treats windows and doors as separate elements, as they are not layered. However, all that mean is that Revit cannot deal with them as sub-elements, as it does for the layers. How this works varies depending on the geometrical BIM software being used.

The challenge for companies then is that modeling tools often handle objects with part of objects as one object with layer properties with their own properties; e.g., a layered wall as one object with material property and other properties for each layer. The specification, calculation, and maintenance tools very often handle the part of objects according to discipline and work and thus describe properties to these as independent objects in themselves.

The challenge here is to map these together; e.g., when quantities from the single building model object is used for pricing more specified objects.

4.3 Structuring and simulation

For structuring and simulation, it is essential to point out which objects are to be included in the process by purpose; e.g., an IDM specification. Classification and type codes will be beneficial for that. But also of great value is being able to see and handle the compositional structure as shown by using RDS in figure 11. There is a need for overview of which objects and related properties will be included in a structural calculation or energy loss simulation, etc.

Every object has properties of its own. With objects composed to become a system, some of the properties of the objects are retained, some are changed and new properties are added. Handling this as a whole for doing a calculation or simulation makes it important also to be able to handle part-of-relation techniques besides classification.

4.4 Specification

An important issue for specification, in relation to BIM, is the link between the construction element objects in the building model and the specifications for the construction elements.

In order to get tendering list with structured prices, the challenge is that both building models and specifications are structured in a way that data will be able to be put on the lists in a coordinated manner. This requires early and uniform structuring in both tools and participants handling the design processes with a lot of data discipline.

An important perspective for specification systems is to move from prosaically texting to placeholders for property data. Data can be extracted, exchanged, and reused from both of the tools, the building model, and the specification system, for simulation, calculation, and execution planning purposes. The conditions will be that every property data is attached to the classified object to make the process work smoothly and create possibilities for automation.

Managing increasingly more complex and integrated construction element systems of contemporary architecture challenges the handling of objects in a compositional aspect being able to identify interfaces and checking that everything is specified in relation to other specified and related construction elements - that all is there and have been specified. Part-of structuring, with the combination of classification and the reference designations systems technique, will support that quality management.

4.5 Costing, cost estimation, quantity take-off, and tendering

The two main elements of a cost estimate are the quantity take-off and the pricing. Quantities measured and taken from a building model can be extracted to a cost database or an Excel file as long as there is an object modeled. However, pricing cannot be attained from the model.

Not all quantities can be taken from the model if construction elements are not modeled; e.g., as the fasteners, bearings of cable trays, and other small parts. These quantities can be derived from other sources like the construction element specification.

And, there are services not being construction elements but operations that are to be priced.

Model-based estimating can be done by:

- BIM integrating tools,
- Paths from BIM to costing,
- Configured compositions of objects (elements and spaces) that make up the building.

There are a variety of ways of getting quantities and material definitions out of a building model into a cost-estimating system. Broad categories of integration approaches include:

- Application Programming Interface (API),
- ODBC connection,
- Output to Excel.

Cost estimation as a 5D function of BIM can be done by:

- Linking the model to an estimating database,
- Developing detailed cost plans through linking a "5D Cost Library" to BIM,
- Applying varying levels of detail to estimates, depending on the project stage.

Cost estimates during particular project stages can be done by:

- Visualizing of the options in pre-investment phase,
- Cost control during construction,
- Revisions of cost plans,
- Maintenance costs.

Advantages and challenges of using BIM from a cost consultant's perspective:
Cost estimating is yet another aspect of the building process that can benefit from computable building information.

Identifying the advantages, challenges, and usability of BIM for cost consultants, and its likely impact during cost estimation, could be:

- Automatic quantification,
- Higher accuracy,
- Better quality assurance.

The better classification and identification coding of objects and the better implementation and use of IFC, the better and more precise automated processes will be able to take place and the better possibilities there will be for securing that everything is included properly.

Challenges to the role of quantity surveyors, cost estimators, and cost consultants according to new BIM practice are:

- Changes in existing practices,
- New ways of working and thinking,
- Change to their role when working with BIM and understanding the potential limitations of automatic measurement,
- How to work with detailed qualitative information regarding cost consultants' routine, and challenges in adopting BIM.

BIM is increasing, and seemingly has the capacity to impact every aspect of the surveying profession; therefore, it makes it essential for cost consultants to adapt and embrace or risk the threat of losing ground to others.

There are certain reservations cost consultants have in connection with the change to an automated process. For the development of automatic quantification, these include:

- To comply with the standard method of measurement rules,
- A lack of confidence in automatically producing something that was previously controlled manually and through this,
- The loss of manual interpretation during measurement.

Opportunities for cost consultant companies could be:

- Providing additional services included in BIM (e.g., environmental data),
- Securing all objects represented in building model, in specifications, and on the tendering list,
- To identify potential areas for expansion of cost-consultancy services, through BIM implementation, and show that BIM has the capacity to influence the operations throughout the construction industry.

Standards are now being put in place to manage the level of detail included within models while ensuring that each team member is aware of the level of detail they are required to produce information. An important issue is if it will be necessary to also standardize and get implemented new measurement rules for cost estimating in BIM. Measurement rules could eventually be related to objects classified and placed in an object library.

It is known that different AEC applications measure quantities differently. It is said that some construction elements are up to 15-20% different. Also, some applications measure on the inside, some on the outside, and some at the centreline of the construction elements.

What implications do this have for quantities taken out right by the moment? Are there discussions about this and eventually the need for an international standard about measurement that all applications should apply to? Is it possible to create universal costing standards?

4.6 Manufacturer information

Manufacturers typically have their own codes for production, part, and trade items.

To manufacturers, two BIM situations with sharing of information could be of interest regarding classification and reference designation.

When a product as a component or a systems delivery is the same as the one of a construction element, the classification code will be an entry for a search of the product. If the properties are standardized (e.g., IFC property sets) and classified as well, these and their values also will be of interest for the consultants, etc., in the design process.

When a manufacturer or the contractor has the obligation to also deliver the product documentation as a part of the total delivery, all the product documentation normally will have to be classified and designated to fit with the rest of the project.

The issue of instances of items as opposed to types is reasonably well understood by manufacturers, who have many versions of each of their products; designers and installers who select and install many versions of a product, such as doors or radiators; and asset managers who have codes for every item they manage.

It is vital that vendors are encouraged to develop their products to accommodate the vast amount of information that needs to be stored against each object modelled, specified, or costed; but it is also important that issues of machine language are understood so that the classification codes can be used unambiguously within programs.

4.7 Timeline

Timeline is related to process and to BIM 4D. Both scheduling the tendering timeline and the production timeline will bring important construction elements as systems and components into the timetable; e.g., being put in line, being critical, etc.

The tendering timeline will tell the combination of time-related properties together with other important information, such as size and location being of significance to the prizing. Classification and identification of objects will make it possible to connect this information.

For the production timeline, another feature will be numbering the construction elements for visualizing the progress of activities on the construction site, informing site staff about the production schedule, analysing potential risks, controlling change impacts during the course of construction, etc.

4.8 Mapping classifications & buildingSMART Data Dictionary (bSDD)

Numerous old classification systems exist in many countries. Some that has not been updated to fulfill a contemporary purpose, some used for very narrow purposes, and some not fit for use by the new BIM processes. Because these classification systems have been used and because a lot information exits classified by these, there will always be a demand for mapping the old classification concepts and codes with new classification systems. The mapping refers to correlating different classification tables. These may be legacy tables, or new tables.

However, if current classification practice is operating more than one classification, such as separate tables for designed elements, work results, specification, etc., mapping will be needed. If it is optional, the final solution in relation to BIM or just a transition for a period might have to be discussed thoroughly as already discussed in chapter 2.6, Type-of relations and the desired level of classification.

Mapping between classification systems is inevitably messy. One might expect most objects within a class to have a 1:1 mapping, but many will not. Some will be 1:N, some N:1, some N:N, some 0:1, some 1:0, and some 0:0 (i.e., the object is picked up in other classifications, but not this one). This variation might arise from mapped tables having differing depths (e.g., one table stops at "clay bricks" and another drill down to "frogged clay bricks"), or using different property classes for classification (e.g., one uses material + form and the other uses function + form - "clay bricks" vs. "load-bearing bricks"). These classification differences are compounded by terminological difficulties; e.g., where concepts do not mean the same thing between tables (e.g., does "la porte" = "doorset system," or does it mean "doorway," "door leaf," or just "door" with all its ambiguities?). Mapping is fuzzy and inaccurate.

So, while mapping might be done semantically (i.e., automatically), manual ratification and correction will inevitably be needed. An example is shown in figure 14. This table illustrates an object type per class that is common to the various classification tables - Uniclass2 tends to be finer grain than the others, and so is the starting point. "Not classified" indicates that the classification system classifies some objects of this class, but not this particular object. Blanks indicate that the system does not deal with this class at all. Experts in the various tables might be able to refine this illustrative mapping further.

Object class	**Uniclass2 2014**	**NBS Create**	**Uniclass 1997**	**NRM 1 2012**	**NRM 2 2012**	**CESMM4 2012**	**OmniClass 2014**	**CI/SfB 1976**
Elements	Ee-35-15 Suspended stairs		G23 Stairs	2.4 Stairs and ramps			21-02 10 80 Stairs	(24) Stairs, ramps
Sub-element	Ee-35-15-45 Suspended stairs - tread and landing finishes		G23:G3311 Stairs: Stair finish - Top/ G3311:G23 Floor finishes, direct: To stairs	2.4.2.1 Stair finishes			21-03 20 40 Stair finishes	(44) Stair finishes
Systems	Ss-30-30-72-90 Rooflight systems	WR-20-25-75/170 Rooflight system	JL11 Rooflights/ Roof windows	2.3.5.1 Rooflights, skylights and openings	23 Windows, screens and lights	Z-3-1-6 Roof lights (Timber)	22-08 62 00 Unit skylights; 22-08 63 00 Metal-framed skylights	(37.41) Roof lights, including dome lights
System	Ss-xx-xx-xx-xx Abc	WR-xx-xx-xx/1xx					22-xx xx xx Abc -	(D6) Placing:

execution	systems - Execution	Abc system - Execution					Execution	laying, applying

Figure 14 –Table with Examples of commonality between classification tables, by object class

The same mapping problems will occur when internationally mapping between national construction concepts and classifications will be done in the scope of the buildingSMART Data Dictionary. The same issues as raised in the chapters 2.4, Terms and definitions for concepts and classes, and 2.6 Type-of relations and the desired level of classification.

An alternative mapping with focus on BIM-object-oriented classification practice could be as shown in figure 15. Using a generic classification, such as CCS, as entry combined with properties (some of them IFC Properties) could possibly secure a better and more precise mapping.

Object class	**CCS Classification 2015**	**CCS defined properties**	**Uniclass2 2014**	**NBS Create**	**Uniclass 1997**	**OmniClass 2014**	**CI/SfB 1976**
Technical systems	-AF Stairway assembly	Construction type: Suspended, String stair, Element stair	Ee-35-15 Suspended stairs		G23 Stairs	21-02 10 80 Stairs	(24) Stairs, ramps
	-AG Ramp assembly						(24) Stairs, ramps
Component	-NCC Flooring	Finish type: Landing finish, Tread finish, Floor finish	Ee-35-15-45 Suspended stairs - tread and landing finishes		G23:G3311 Stairs: Stair finish - Top/ G3311:G23 Floor finishes, direct: To stairs	21-03 20 40 Stair finishes	(44) Stair finishes
Component	-QQB Window unit	Location: Roof Type: Skylight, Rooflight, Dome Frame material: Metal, Timber	Ss-30-30-72-90 Rooflight systems	WR-20-25-75/170 Rooflight system	JL11 Rooflights/ Roof windows	22-08 62 00 Unit skylights; 22-08 63 00 Metal-framed skylights	(37.41) Rooflights, including dome lights

5. Bibliography and other sources

5.1 Standards referred to

ISO 704:2009 - *Terminology work - Principles and methods*

ISO 1087-1:2000 - *Terminology work - Vocabulary - Part 1: Theory and application*

ISO 12006-2:2015 - *Building construction - Organization of information about construction works - Part 2: Framework for classification*

ISO 12006-3:2007 - *Building construction - Organization of information about construction works - Part 3: Framework for object-oriented information and buildingSMART Data Dictionary (bSDD)*

ISO 16739:2013 - *Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries*

ISO 22274:2013 - *Systems to manage terminology, knowledge and content - Concept-related aspects for developing and internationalizing classification systems*

ISO/IEC 81346-1:2009 - *Industrial systems, installations and equipment and industrial products - structuring principles and reference designations - Part 1: Basic rules*

ISO/IEC 81346-2: - *Industrial systems, installations and equipment and industrial products - Structuring principles and reference designations - Part 2: Classifications of objects and code for classes*(under revision - expected DIS-version 2017)

ISO 81346-12 - *Industrial systems, installations and equipment and industrial products-Structuring principles and reference designations - Part 12: Buildings and building services* (under development - DIS-version 2017)

5.2 Books, publications, papers, and presentations used

BIM Handbook, Chuck Eastman, Paul Teicholz, Rafael Sacks and Kathleen Liston, published by Wiley, 2007.

International Classification Survey 2012 in relation with revision of ISO 12006-2, by the Danish association bips (now Molio) on behalf of Danish Standards (DS) and ISO TC59/SC13/WG2.

Paper on Classification topics, Neil Greenstreet, NATSPEC, Australia, 2014.

Paper on Cost estimation, Barbora Pospisilova, URS, Czech Republic and Albert Müller, CRB, Switzerland, 2014.

Paper on Classification strategies over the Different Stages of the Construction Process, Forrest Grierson, Grierson Specifications, Canada, 2014.

Paper on Implementing Systems Engineering in Civil Engineering & Construction Sector, Henrik Balslev, Systems Engineering, 2014.

Uniclass2 Manual: Principles, rules and use, John Gelder (NBS).

5.3 Classification systems and materials viewed and used

BSAB/CoClass - Sweden

CCS - Denmark

CRB - Switzerland

JCCS - Japan

OmniClass - United States, North America
SfB - Earlier editions from different countries
UniClass 2015 - United Kingdom

5.4 Organizations - websites and references used

bips and cuneco – now MOLIO (DK)
buildingSMART (INT)
CRB (CH)
NATSPEC (AU)
NBS (UK)
NIBS (US)

Annex A - The international classification survey and end-user comments, in detail

Referring to the introduction and the purpose of the survey in chapter 2.2, and the summarizing and concluding remarks in chapter 2.3, the following questions and answers (Q&A) appeared in the questionnaire.

The main question was: *Is existing classification useful to BIM?*
Some of the discoveries were:

- In general, when considering the agents across the construction industry, the participants noted that the national level of implementation of tables according to ISO 12006-2 is medium, low, or very low,
- Consultant architects and consultant engineers are considered as the construction agents with the highest level of implementation and use with around 40-45% - other agents of construction with less (13-38%),
- Until 2015, the use of classification in construction is primarily focused on design, calculation, and specification purposes.

When considering BIM to be a collaborative process with all parties throughout the lifecycle, five questions then could be of interest:

- *Are the efforts of implementing classification with BIM and construction in general just too small to gain an effective result and use?*
- *Is it because there is nobody in the value chain that demands classified information seen as value creating for either their processes or the final production result?*
- *Is it because classification as such is unnecessary with BIM - e.g., can the 3D model handle everything?*
- *Or is it because the existing classification does not fully support either an analogue or a digital practice, especially BIM?*
- *Instead of classifying/grouping the approximately same type of objects (spaces, elements, and systems), is it then more important for BIM practice to classify and identify specifically the single/generic object as the bearer of all information?*

Some of the answers to these questions can be found in the more specific remarks in the survey. Below are some comments about what classification supports at the moment and in relation to BIM:

> *…the standard* (ISO 12006-2:2001) *is focusing on the design and production of a building. Facility Management is not well supported. Not sure if prefabrication/units are supported well…*
>
> *We still need more things to standardize especially for information sharing. ISO 12006-2 is just a framework. If implemented well, then the implementation will support classification of objects with attached information. If implemented badly, then the implementation won't.*
>
> *There are weak spots in the structuring allowed in and supported by the software, as well as in the tables themselves. Additional aspects need to be addressed primarily in order to support*

relations between objects. Also the classification of all properties that can be attached to objects is needed (and a huge undertaking).

Relations between objects are handled by the tools. Properties can be defined according to ISO 12006-3. Classification of properties could be useful.

Tables based on ISO12006-2 must be useful to identify various objects for BIM.

Another question was: *Does ISO 12006-2 support and fulfill the needs for classification and structuring?* (e.g., providing identification on which classification is often being used for)

- 62% agree or strongly agree to the need for a compositional (part of) structuring of construction entity parts (construction elements, as not directly supported by ISO 12006-2:2001).
- 65% agree or strongly agree there is still a need for (type of) classification of construction entity parts (construction elements, as already supported by ISO 12006-2:2001).

Comments to the question about ISO 12006-2 supporting structuring as part of were:

I think this will be needed for BIM information.

Small parts "grow" to be bigger parts, need for collections where knowledge is connected to bring insight in relationships. Relationships are therefore needed, independent of classifications. This can then be supported by ISO 12006-3.

… It is important to maintain focus on what you are attempting to serve with any discussion of information ordering, classification included. What uses does it serve? What can it do well? What should it not try to do?

Composition is a process for designers, just as decomposition is a process for contractors....

The need for "part-of" relationships to enable BIM support is critical.

The compositional nature of construction and the large number of entity parts makes it essential to have a means of defining their relationships to each other. Compositional structuring would overcome the limitation of the discrete table/facet view of entities imposed by ISO 12006-2.

Comments to the question about ISO 12006-2 supporting type of classification:

I think we need simplified classification for construction entity parts (Construction elements)*.*

Classifications as being working methods are needed to support structure for humans to work with.

There are some tables within the 12006-2 standard that are in more use than others. Among the most used and most useful are the following: Elements, including Designed Elements Work Results Construction Products…. It seems clear to me that "construction entity parts"

(Construction elements) *are well represented in that list. Removing any of these tables from the standard would be a disastrous decision.*

ISO 12006-2 does not refer to the contents of the tables which should be formalized to some extent.

A question addressing the complexity of existing classification systems today and the fact that construction elements, for example, are classified through many/different tables was: *Is there a need for mapping of concepts in classification tables?*

- 67% agree or strongly agree there is a need for mapping of concepts in classification tables.
- The rest, 33%, are neutral or do not know.

Comments to the mapping-issue was:

One entity or object has many aspects, so mapping would be helpful.

If you mean a diagram indicating how the concepts relate to each other, then I think this is needed in the ISO.

…not within classification tables itself, but mapping is needed. Use universal platforms to connect classifications to each other (e.g. OmniClass to UniClass to SfB)

Mapping between related tables within a system to expose the many-to-many relationships contained within them … serves to enhance their use by easing the chore of classification for the end users.

Cross mapping can only be done between strongly disciplined tables of the same 12006-part 2 basis.

I agree with this statement for reasons similar to those given supporting compositional structuring of construction entity parts - making the relationships of one concept to others more explicit would enhance the value of the classification system.

A mapping system should be needed to cope with an object-oriented BIM framework.

During the revision of 12006-2, further end-user comments were received about:

- We do not want to change classification code several times and especially not in an unrecognizable way through the BIM processes - there is a need for a classification code that can be the same all through the lifecycle and that everybody can attend to,
- We want the classification codes to be transferred between software-platforms,
- We want to be able to know and distinguish (classify uniquely), and identify (specifically), every single object that we use in BIM - not a whole class of objects,
- We want to use classification and identification without always relating it to a geometrical building model (especially mentioned in relation to non-geometrical tools, smaller projects, and maintenance of existing buildings with no model representation),
- We want classification and identification to support linking object-based information together,

– We want classification and identification to support automated exchange and use of data.

About the classification and identification purposes, end users said they wanted to:

Classify objects in order to:

– Sort and group by type
– Seek and find specific object types
– Define generic sets of properties for the objects

Identify objects in order to:

– Trace and identify the specific instance of the object in its lifecycle
– Distinguish, separate, and handle them individually, being able to reference them unambiguously
– Group them according to a systems point of view (assembling in constructions/systems)
– Communicate the context of the object
– Secure unambiguous exchange of data