Classification of Building Element Functions

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ABSTRACT: Classification is an important issue in building construction. In this paper, it is assumed that building design is performed by modelling and that computer based building models are used as the basis of data exchange. Therefore, the primary focus of the paper is classification in connection with modelling and how classifications can support this. A major issue in modelling is the initial identification and definition of model objects. Subsequently, it is assumed that the objects will persist and that they are further detailed. Instead of classifying building elements by function, it is proposed to classify functions and link building component types/classes to function nodes. When a model component is created, a primary function can be attached to the component and a component type can be selected. Each time a function is attached to an object, the defined attributes can also be attached and, when a component type is selected, values of attributes can be assigned.

1 INTRODUCTION

In the built environment, many different classification systems have been developed during the last fifty years. The primary purpose has been to support data exchange between partners in building construction projects and the assumption has been that traditional document based collaboration is used.

The collaboration processes have changed, new model based design approaches have been developed, new support tools are used and, therefore, new demands for classification systems have been raised. In the future, building design will to a much larger degree be performed by modelling and computer based building models will be used as the basis of data exchange.

2 EXISTING CLASSIFICATION SYSTEMS

Various classification systems have been developed by different nations and institutions, e.g. SfB, BSAB in Sweden (Svensk Byggtjänst, 1998), CI/SfB, Uniclass in UK (Crawford, 1997), Building 90 in Finland and OmniClass in North America (OCCS, 2006). In Scandinavian, the SfB classification system was introduced already around 1950. In Sweden, further developments took place over many years and the current system is BSAB 96. Similarly, the SfB/UDC was introduced in UK around 1960 and was revised in 1976 as CI/SfB (Ray-Jones, 1978. This system has been succeeded by the Uniclass system in 1997. OmniClass and Uniclass are both faceted classification systems, each incorporating 15 tables representing many specific facets of construction information.

Many existing classification systems are referring to the standard ISO 12006-2 (ISO, 2001). In this standard, the concept *element* is introduced as a foundation for classification. The concept is defined as *"a construction entity part which, in itself or in combination with other such parts, fulfils a predominating function of the construction entity"*. This concept represents an abstraction and underlines that, in the initial life phase of a building model component, only functions are considered and e.g. technical solutions, material possibilities and construction methods are not taken into account.

OmniClass Table 21 Elements (Including Designed Elements) is organized by elements' implied functions and Uniclass Table G covers elements of buildings. BSAB 96 deals with a problem with the element definition and differs from the ISO standard. It defines a slightly different concept, where the phrase *"in itself or in combination with other such parts"* is omitted (Ekholm, 2003) and, consequently, it is explicitly stated that only the main function of elements is used as basis for classification.

Building components can be decomposed and assembled and this is clearly underlined in OmniClass in relationship with Table 21 and this is also highlighted in connection with BSAB 96. The first steps of modelling often regards major and often composite components but such components create major problems regarding classification by function because they represent multiple functions and, thus, identification of main functions may be difficult. Otherwise, such element classes may occur at multiple positions in classification taxonomies. In BSAB 96, a separate entry is reserved for classification of composite elements and systems as a separate classification compared to elements. Consequently, there are conflicting requirements regarding modelling and classification.

A major issue about all the classification systems is that the classification criteria are not clearly stated and, in case that functions are the criteria, these are only expressed indirectly, e.g. 'substructure' and 'superstructure'. Furthermore, there are many examples, where multiple classification criteria are used. In BSAB 96, the above mentioned separate entry for composite elements is one example. However, this table is formed by levels, where different classification criteria may exist for each level. For instance, several entries are characterised as completion element and this is not a division based on element function. Similarly in OmniClass, there are many examples, where function is not the criterion, e.g. divisions under 'superstructure': 'floor construction', 'conveying systems', 'bridge construction' and 'tower superstructure construction'. Further, the position 'conveying systems' is subdivided into e.g. 'vertical', 'horizontal' and 'sloped' transportation, which is rather a form criterion.

Overall, the existing classification systems are primarily oriented towards physical building components, which are identified from a geometrical point of view. New needs in relationship with building modelling are not incorporated. In such processes, other approaches for identification and creation of building model components may play a prominent role.

The issues, which have been discussed above, have created the idea that the subject should be turned upside down. Instead of classifying building components by function, it would be better to classify functions and attach building component types/classes to function nodes.

3 ABOUT CLASSIFICATION

Classification (Bunge, 1983) is an *abstraction mechanism* (Smith, 1977a, Smith, 1977b) by which component classes can be arranged in a hierarchy, termed *taxonomy* (Jørgensen, 1998). The most general classes are at the higher levels (root levels) and the most special classes are at the lower levels. This means that, at any node, the sub-classes must be *specialisations* of the super-class and, in contrast, any super-class is a *generalisation* of its sub-classes. Each sub-class is said to *inherit* the attributes of the super-class and, in addition, each sub-class must have its own attributes. Classification is the foundation for the paradigm *object-orientation*, which has a general scope but most extensively has been used in software development (Rumbaugh, 1991, Booch, 1998).

Composition is another abstraction mechanism about *building structure*, i.e. *whole-part structure*, by which a building is subdivided into components/parts, which again are subdivided into other components/parts etc. down to an appropriate level. Classification and composition are very different and are sometimes characterised as *orthogonal* to each other. Classification may be very useful in modelling as the basis for identification and creation of components and, when components are created, the composition structure can be created. In this way, both abstraction mechanisms will be used in modelling tasks. Another characteristic difference is that classification may include classes of components at all levels of a composition.

For a selected set of components, multiple classifications can be developed and it is therefore necessary to select a *classification criterion* to determine the nodes of the taxonomy. Hence, different classification criteria result in different taxonomies of the same components. If each node in the hierarchy can express a class according to only one criterion, the classification is *clean* and if multiple criteria are used, the classification is *mixed*. In this case, only one criterion should be used on each level of the taxonomy. A criterion must be selected due to a purpose, so not all classifications (included clean classifications) may be useful or relevant for a selected purpose.

Ideally, components belong to only one node in a taxonomy, but very often components can be characterised by multiple nodes. In this case, it is often possible to identify one of the nodes as the primary characterisation, i.e. the *primary* class. The other classes are *secondary* classes.

Taxonomies can give overview and make it easier to identify something new. By having classifications in advance, this can support finding and selection among presented alternatives as illustrated in Figure 1. The purpose and practical use of taxonomies for identification of building components may be very different in different life phases of a building. In the very early phases, a primary purpose could be to give inspiration about what functions should be required or provided by the building or by building components.

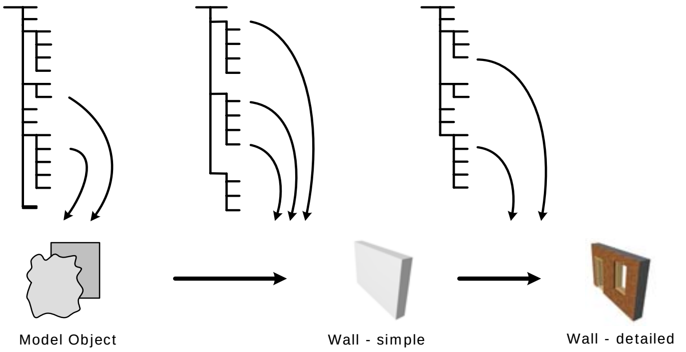

Figure 1 – Use of classifications (taxonomies) in modelling and model detailing

In building modelling, selection of new building model components is necessary many times. At first, such components may be major model components and only roughly specified, i.e. no internal structure is defined and only few attributes are determined. Later on, the model components are detailed by two dimensions: *specification* and *structure*. Specification detailing concerns further identification of attributes and structure detailing includes sub-division into sub-components, ultimately down to *building products*, *building articles* or *building materials*. This means that key issues about data exchange in connection with modelling is to formulate requirements about the degree of model detailing. For instance in the maintenance phase, the need may be to detail further compared to what is needed for construction. Important data about components could be e.g. instructions for operations and maintenance.

If multiple taxonomies can be created for the same set of component types, multiple alternative overviews are available. With databases of existing component types, software products may be able to create and display different catalogues. *Users will thereby have alternative ways to find and select components.* This approach can be followed, when each component type has a set of properties and these have values assigned. If an overview of the properties is given, the classification can be based on this. A property can be selected for each level, the occurred values of the properties can be analysed and then classes from these values can be identified. By setting some rules, such a classification can even be performed automatically each time a user selects a property.

Observe that such an approach can reduce the demand for classification and, on the other hand, increase the importance of identification and systematic definition of attributes of components. It also indicates that classification and selections based on attributes can be combined, i.e. a primary overview can be established by classification and details can be selected via attributes. If for instance a material attribute is specified for a class of components, it may provide the basis for selection in favour of a classification criterion.

4 FUNCTIONS OF BUILDING COMPONENTS

Functions of building components are important through the whole life time of building construction projects but most importantly in the early project phases (a new building or renovation of an existing building), where requirements are identified and specified – *function modelling* (Kiviniemi, 2005). In the building modelling phase, building components are identified to provide the required functions. If parts of a building need to be renewed or extended at a later time, functions play the same important role.

Functions of building construction components are initially considered without regard to any technical solution to perform the function and for each component, there may be several solutions. Furthermore, a technical solution can be produced on site, manufactured on other locations or purchased as a building product. Modelling by use of a traditional CAD system is oriented towards geometry and supports most often selection of model components from a library.

Construction components have many functions but, when they are initially identified, they are often justified by only one or a few functions. A window, for instance, has normally at least two primary functions, to draw natural light into a room and to give view from the room. However, a window has also an insulation function, an acoustic function and a ventilation function (if it can be opened). In principle, a building component may be identified and created solely on the basis of its primary function and before its geometry is determined.

Spaces can also have many functions because they can have multiple uses and many concurrent activities can take place in each space, e.g. social living, sleeping, work, personal care, and storage. For spaces in particular, the two different approaches analysis and synthesis form two alternative ways to identify functions of spaces. One is by what they are actually used for (analysis view) and the other is by what the intended use is (synthesis view). An often used building design approach is to identify the primary space function before sketches of the building form are developed. Consequently, it is useful to create model objects of spaces before the shape and position is determined.

Some functions of spaces must be considered abstractions, because it must be remembered that such functions are actually provided by e.g. equipment, installations, construction components or furniture in the space or related to the space. Some examples are: to offer comfort by heating/cooling, to shield from weather or noise, to protect against theft/robbery, to provide floor or volume, and to offer internet access.

5 CLASSIFICATION OF FUNCTIONS

In this section, an attempt is made to form a clean classification by use of function as the classification criterion. The aim is to provide a taxonomy, which can give overview over the most important functions, which can be used to first-time identification of building components in building models. This identification is in contrast to selection of components by geometry, e.g. by a CAD system, where the determining functions of the components are not explicitly stated. When each component is identified, it can be created as a model component and, as a consequence, attributes for the selected function can be created also. Consequently, there is a clear distinction between modelling before and after the identification of components.

As soon as a model component is created, a stepwise specification of further attributes and of subcomponents commences as a fundamental modelling approach. This approach may open for other needs of classification and eliminates partly the need for the concepts *element*, *designed element,* and *work result* in ISO 12006-2.

The following taxonomy identifies a number of functions organised in levels and each node in the hierarchy expresses a function class and the emphasis is put on identifying appropriate functions on all nodes. Because only function is used as the classification criterion, it is possible to combine classification of space functions and classification of building component functions.

Taxonomy 1 – Taxonomy of functions

Provide built environment for human activities
. *Provide space (for...) (applied to spaces)*
. . *Living*
. . . *Social living/sitting*
. . . . *Eating*
. . . . *Communication*
. . . . *Relaxation*
. . . . . *TV viewing*
. . . . . *Radio listening*
. . . . . *Reading*
. . . *Sleeping*
. . . *Creativity*
. . . . *Performance*
. . . *Work*
. . . . *Cooking*
. . . . *Administration*
. . . *Personal care*
. . . *Personal fitness*
. . *Passing (to/from/between)*
. . . *Entrance/exiting*
. . . *Elevate/lower*
. . *Containment*
. . . *Storage*
. . . *Equipment containment*
. . . *Protection from people*
. . . *Garbage disposal*
. *Provide physical environment (for...) (applied to construction components)*
. . *Strength (indispensable, distinctive primary)*
. . . *Load supporting/distributing (including user loads)*
. . . *Load bearing*
. . *Shielding*
. . *Insulation*
. . *Space division*
. . *Space connection*
. . *Space expansion*
. . *Opening for light/air*
. . …
. . *Servicing*
. . . *Heating*
. . . . *Distributing*
. . . . *Convection*
. . . . *Production*
. . . . *Exchanging*
. . . *Cooling*
. . . .
. . . *Ventilating*
. . . .
. . . *Water distributing*
. . . .
. . . *Waste water disposing*
. . . .
. . . *Electricity*
. . . . *Distributing*
. . . . *Lightning*
. . . . *Connection*
. . . . *Control*
. . . .
. . . *Broadcast signal distributing*
. . . ...
. . *Goods keeping (for storing/placing)*
. . . ...
. . *Supporting basic human needs*
. . . ...
. . ...

Observe that the proposal is made just as an illustration and must not be considered a true and complete classification. There may be better proposals and additional sub-classes may be inserted.

The primary partition is between functions of spaces and functions of building components and, within each of these branches, additional levels of division are proposed. A major advantage of the taxonomy is that, for each function, a range of attributes can be identified and attached to each function node. These attributes clearly underline the importance of selection of functions as the basis of identification of component types. In fact, to establish a list of attributes specific for each function would ease the work with identification of requirements and specification of models for testing and simulation.

As stated, this taxonomy may be useful as inspiration for first-time identification and creation of building model objects and on the basis of required functions. By creating a clean classification, the taxonomy is relatively easy to use. Each function is only represented once and there is no confusion about how to step down in the hierarchy. When a model object is created, the primary function can be attached to the object. One example could be function for 'passing (to/from/between)' and more specifically for 'elevate/lower'. Another model object could be for 'servicing' | 'heating' | 'production'. Subsequently, additional functions can also be attached. Each time a function is attached to the object, the defined attributes can also be attached.

A major advantage of this approach is that space model objects and building construction components can be identified and created in parallel or as suited otherwise and this is in contrast to the support from many CAD software products. Instead, the presented approach can easily be supported by another kind of software.

6 CLASSIFICATION OF BUILDING COMPONENTS

When building components have already been identified by functions, a subsequent modelling phase will include tasks, where each model component needs to be further specified and detailed and e.g. the building component type and subsequently a specific technical solution must be determined. In this process, a taxonomy of building components may be useful for selection of alternatives.

Taxonomy 2 – Taxonomy of building component types (not classified by function)

Building components
. Spaces
. . Rooms (physical delineated)
. . . ...
. . (Non-physical, notionally delineated spaces)
. . . ...
. Building construction components
. . Primary
. . . Walls (heavyweight walls)
. . . Floor slabs
. . . Footings
. . . Beams
. . . Columns
. . . Shafts
. . . Piles
. . . ...
. . Supplementary components
. . . Roofs and Roof trusses
. . . Walls (lightweight walls)
. . . Curtain walls
. . . …
. . Completion components
. . . Doors
. . . Windows
. . . Gates
. . . ...
. . Elementary components
. . . Battens
. . . Posts
. . . ...
. Building services components
. . Plumbing, components for ...
. . . Devices
. . . . Toilets
. . . . Wash
. . . .
. . . Elementary components
. . . . Pipes
. . . . Fittings
. . . . Terminals
. . . .
. . Electrical/electronic components
. . . Devices
. . . . Access control central
. . . . Alarm central
. . . . Control
. . . . Transformers
. . . .
. . . Elementary components
. . . . Wires
. . . . Terminals
. . . . Sensors
. . . . Fuses
. . . .
. . Services ducts
. . . Cable ducts
. . . ...
. . Complex plants/units
. . . Heaters
. . . Boilers
. . . Ovens
. . . ...
. . Systems
. . . Heating
. . . Ventilation
. . . Air Condition
. . . …
. Fixtures
. . Shower cabins
. . Cabinets
. . ...
. Equipment
. . Vacuum cleaners
. . Refrigerators
. . Computers
. . ...
. Furniture
. . Chairs
. . Tables
. . ...

Observe that the taxonomy is made as an illustration of how the principles can be used and must not be considered a complete classification. In order to underline that all terms are component types and not individual components, they are listed in plural form.

The component types in the taxonomy above are defined regardless of composition. Composites/assemblies/systems are included as well as subcomponents. This solves the problems from using function as the classification criterion.

In general, it is important that the construction partners can exchange information about building components and various taxonomies of building components may support this as illustrated in Figure 2. According to ISO 12006-2, classifications of *designed elements*, *work results* and *products* would be useful. It may be useful to have multiple classifications of building components but it would of cause be simpler, if one superior taxonomy could satisfy the needs for detailing. As stated, a taxonomy of building components will be necessary but a taxonomy of products will also be useful and producers of such products can, with reference to this taxonomy, publish information about the products. This would enable designers, constructors and other consumers to use the taxonomy to find alternative products. Examples of such useful information are detailed product description, instructions for handling and assembly of components, instructions for maintenance, warranties, prices and cost values.

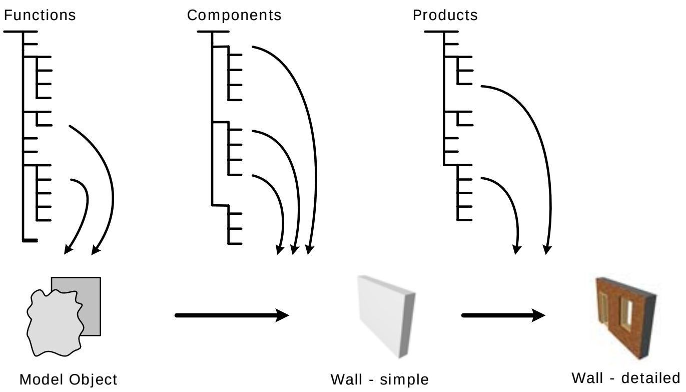

Figure 2 – Use of taxonomies with different content at different modelling stages

As stated, the aim is to support the specification and detailing process by providing overview over alternative technical solutions. In this process, one or multiple functions of each model component is already identified and possibly specified. Consequently, it may be suitable to use other classification criteria than function.

7 TAXONOMY RELATIONSHIPS

It is very useful to establish relationships between taxonomies (illustrated in Figure 3).

The relationships between the function taxonomy and the component taxonomy can be used when a model object is initially created by selecting a main function and, subsequently, a component type must be selected. This can be performed via the relationships, i.e. a set of component types can provide the function. For the function 'passing (to/from/between)' | 'elevate/lower', mentioned above, related sample component types could be staircases, lifts/elevators or escalators and, similarly, for the function 'servicing' | 'heating' | 'production', boilers could be referenced.

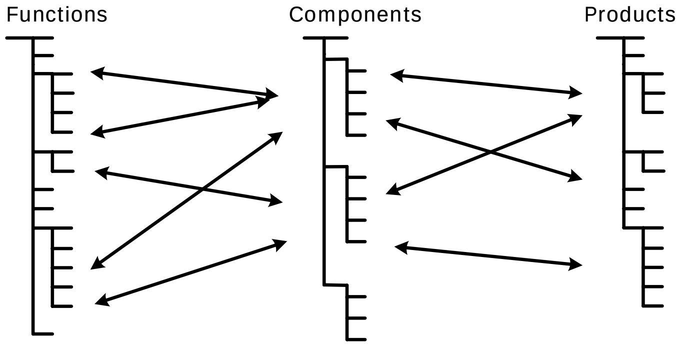

Figure 3 – Relationships between taxonomies support efficient specification and detailing processes

The reverse relationships would also be very useful. They will show, which functions are considerable for specific component types. Consequently, if a component type is selected in the component taxonomy, relationships to functions would indicate, which secondary functions could be selected. This would be important in order to add attributes to each component for further specification.

Similarly, very useful relationships between the component taxonomy and the product taxonomy could be established. Each component type could refer to a set of products, which could replace the component.

8 MODELLING APPROACH

When building models are created, specific building components are selected and related to each other. The individual building components can be seen as *instances* of the component classes, which are included in the taxonomy above. For each component, a type is selected, the component is created and values are assigned to the attributes of the component. As already stated, attributes for one or more functions can be attached when functions are selected from the function taxonomy and other attributes can be provided, when the component type is selected from the component taxonomy. If further relevant data are attached to building component types in the taxonomy and proper attributes are available, these data may be transferred directly to the model components.

In order to support an efficient modelling approach, modelling tools must have the hierarchies implemented. They must also have libraries of component types and the component taxonomy will be suitable as a common overall structure, i.e. for manual selection. Tool specific libraries may be further detailed in order to provide a wide range of solutions.

Supported by an appropriate modelling tool with implementations of these taxonomies, an outline of a modelling approach would be:

1. Create model objects by selecting its main function from the function taxonomy and attach function attributes for specification.
2. For each model object, select via the relationship to component types of the component taxonomy the most appropriate type, which can provide the specified function and typify the model object to a component of this type.
3. Model the geometry of the components as usual.
4. Attach further important functions to each component by the relationships to the function taxonomy and attach further function attributes for specification.
5. Perform an automatic update of the model by data attached to component types in the component taxonomy.
6. Select appropriate technical solutions and detailing from the component taxonomy.
7. Via the relationships between component types and the product taxonomy, specific products may be selected.

Tasks 4-7 may be may be performed in another order or in parallel.

It is not considered, which actors of a building design project should carry out which tasks.

9 CONCLUSION

Classification is a fundamental abstraction mechanism, which is very useful in relationship with building construction, and many different classification systems have been developed. The primary purpose has been to support data exchange between partners in building construction projects.

Based on the assumption that building design is performed by *modelling* and that *computer based building models* are used as the basis of data exchange, the paper includes issues about *classification in connection with modelling* and how modelling can be supported by classifications.

A major issue in modelling is the *initial identification and definition* of model objects and it is proposed to develop and use *classification of functions* in contrast to *classification of building elements by function,* which is included in all known existing classification systems. This classification can be performed as a *clean classification*, where each node in the hierarchy expresses a function so that these functions form the structure of the classification hierarchy (taxonomy), i.e. functions and sub-functions. A draft proposal of classification of functions is developed.

For subsequent modelling activities, a classification of building components useful but in this case it may be more suitable to classify building components by other criteria than function. Having these two taxonomies, they can be linked so that each function can relate to the components, which can provide the function, and each component can relate to the functions, which the component can provide. These relationships are very essential in order to offer efficient and effective modelling support.

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