Link between a Structural Model of Buildings and Classification Systems in Construction

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Abstract

It is presumed that the classification systems will have a greater role in the construction process in the near future. They will support the communication between industry players while they will be dynamically formed by particular users based on common agreements. The existing international classification systems differ markedly in terms of the levels and details of specification. The internationally developed OmniClass and the Finnish Building 2000 differ in structure but both adequately serve the demands of the industry. With the available software intelligence, the most beneficial solution is to apply a mixed indirect and manually adjustable object classification system in a 4D modelling software. The present situation of information flow and 3D model usage is mapped in the construction industry in Finland. The information flow breaks several times in the process in the means of changing nomenclatures and switching from 2D drawings to 3D model, and back to 2D drawings. The recommendation is: utilizing the benefits of BIM by agreeing on the base classification system, and making it to follow the whole construction process. The changes in the plan are more easily handled with the use of BIM and the common classification system.

Keywords: Building information model (BIM), classification systems, construction, filtering, 3D, 4D
1. Introduction

This study is part of the on-going joint research project between Tekla Corporation and Construction Management and Economics Unit at the Helsinki University of Technology (TKK/CME).

The whole society will benefit from the changes happening in the construction industry, namely the shift to optimal utilization of Building information modeling. Owners will easier assess the cost of buildings and make better decision on the design and construction methods. One target for change is the format of information, to support the Integrated Design Solutions. In line with these development efforts the construction classification systems are in the focus of this study.

The classical intent for using classification systems is to support cost estimation, procurement, cost follow up and product manufacturing. It is predicted that classification systems will have a much greater role in the construction process in the near future. They will strongly support the communication between industry players while they will be dynamically formed by particular users based on common agreements. This study presents suggestions to the focal parties, describing the way of contributing to information flow jointly used by other parties in a particular building information model (BIM).

The direct and indirect classification methods are discussed and compared in the paper, taken into account is the software intelligence and the complexity of the built environment. The structure of the Finnish national classification system, Building 2000 and the comprehensive internationally developed OmniClass are compared. In this paper the nationally accepted or widely used classification systems are called base nomenclature or base classification system.

Besides the theoretical recommendations, a technical tool is presented, which facilitates the implementation of the suggestions. Tekla Structures, a 4D structural design software, is used for demonstration of the theoretical and practical solutions. (By adding time to a 3D CAD application one forms 4D.) The Model Organizer is a new Tekla Open API (Application programming interface) application in Tekla Structures. The logic of the Model Organizer allows parties in construction projects to apply their own classification systems, and it can be utilized in many different ways for the benefit of all construction-related parties.
2. Method and critique of the study

The research methods of this study involve literature review and expert interviews. The literature review targeted the relevant references about Finnish and international classification systems, standards, and the latest research results on Building Information Modeling. The interviews were conducted for gaining deeper knowledge of the information flow in the construction industry, and to test the suggested solution about the classification system utilization. The aim of the interviewee search was to find the representative interviewee(s) from within each of the six interviewee groups by branch type, i.e. owners, facility management companies, contractors, subcontractors, designers, and building products suppliers. Complementary interviewees were arranged with experts in the software industry, namely from Tekla Corporation. The second choice criterion implied that the interviewees would know Tekla Structures, and preferably already used it in their projects. Owners, architects and facility management companies’ representatives are going to be interviewed later as the project continues.

As a critique of the study it is noted that the study describes only a part of the construction industry in Finland through the means of working and information exchange methods. In the opinion of the authors in the long run, as the technology develops, the classification systems will change its form and meaning. The present description of application is a step towards a more generally applicable solution. Therefore the presented approach can be considered as a temporary way of working to enhance the cooperation between construction industry players.

3. Functions and applications of classification systems

The extent of application of classification systems differs greatly in different countries. Within single countries there can be several independent classification systems in the construction industry. Parties of the construction industry are seeking new ways of cooperation to reach more effective operation methods. The international standards are created to support these efforts between and within different countries. National classification systems have been changed and others could be changed to follow the directions of the international standard: International Organization for Standardization (ISO) 12006-2

3.1 Classification systems used in Finland and internationally

The basic process model of any construction classification system, stated in the ISO 12006-2 standard, is as follows: construction resources are used in or required for construction processes, the output which are construction results.

There are numerous construction nomenclatures used all around the world. OmniClass Construction Classification System (OmniClass™) is presented here as an example. OmniClass is a strategy for classifying the entire building environment. It incorporates other extant systems as the basis of its Tables – Master Format™ for work results, UniFormat for elements and EPIC (Electronic Product Information Cooperation) form products. OmniClass is designed to provide a standardized basis for classifying information created and used by the North American architectural, engineering and construction (AEC) industry, throughout the full life cycle of buildings. OmniClass follows the international framework set out in the ISO 12006-2. Table 1 lists the table titles of OmniClass.

In Finland there is a long history of applying national construction classification systems like Building 70, Building 80, Building 90 and Building 2000. Benefits have been realized but there is need for further adjustment of activities to fully utilize the inherent opportunities. The two commonly used nomenclatures at this time are the Building 2000 (by architects) and Building 80 (by constructor companies). Despite the widespread use of national nomenclature, several brakes can be recognized in the digital information flow in Finland due to the slow change towards 3D modeling. Strong efforts are currently being taken to tackle the problem with the involvement of several construction related companies. Building 2000 is the favorable choice of classification systems for the future because it supports BIM.

Table titles of Building 2000: Building Elements, Construction Resources, Work Sections, Premises and Spaces, Project Classification, Worksite Equipment. When applying the Building 2000 nomenclature, the Building Element and Project Classification table is used during the design and construction phase. For the preliminary specification of elements, the tables of
elemental bill and estimates and tender cost estimates are used. The tender cost estimation is based on an elemental bill, which may be itemized by activities when needed. The target estimation is based on a schedule of work sections.

Table 1. Relation between the tables of OmniClass and Building 2000.

<table>
<thead>
<tr>
<th>OmniClass tables</th>
<th>Basic dimensions of general classification</th>
<th>Building 2000 tables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 11 – Construction Entities by Function</td>
<td>Construction Results</td>
<td>In Premises and Spaces Classification</td>
</tr>
<tr>
<td>Table 12 – Construction Entities by Form</td>
<td>--</td>
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<tr>
<td>Table 13 – Spaces by Function</td>
<td>--</td>
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</tr>
<tr>
<td>Table 14 – Spaces by Form</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Table 21 – Elements</td>
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<td>--</td>
</tr>
<tr>
<td>Table 22 – Work Results</td>
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</tr>
<tr>
<td>Table 31 – Phases</td>
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<td>--</td>
</tr>
<tr>
<td>Table 32 – Services</td>
<td>Construction Processes</td>
<td>In Building Element and Project Classification</td>
</tr>
<tr>
<td>Table 23 – Products</td>
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<tr>
<td>Table 33 – Disciplines</td>
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<td>Table 34 – Organizational Roles</td>
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<tr>
<td>Table 35 – Tools</td>
<td>Construction Resources</td>
<td>Worksite Equipment Classification</td>
</tr>
<tr>
<td>Table 36 – Information</td>
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</tr>
<tr>
<td>Table 41 – Materials</td>
<td>--</td>
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</tr>
<tr>
<td>Table 49 – Properties</td>
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</tr>
</tbody>
</table>

Table 1 organizes the table titles of Building 2000 and OmniClass in three groups based on the standard ISO 12006-2. The groups describe the basic dimensions of classification systems, like Construction Results, Construction Processes and Construction Resources. The Building 2000 tables are organized differently than the OmniClass tables. The content of Building 2000 tables can be paired with one or more similar OmniClass tables. The extent of Building
2000 is narrower than the extent of OmniClass. Building 2000 does not cover the classification for infrastructure, and as visible from the table titles, the Construction Entities by Form, Spaces by Form, Phases, Disciplines and Organizational Roles; while OmniClass does cover the whole built environment. Also the depth of Building 2000 stays at a more general level with it’s 4 digit code within the tables, while OmniClass has the maximum of 8 digit code within the tables.

3.2 Extent and depth of a classification system

The extent and depth of a classification system is adequate if it serves the needs of the users. In the case of national nomenclature the goal is to cover the whole built environment and the structure of the classification system must support the BIM applications. The question is, how precise or deep should a classification system be in order to enable its wide applicability within and between several parties? Based on the interviews there is no need for very detailed base nomenclature, because the constructor and subcontractor companies’ organizational structure and working practices widely differ. They see the adequately refined classification system as their competitive advantage. They can further refine the national nomenclature and still they can communicate to other companies through the base nomenclature or through the commonly agreed refined classification system. As a comparison base, OmniClass is the deepest nomenclature to be used when architects or structural engineers implement the classification.

3.3 Predefined and dynamic classification system

Present CAD software are capable of storing classification information about the model objects in different ways. The Tekla Structures Model Organizer can store predefined classification groups, but the user is free to create any number of new groups that the project requires. The model object are filtered and linked to the corresponding classes in the Model Organizer. The predefined part of the classification system is the base nomenclature in the Model Organizer. Structural engineers and architects deal with the predefined part. The dynamic part is the further refined nomenclature serving the needs of the contractor, subcontractors and other users of the 4D model. There is a possibility to agree on specific use of
the nomenclature, and on the method of extending or refining it project by project. Contractual forms must reflect these project needs.

Figure 1 shows an example of classification with OmniClass in Tekla Structures Model Organizer. OmniClass can be the basic nomenclature in an international project implemented in Finland. Civil Defense Shelter is an obligatory part in most of a multistory block house in Finland. OmniClass does not contain the category Civil Defense Shelter therefore a User Defined Class is added to the Element categories in this project. The parts comprised by the Civil Defense Shelter are listed with their product classification code within the element, because this can support the cost calculations.

![Figure 1](image_url)

**Figure 1.** Example of classification with OmniClass and a user defined refinement.

### 3.4 Linking objects to classification system

The automation of the direct linking of the 3D model to the classification brings a great benefit to the creators and users of classification information. There are several theories and implemented applications for solving this technical challenge. This paper aims to present the major differences between the methods.
Object property: In this paper the property of an object is understood as the minimal definitive property of the object and it is created when the object is created.

Attribute: In this paper the attribute is understood as an additional property of the object, which is linked to it after creation.

In general means, depending on the properties of the objects they can be classified to different classes:

- All red beams greater than size 10, belong to class 1.
- A red beams smaller than or equal to size 10, belongs to class 2.

Once defining the classifier rules, the assignment of the object to a class can be done automatically by a CAD program. The program is able to handle any changes in the model by rerunning the assignments to classes or by redefining the classes. In order to use this system in practice the user has to be able to overwrite the rule and assign the object to any class.

There are two principal methods for connecting classification information to model objects.

- **Direct classification method:** the classification information is stored as an attribute to each object. The nature of this connection is one-to-one.

- **Indirect classification method:** the model objects and classes are connected to each other with a dependency. Dependency is typically a condition. If properties of an object match with the condition, it belongs to the class. The nature of this connection is one-to-many.

In the **direct** classification method, the object class is defined as an attribute of the object. Attributes and the way of linking it to the objects can be divided to two main categories:

- **Geometrical** attributes are created to define the geometrical appearance of the object.

- **Non-geometrical** attributes are additional information tagged to the objects.

Both main attribute categories can be used for storing the classification information.

**Geometrical attributes** are either linked to the objects in product libraries, or define the physical appearance of the objects otherwise. If geometrical attributes are used with **direct** classification, the geometrical appearance of the object is
directly connected to its class. This means that the size of the object library becomes needlessly big in normal buildings having a lot of variation. All the changes in geometric appearance are reflected in the class and vice versa. Management of the library and classification becomes laborious. However this method is well-suited for situations where minimal or no variation is needed in either the object library or classification (pre-engineered buildings made of standard components). A basic example is shown in Figure 2.

If **non-geometrical attributes** are used with **direct** classification, the geometry of the object is not directly dependent on the classification. The class is tagged to the object. However the automation for connecting the objects with classification system is difficult to arrange due to the one-to-one nature of the connection. The implementation possibilities of one-to-many connections are limited. Deficiencies in automation capabilities in practice easily lead to situations where the end user has to manually take care of the classification validity. The link between an object and its non-geometrical attributes created with the direct classification method is demonstrated in Figure 3.

![Figure 2. Direct Classification method with geometrical attributes.](image)
The **Indirect** classification method has several benefits over the direct one. With the indirect classification method the automation is easy to arrange. Objects are automatically linked to classes and automatically switched to the correct class when changes occur in the model. Objects belong to as many classes as needed, there are no theoretical limitations. The way of object filtering with the indirect classification method and the manual adjustment is shown in Figure 4.
In practice automation seldom provides a 100 percent precise classification result as there is a great variation of needs, therefore the semi-automated method is suggested. Satisfactory classification functionality is reached by the combination of automatic indirect classification and the possibility of manual adjustment. The one-to-many nature of the classification does not change when manually comprehending to the process.

3.5 User groups of classification systems in the construction industry in Finland

The interviewees described their contribution to the information flow and the way of utilizing different nomenclatures at the present time. The following working methods are derived from the result of the interviews; they are only examples and not exclusive methods in the industry.

1. Architects
   - use 2D CAD application and provide the drawings on paper
   - use 3D software for the design. There can be a certain level of classification in the model, and possibly also the Building 2000 classification number of the object in the attributes.

2. Structural engineer – creates the structural 3D model based on the 2D drawings in most cases, or imports the architectural model as a reference model and creates the structural model based on it. Based on RT (Rakennustieto, Finnish Building Information Group) recommendations, the structural engineer uses prefixes as object attributes. The structural engineer creates filters to the objects for the following purposes:
   - owner requirements (for repeated project types)
   - phases (layers) for self purpose: used with prefixes for drawing creation and reports.

   It is up to the designer whether the Building 2000 classes are entered as attributes or not.

3. Mechanical and electrical designer – can use the 3D model created by the structural engineer as a reference model for the design. They utilize the classification created by the structural engineer e.g. the Building 90 in
the model and complete it with RYL 2002, the classification system for mechanical engineering.

4. **Project Management Company** – usually uses Building 80 as the base of bid packaging, cost estimation and other purposes. The classification is added to the objects in the 3D model. Without 3D model and precise bid package preparation for subcontractors, the received tenders are estimative and they have great deviation in pricing.

5. **Contractor** – use Building 80 nomenclature for quantity survey, pricing and cost estimation. They are done by manual calculation or software is used. The 3D model is recreated in a chosen “quantity take off” software, and direct classification is used to support filtering. For construction scheduling and implementation monitoring, separate project management software is used, where the building objects are entered manually. In some company several separate internally developed coding systems are used. For example one coding system is based on Building 80 and the other is based on Building 2000, and they are used parallel to each other in the cost estimation and purchasing.

6. **Subcontractor**
   - **Subcontractor** – for implementation work receives 2D drawings or rarely 3D model, which is used for bid offer creation. The organization of implementation work is done manually and is paper-based.
   - **Steel fabricators and precast manufacturers** – mostly 3D model elements and project management software is used when the subcontractor is the product manufacturer at the same time. They also receive 2D drawings or a 3D model. When 2D drawings are received, the 3D element model for production is created. When the 3D model is received the elements are ready for production. They use an internal product classification system. Steel fabricators and precast manufacturers frequently use other subcontractors for the erection process.

7. **Product manufacturer** – receive orders and offers from the contractor.
8. **Mechanical (HVAC) subcontractor** – receives 2D drawings, sometimes a 3D model. As the received model is getting more and more reliable they are producing more prefabricated parts.

9. **Authorities** – require 2D drawings and do not accept 3D model.

### 3.6 Recommended use of nomenclatures in the construction industry

To support the information flow in the construction industry the following actions are recommended. Examples are taken from the Finnish Building 2000 classification system.

1. **Software vendor** – provides the classifier tool e.g. Tekla Structures Model Organizer and the base nomenclature (Building 2000) included.

2. **Owner** – Agrees in the contracts with the architect and the structural designer:
   a. The architectural model contains object filtering using all four digits of the Building 2000 Elements table.
   b. The structural model contains the classification of objects to the level of Building 2000, four digits.

3. **Architect** – classifies the objects with Building 2000 Elements to full depth (four digits). The classification information is transferred to the structural model through IFC model transfer.

4. **Structural engineer** – opens the imported reference model, and creates the structural model based on it. Classifies the structural and non-structural elements with the use of the Model Organizer. The base nomenclature with its search conditions (Building 2000 Elements to full depth) is already provided with the Model Organizer, so the engineer only runs the search functions of the Model Organizer. Model Organizer uses the classification in the object attributes to identify the non-structural reference model objects. Drawings are created based on the Model Organizer classes. The structural designer creates the combined model in Tekla Structures based on the architectural, structural and mechanical model. Spaces imported with the reference model are also entered into the Model Organizer. Reporting is done based on the classes in the Model
Organizer. When changes are made to the model, the classification with Model Organizer is easily redefined.

5. **Mechanical and electrical designer** – They have attributes in their model which can be used as a classification base, and can utilize a similar classification tool as the other parties. They utilize the classification created by the structural engineer e.g. the Building 90 in the model and complete it with RYL 2002, the classification system for mechanical engineering.

6. **Contractor** – Receives the model with a model sharing method. Refines Building 2000 to the level of needs in the Model Organizer. In the following points there is an example for the Contractor’s process order.
   a. Quantity list, cost estimation, project budget creation, project schedule creation – Building 2000 Elements depth can be enough, but checking and refinement is probably needed.
   b. Bid package creation – Building 2000 Elements depth is enough for this purpose.
   c. 4D work schedule e.g. in Tekla Structures Task Manager, or other software – easy to create tasks based on the Tekla Structures Model Organizer classes.
   d. Subcontractor tendering – get the precise, time and work package schedule created with the help of the Model Organizer.
   e. Budget comparison and acceptance.
   f. Combining models of the contractor and subcontractor if needed.
   g. Control of implementation – Tekla Structures Task Manager and Model Organizer is utilized, utilizing the 3D model for surveying and for measurement of object positions in the field.

7. **Subcontractor**
   - **Subcontractor** – for implementation work receives 3D model. Refines Building 2000 to the level of needs in the Model Organizer. The organization of implementation work is done digitally.
   - **Steel fabricators and precast manufacturers** – 3D model elements and project management software is used when the
subcontractor is the product manufacturer at the same time. They receive 3D model. When the 3D model is received the elements are ready for production. The internal product classification is a refinement of the Building 2000, so the communication is supported with the other parties. Steel fabricators and precast manufacturers frequently use other subcontractors for the erection process.

8. **Product manufacturer** – receive orders and offers from the contractor. The product numbers or classes correspond to the base classification.

9. **Mechanical (HVAC) subcontractor** – receives 3D model from the mechanical designer, there are no clashes in the model, so there is no need for onsite changes of the plan.

10. **Authority** – Classification system with the 3D model will serve the building acceptance and the building inspection.

11. **Facility manager** – utilizes the combined architectural, structural and mechanical model for maintenance. Facility managers have a special need for the spatial classification.

### 3.7 Industrial impact of the new solution

The compatibility of construction-related information is increased when working on common ground within the classification systems. One of the greatest benefits of the suggested working method is that the changes in the plan are more easily handled with the use of BIM and the common classification system. Construction time can be reduced, costs can be reduced; therefore owners and developers can gain competitive advantage and give their organizations a better return on their capital investments.

### 4. Conclusions and recommendation for future research

The existing international classification systems differ markedly in terms of the levels and details of specification. There are major differences between their uses by construction industry players in particular countries. OmniClass and the Finnish Building 2000 differ in structure but both adequately serve the demands of the industry, and can serve as a base for further project specific refinements.
As a comparison base, OmniClass is the most detailed nomenclature to be used as a base nomenclature. The initial guidelines are suggested to construction industry players to reach common agreement on the applied classification system with utilizing the benefits of Building Information Modeling. With the available software intelligence, the most beneficial solution is to apply a mixed indirect and manually adjustable object classification system in a 4D modeling software. Tekla Structures Model Organizer is a commercially available tool to implement the suggested working method. After defining the classifier rules once, the assignment of objects to classes is done automatically by the program. The program is capable of handling any changes in the model by rerunning the assignments to classes or by redefining the classes. In order to use this system in practice the user is able to overwrite the rule and to assign the object to any class.

Based on the interviews, the interviewees seem to be convinced about the need for change in the information process in the construction industry, and are committed to the use of 3D modeling and common base nomenclature. The construction industry is slowly changing and still follows traditional methods, but given the right hardware, software tools and applications, people will change their working methods.

The working-out of correct contractual forms supporting the BIM process and requiring the common language of information exchange is inevitable for the success. The present study discusses only the Finnish construction process. In each country, all the different construction methods and processes should be analyzed and developed. In many of the cases the shift form one classification system to another will be necessary towards the optimal information flow. More detailed analyses and formation of public recommendations for certain types of construction processes would help the company managers to formulate the right steps for smoothly shifting the tools and language of information exchange.

References


