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Standards, codifications, and Classifiactions for a General Contractor

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Special thanks to all my Master colleges.

STATEMENT OF INTEGRITY

I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of undue use of information or falsification of results along the process leading to its elaboration.

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SOMMARIO

In questo documento l'obiettivo principale è la ricerca e l'analisi dei sistemi di classificazione. Per raggiungere questo obiettivo, nel lavoro effettuato vengono effettuati diversi passaggi . Seguendo l'approccio BIM, questo documento mostra l'importanza del sistema di classificazione e il loro utilizzo in diverse fasi e attività del progetto come la pre-progettazione, la gara d'appalto e la stima dei costi. Il primo passaggio evidenzia e descrive la maggior parte dei sistemi di classificazione standard. Il passo successivo consiste nell'analisi e comparazione dei diversi sistemi di classificazione per ottenere le loro caratteristiche principali come vantaggi, svantaggi, struttura. Un ulteriore passo consiste nel mostrare la classificazione degli oggetti seguita dall'interoperabilità tra diversi sistemi di classificazione. La parte finale del documento comprende un semplice esempio di interoperabilità tra diversi software che utilizzano classificazioni e di creazione di un database utilizzato per supportare l'interoperabilità in termini di scambio di dati tra diversi sistemi di classificazione. Nella conclusione viene affrontata la fattibilità dell'utilizzo dei sistemi di classificazione per scopi diversi , in modo da contribuirea migliorare lo scambio di dati tra diverse discipline.

Parole chiave: (BIM, sistemi di classificazione, UniClass, OmniClass, CESMM4, interoperabilità, UniFormat, MasterFormat, POMI)

ABSTRACT

In this document the main is focus is to research and analyse classification systems. To reach this objective different step are taken in this study. Following the BIM concept or approach, this document shows importance of classification system and their usage in a different project stages and activites such as predesign, tendering, cost estimation. The first step highlight and describe standard most of the classification systems are based on. The next step is to analyse different classification systems to obtain their main features such as benefits, disadvantages, structure. Further step is to show object classification followed with interoperability between different classification system. Final part of the document comprises a simple example of interoperability between different software using classifications and to create basic data base that is used to support interoperability in terms of data exchange between different classification systems. The conclusion section addresses the feasibility of the usage of classification systems for different purposes that will help improve data exchange between different disciplines.

Keywords: (BIM, classification systems, UniClass, OmniClass, CESMM4, interoperability, UniFormat, MasterFormat, POMI)

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1. INTRODUCTION

1.1. Classification as a part of BIM

Nowadays in construction sector the problems mostly occur due to received or sent wrong information. Controlling proccesses means to handle information not only in the design stage but also in the whole lifecycle.Industries, such as car industry, 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. The whole supply chain is involved since the beggining of project and thas what construction sectory have been trying to achieve and benefit from it. 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. Getting classification and reference designation to fit the modeling process is an important issue in order to reach „perfect“ workflow in BIM work and secure the use of integrated and interoperable data.

Therefore, BIM is changing on the basis of digitalization of information the way we have been producing, using, and sharing information in AEC. 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 dana 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.

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.

In order to determine if a classification and the way of information structuring is useful to BIM, it will be required to test what the classification as such can support, which is the main goal of the thesis.

1.2. Classifications for a general contractor

For a long time, main players in the construction sector had looked for a way to order their works. As the Building information modelling has become a significant milestone in AEC industry, especially in the project management.

BIM has been used during the early design phases, when the chance to find mistakes is high and doesn't have a big impact on the total cost of the project. In terms of project planning and cost estimating, it is crucial for a classification system to be capable of identifying and describing any model element. Parameters such as location, material, geometry, structure, function define BIM model. According to these parameters, construction method, stages and the cost are defined. To compose a work breakdown structure (WBS) activity needs to be assigned to each element.

1.3. Definitions

Classification – is a means to describe construction entities in a standardize way

Work Breakdown Structure (WBS) – is a tree structure that starts with the end objective and is then successively sub-divided into the main components and sub-components that make up the entire building project

Cost Breakdown Structure (CBS) – is the financial breakdown of a building project into cost targets for elements or work packages; is a WBS with money attached to the items in the breakdown structure

Product Breakdown Structure – is a hierarchical structure of things that the project will make or outcomes that it will deliver

Construction information – information of interest in a construction process

A "contractor" – a business entity that initiates, plans, executes, controls and closes projects where the project itself is a "profit center"

Work – this include work to be carried out, materials and services to be supplied and the liabilities, obligations and risks to be undertaken by the contractor under the contract

Bill of quantities – a list of items giving brief identifying descriptions and estimated quantities of the work comprised in a contract

Daywork – the method of valuing work on the basis of time spent by the operatives, the materials used and the plant employed

Commencing surface - In relation to an item in a Bill of Quantities, the surface of the ground before any work covered by the item has been carried out

Excavated surface - In relation to an item in a Bill of Quantities, the surface to which excavation included in the work covered by the items is to be carried out

2. METHODOLOGY

2.1. Framework for classifications ISO 12006:2

The classification includes the general hierarchical nomenclatures that are used for assigning a unique “purpose” through the specific code.

Fast growing concept of Building information modelling and modern forms of procurement require all the object classes to be used, along with many others. The core of Building information modelling is data exchange throughout all the project stages and between participants and applications. Participants include clients, constructors, end users, designers. Applications include modelling, specification, product information. The data comprises of the many types of information such as geometrical data, functional data, cost data and applications. In order to have successful, complete and consistent data exchange the object classification is required within the project. The part of ISO 12006:2 provide framework for classification to facilitate this exchange. Due to differences in construction culture and legislation mapping between them should be straightforward. This will be of great benefit to international construction projects (with participants from many countries).

2.2. Purpoe and basic principles

The starting point for the design of construction complexes and construction entities is a need. Documentation of user activities and functional requirements is an important part of the information needed in the construction process.

The different classes in the standard are related in a basic process model which states that a construction process uses construction resources to achieve construction results. It creates a principal structure for the classes of great interest. The stage of the construction process lifecycle characterizes a construction process. There are four main types of construction processes:

- Pre-design process
- Design process
- Production process
- Maintenance process

.

Construction entities enable user activities and functional requirements. They can be aggregated into construction complexes. Construction entities consist of construction elements which can be made up of parts in several levels of complexity.

A space is an activity space, a built space, or a construction space. A built space I defined by construction results.

Construction resources comprise construction products, construction aids, construction agents, and construction information. The difference between a construction resource and a construction result is a question of its relation to a construction process and not of difference in object class. For example, construction information may be used as a resource to inform and control a construction process, or may be the result of such a process itself.

Construction objects have construction properties. Properties are represented as attributes in construction information. Member of classes have properties. These properties can be used to define and subdivide the classes to finer level of detail.

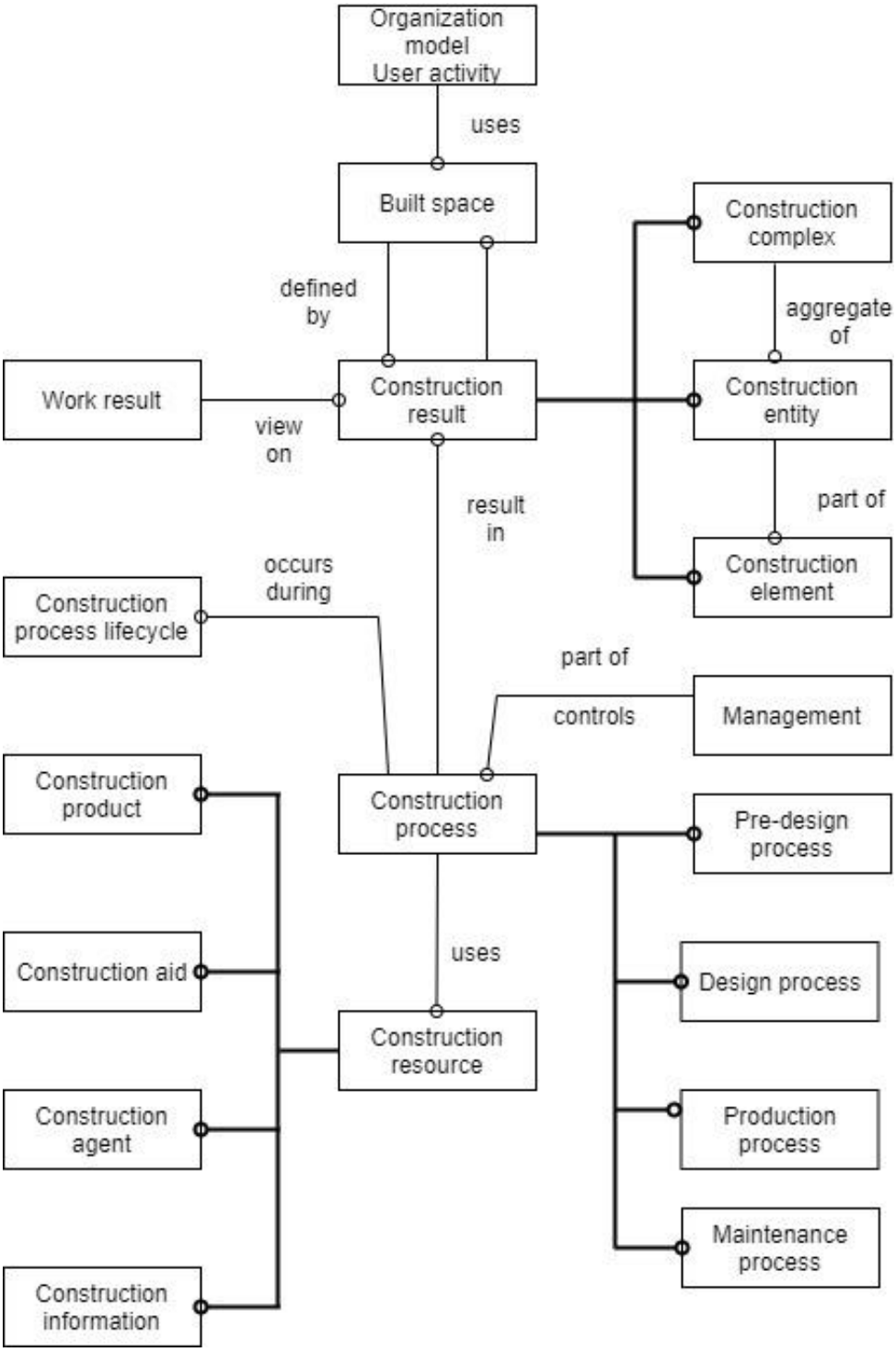


Figure 1. Concept of classification (ISO 12006:2)

2.2.3 Recommended classification tables

Table 1. Framework for classification

Class	Table
	Classified by
CLASSES RELATED TO RESOURCE	
Construction information	Content
Construction product	Function or form or material or any combination of these
Construction agent	Discipline or role or any combination of these
Construction aid	Function or form or material or any combination of these
CLASSES RELATED TO PROCESS	
Management	Management activity
Construction process	Construction activity or construction process lifecycle stage or any combination of these
CLASSES RELATED TO RESULT	
Construction complex	Form or function or user activity or any combination of these
Construction entity	Form or function or user activity or any combination of these
Built space	Form or function or user activity or any combination of these
Construction element	Form or function or user activity or any combination of these
Work result	Work activity and resources used
CLASSES RELATED TO PROPERTY	
Construction property	Property type

‘

2.2. Relations within classfication

2.2.4.1. Type-of relation

The purpose of classifying is to distinguish between objects in a collection based on properties of interest. Classes are defined by attributes representing the properties of interest.

The properties common to the whole collection must be determined. The resulting class is the most general in the classification. Then, the general class may be subdivided into more specialized classes in several steps based on differences in properties of interest.

The subdivision result in classes that run from the general to the specialized. The classes are ordered in levels determined by the relation type-of, where specific classes are types of more general classes. The classified objects are members of the classes (ISO 12006-2).

2.2.4.2 Part-of relation

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. Systems may be load bearing system, roof system, wall system, HVAC system, procurement system, suspension system, etc.

System can consist of sub-systems in different compositional levels. By subdividing or structuring a system in sub-systems, using part-of relations, large sets of information in a complex design can be handled in smaller parts. A system of systems brings together a set of systems for a task that none of the systems can accomplish on its own (ISO 12006-2).

Parts may be identified from different aspects. Depending on the aspect, there may be different part-whole relations, the following are examples:

- Using a functional aspect, the function of a part is fundamental to the function of the whole
- Using a spatial aspect, the spatial extension of a part is included in that of the whole

- Using an assembly aspect, the part-whole relation means that the existence od a physical part precedes the existence of the whole

2.3. Classifications systems

Objects can be grouped according to two organizational models:

- Hierarchical-enumerative classification system

This organizational model is more traditional classification system based on taxonomy. Classes are subdivided from the most general subjects to the most specific. Figure 1 shows an example of hierarchical classification systems.

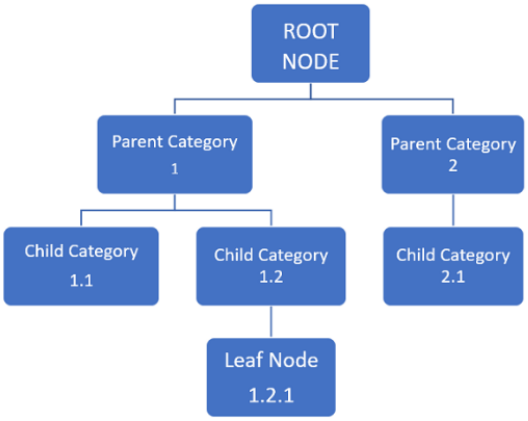


Figure 2. Example of hierarchical classification

- The analytical – synthetic classification (faceted)

Faceted classification systems are more easily adaptable in case of subsequent modifications. The object is not classified by a single position in a classification system, it can be simultaneously described and classified by several non-overlapping characteristics, “facets”. The object described is easily identifiable by a multiple search criteria. Figure 2. shows an example of faceted classification system.

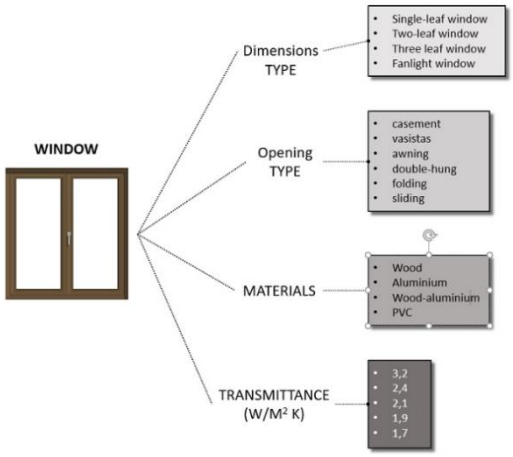


Figure 3. Example of faceted classification

2.3.1. Uniclass

The Uniclass classification systems were developed under the sponsorship of the CPIC and NBS, UK. There are three versions of the classification systems, but the one currently in use is Uniclass 2015. Uniclass was developed based on the CAWS, EPIC, CI/Sfb classification systems and also aligned to ISO 12006-2.

2.3.1.1 Purpose and application scope

Uniclass can be used to categorize information for costing, briefing, CAD layering, when preparing specifications or other production documents.

Uniclass provides:

- A unified classification system for the construction industry
- A numbering system that is flexible enough to accommodate future classification requirements
- A database of synonyms to make it as easy as possible to fine the required classification using standard industry terminology

Benefits of using Uniclass:

- It is free and open
- It covers both buildings, landscaping and infrastructure in a common class-system
- Compliance with ISO 12006-2 ease integrations with and translations to other classification schemes in the future

Disadvantages

- Doesn’t cover some sectors and project stages in details

There are some examples of using Uniclass by different professions listed below:

- Asset management - An asset manager needs to be able to find details of plant and equipment quickly when issues arise, and having them classified can help with this. The spaces within a building or other facility can be listed using their classification codes, along

with all the activities associated with them. The systems serving each space and the products that form them can also be included by classification, providing a complete information trail. When a product reaches the end of its life and needs to be replaced, having it correctly classified makes it easy to identify which spaces are affected, so that arrangements can be made and people informed.

Using Classification to interrogate models - as a different example, imagine a requirement to check that all doors in a project model are compliant with the requirements of Part M of the Building Regulations. There may be hundreds of doors on the project but they are all classified as door systems using the Systems table:

Ss_25_30_20 Door, shutter and hatch systems

The data can be searched for instances of this code to produce a list of all objects classified as doors. Once all the doors have been identified, software can interrogate the properties of the objects to determine for example, whether the clear opening width of each door is in accordance with the requirements of the regulations.

2.3.1.2. Flexibility and customization (tables)

The suite of tables is broadly hierarchical, and allows information about a project to be defined from the broadest view to the most detailed. The Complexes table describes projects in overall terms and can be thought of in terms of the provision of an Activity. Complexes can be broken down as groupings of Entities, Activities and Spaces/ location depending on the particular use (Delany, 2017).

Entities can be described using the Spaces/ location and Activities tables if required. The linear Entities can also be described using the Systems table. For detailed design and construction, the main starting point is Entities.

The main architectural components of an Entity are Elements, such as roof, walls, floors, etc. Other requirements in an Entity, such as drainage, heating or ventilation, are included as Functions which are part of the Elements table which is named Elements/ functions. Functions can be used in the early stages of a project to define what services are required but can also be used to describe facets of an asset manager’s role for managing these services or functions (Delany, 2017).

Elements and Functions are described in more detail by Systems which in turn contain Products.

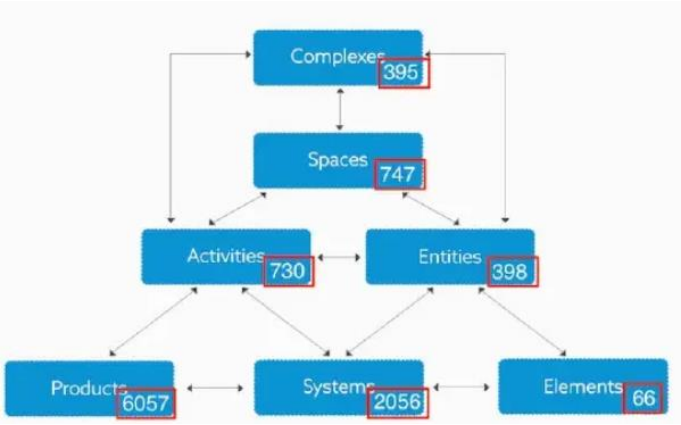


Figure 4. Uniclass tables

Figure 4. shows tables and their interrelations which are described below:

- Complexes

This describes a project in overall terms. It can be a private house with garden, drive, garage and tool shed, or it can be a University campus with buildings for lecturing, administration, sport, halls of residence, etc. Rail networks and airports are also all examples of complexes.

- Entities

Entities are discrete things like buildings, bridges, tunnels etc. They provide the areas where different activities occur. Within the holiday village above is a restaurant which is an Entity.

- Activities

The Activities table defines what user activities are accommodated in the complex, entity or space. For example a prison complex provides a Detention activity at a high level, but can also be broken down into individual activities like exercise, sleeping, eating, working, etc.

The Activities table also includes project management, surveys, operation and maintenance and services. The user activities of dining and access are provided for by the Spaces in the restaurant

- Spaces/Locations

In buildings, spaces are provided for various activities to take place. In some cases a space is only suitable for one activity, for example a kitchen, but a school hall may be used for assemblies, lunches, sports, concerts and dramas. For linear entities, such as transport corridors, the term location is more appropriate than space for breaking the project into suitable sections.

- Elements

Elements are the main components of a building (floors, walls and roofs) or of a structure like a bridge (foundations, piers, deck). Functions are the building services to be provided and managed.

- Systems

Either one or more Systems are collected together to describe an element or a function. Systems are collections of products, for example, a system for a timber pitched roof includes timber structural members, boards, fastenings, etc.; and a low temperature hot water heating system includes a boiler, pipework, tank, radiators, etc. A signal system for a railway is made up of signals, detection and warning equipment, posts, cables, etc.; and a scum removal system, part of a wastewater treatment entity, includes scum containers, scum pipelines, valves, pumps, etc (Delany, 2017).

Table 2. Examples of tables content ((Delany, 2017)

	Buildings	Infrastructure
Complexes	University campus Hospital Airport	Rail network Road network
Entities	Teaching block House Nurses residential Block	Bridge Tunnel
Activities	Lecturing Tutorials Lighting Heating	Transportation Drainage
Spaces/Locations	Student bar Departure lounge	Embarkation point Workshops
Elements	Roof Wall	Rail track
Systems	Timber roof framing system Low temperature hot water heating system	Ballasted rail track system Hot rolled paving system
Products	Joist hangers Terrazzo tiles Gas fired boilers	Conductor rails Rail track tie bars Hot-rolled asphalt (HRA) surface courses and slurries

Additional tables for managing the BIM process:

- Project Management

The Project management table includes classification codes for information for use throughout the life cycle of a project.

- Tools and equipment

The Tools and equipment table includes lists of plant, equipment and tools for carrying out the construction of a project and the maintenance of a project.

- Form of Information

The Form of Information table includes codes for the type of information format. For example, Communication includes Brochure, Correspondence and Memo; Graphical includes Animation file, Model – Three dimension, Photograph; and Record information includes Certificate, Plan, Report and Survey. The table does not include details of content.

The tables need to be flexible and to be able to accommodate enough coding's to ensure coverage, to allow for a multitude of items and circumstances, including new technologies and developments that are yet to emerge.

Work is being done to support the tables and their users: synonyms are being added to terms to aid searching, and mappings to other classification systems are being prepared, to allow a seamless cross-over.

Each code consists of either four or five pairs of characters. The initial pair identifies which table is being used and employs letters. The four following pairs represent groups, sub-groups, sections and objects. By selecting pairs of numbers, up to 99 items can be included in each group of codes, allowing plenty of scope for inclusion.

For example, Systems are arranged in groups with subgroups which are sub divided, which leads to the final object code.

30 Roof, floor and paving systems

30_10 Pitched, arched and domed roof structure systems

30_10_30 Framed roof structure systems

30_10_30_25 Heavy steel roof framing systems

50 Disposal systems

50_75 Wastewater storage, treatment and disposal systems

50_75_67 Primary sewage treatment and final settlement systems

50_75_67_46 Lamella tank systems

The tables are designed to be flexible and to be able to accommodate sufficient codings to ensure coverage to allow for a multitude of items.

It can be seen how the different tables relate to one another ad how bigger complexes are divided into smaller components.

Uniclass codes consists of either four or five pairs of characters. The four following pairs represent groups, sub- groups, sections and objects. Up to 99 items can be included in each group of codes. The figure below shows the Uniclass division into groups, sub-groups sections and objects.

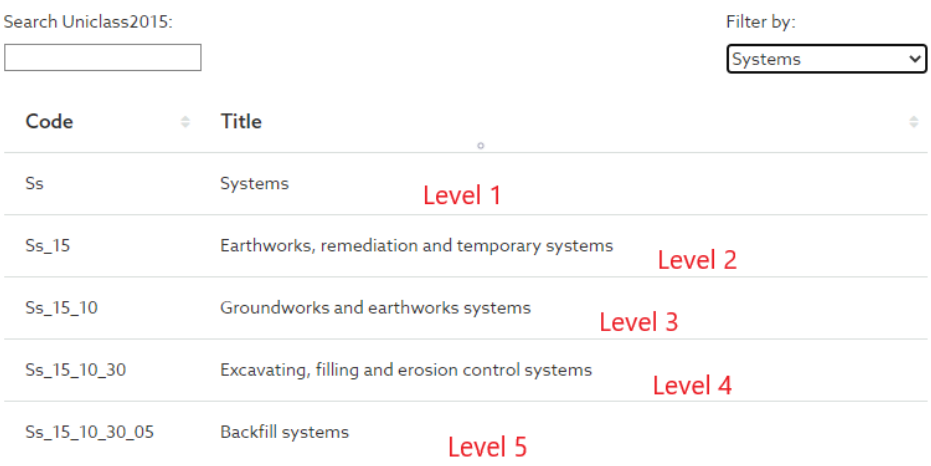


Figure 5. Uniclass divisions

2.3.2. Omniclass

Omniclass is the classification currently in the construction industry in US based on ISO 12006-2 (Organization of Information about building Works – Framework for Classification), and incorporated inside a number of 3D BIM authoring software e.g. Revit. OmniClass is supported by CSI (Construction Specifications Institute) and CSC (Construction Specifications Canada)

OmniClass encompasses many of the positive aspects of legacy systems that it incorporates, while expanding the subject matter addressed to accommodate the demands of building information models and integrated processes in the AEC industry. OmniClass has become an important requirement within the growing area of product search and comparison. It supports the demand for highly articulated product information in BIM format, and can normalize and categorize detailed attributes/properties and processes developed and supported by the National BIM Standard and Integrated Project Delivery. Complementing OmniClass is the International Framework for Dictionaries(IFD) Library. The IFD Library is an international effort and is currently operating in the Netherlands, North America and Norway as part of ISO 12006-3, Organization of Information About Construction Works—Part 3: Framework for Object-Oriented Information, and other standards.

2.3.2.1.Purpose and applications scope

Omniclass is designed to provide a standardized basis for classifying information throughout the full facility life cycle from conception to demolition or reuse. It can be used for organizing, sorting and retrieving information and deriving relational computer applications.

Benefits

- it incorporates other systems currently in use as the basis of many of its tables such as MasterFormat for work result table, UniFormat for elements table and EPIC for structuring products
- its implementation in computer technology (primarily relational or object-oriented databases), using that to relate information from variety of perspectives and to produce reports from all perspectives

Disadvantages

- not all the scopes of the tables incorporate Architecture, Civil and Services engineering
- the depth of levels of the tables varies from two to eight levels of hierarchy, which causes inconsistence in the level of description of the components

- difficulties in the mapping between the tables and some deficiencies in them have also been identified e.g. the Work Results Table has deficiencies serving the entire project timeline and all procurement routes
- the object's description inside the tables is sometimes for groups of objects and sometimes for individual objects, which can cause discrepancy in specification

2.3.2.2. Flexibility and customization (tables)

OmniClass is a faceted classification that has the ability to classify from different perspectives. It has fifteen tables. Each table represents a different facet of construction information.

Figure 3. shows OmniClass tables

OmniClass 2006-2013
Table 36 - Information
Table 23 - Products
Table 41 - Materials
Table 33 - Disciplines
Table 34 - Organizational Roles
Table 35 - Tools
Table 32 - Services
Table 31 - Phases
-
Table 11 - Construction Entities by Function
Table 12 - Construction Entities by Form
-
Table 13 - Spaces by Function
Table 14 - Spaces by Form
Table 21 - Elements (Includes Designed Elements) (Uniformat)
-
Table 22 - Work Results (MasterFormat)
Table 49 - Properties
-

Figure 6. Omniclass tables

OmniClass Table 22 –Work Results is based upon the content provided in MasterFormat. At the same time, the indexesand explanations of MasterFormat draw information from OmniClass Table 23 – Products and Table 21 –Elements, making it an application of OmniClass. Reference to other OmniClass tables is also made in the Applications Guide.

Mapping between systems and products is problematic because, read with the non-OmniClass SectionFormat, there are no homes for System outline (or compositional) specifications. Indeed, Systems and Products are conflated. This means that the Work Results Table, plus SectionFormat, can't properly serve BIM, which requires mapping between objects of different classes in the object hierarchy (e.g. this product is part of that system, this system comprises those products). Making this explicit in the specification requires outline specifications. We can't rely on this mapping being delivered through the geometrical part of BIM (CAD) since many systems and products are not modelled geometrically at all.

Most useful Omniclass codes for contractors to create work breakdown structure (WBS) are:

Table 22- Work Results. This table defines the DELIVERABLES required under or by the contract documents. This is normally known as the Contractual Work Breakdown Structure and defines what the Contractor must deliver or create to have successfully completed the project. While the WBS defines WHAT needs to be done, it is the next level deeper, the Cost and Resource Loaded CPM schedule, which tells us HOW (what is the sequence of activities or the work flow) as well as WHEN the work will be done, which is established by the early and late start and finish dates, calculated by the forward and backwards pass.

Table 41- Materials. This table contains a list of bulk materials, which are normally purchased by the truck, trailer, tank or rail car volumes. These would most likely be used if a contractor has set up their own concrete batch plant or asphalt plant rather than being used for most construction sites.

Table 23- Products. This table contains almost 7,000 "products" used in the construction process. These can be broken down into a more refined set of codes.

2.3.3. Uniformat

UniFormat is used in North America and is produced by the Construction Specifications Institute (CSI) and Construction Specifications Canada (CSC). It is classification system for arranging construction information, organized around the physical parts of a facility known as functional element.

Uniformat as a coding scheme is more closely aligned with the nature of composite elements in a Building Information Model. BIM authoring tools are more compatible to assign UniFromat than other formats, for instance, Master format. Analyzing a project with Uniformat coding is also more closely aligned with the design decision making process. Using UniFormat increses the accuracy of iterative design decisions which results in a better design and improved constructability at the site.

Main features:

- Better information, generated at less cost helps users build and manage their building for lower life-cycle costs
- its system organization allows objects to be placed before their properties have been further defined (preliminary design)
- able to achieve consistency in economic evaluation of existing and new projects
- compatible with MasterFormat

2.3.3.1. Purpose and application scope

UniFormat is a format for estimators to present cost estimates during the schematic design phase. Coding with UniFormat, breaks a facility into systems and assemblies that perform a predominating function, such as substructure, shell, interiors, and services, without defining the technical solutions to provide these functions. This allows the facility to be priced at the elemental level, allowing design alternatives to be better evaluated, and allows facility performance to be established at the system level as the project design is being refined.

Uniformat is applicable in all phases of a building life cycle and suitable for applications including cost control and schematic phase preliminary project description. Some classification uses are listed below:

- Planning estimates
- Preliminary Project Descriptions
- Preliminary Construction Schedules
- Organizing drawings and BIM object libraries

- Design-Build Facilities Procurement

BIM authoring tools provide more opportunity to assign UniFormat coding than MasterFormat coding. Analyzing a project with UniFormat is also more closely aligned with the design decision making process.

Uniformat seems like the most logical way of organizing construction plans because that way it is easier for the construction team to put the design.

2.3.3.2. Flexibility and customization (tables)

UniFormat consist of nine major categories of construction information separated by their special function. Figure 4. shows the major categories.

The Uniformat is a method that organizes the building design in a way that links the systems of the project. For example, Masterformat would organize the foundations into one group, and Uniformat would group the concrete reinforcement together into one group. When looking at the construction documents that Design put together it was more oriented towards the Uniformat. We would first specify the system (Bridge, Foundation, Dam, etc.), then go into detail regarding these systems. In a way when using this type of organization, you are also using the Masterformat as well. The reason why is that after you specify the system you still have to talk about the materials that will being used. That way the construction crew builds the project as needed. I do not believe that the food build construction documents could be built in any other type of way. Using Masterformat would not work because the materials that are being used are up to the construction team.

INTRODUCTION

A	SUBSTRUCTURE	E	EQUIPMENT AND FURNISHINGS
B	SHELL	F	SPECIAL CONSTRUCTION AND DEMOLITION
C	INTERIORS	G	BUILDING SITEWORK
D	SERVICES	Z	GENERAL

Figure 7. UniFormat categories

UniFormat consist of nine major categories of construction information separated by their special function. Figure 4. shows the major categories.

Uniformat divisions:

- Level 1 categories are divided into classes of information by separating the categories into the discrete concepts
- Level 2 classes carry the letter of their parent category, plus a two-digit number
- Level 3 and 4 are developed by further subdividing Level 2 classes. These subclasses carry the alphanumeric designation of their parent category and class, plus a two-digit number per level. With the two- digit Level 4 numbers being set off by a decimal point as hown in the example below.

A	SUBSTRUCTURE	Level 1
A10	Foundations	Level 2
A1010	Standard Foundations	Level 3
A1010.10	Wall Foundations	Level 4
A1010.10.CF	Continuous Footings	Level 5

Figure 8. Unifromat structure

2.3.4. Master format

MasterFormat is a standard for organizing specifications and other written information for commercial and institutional projects in the U.S. and Canda. It is product of the Construction Specifications Institute (CSI) and Construction Specifications Canada (CSC).

Today, the CSI MasterFormat is used in a wide range of industry construction, such as hospitals, schools, industrial and commercial green buildings. Hospitals and other healthcare facilities are complex. The security, back-up power, HVAC, medical gas and other systems are more complicated that the traditional institutional building. With so much on the line, it's critical that the building will perform properly for both healthcare workers and patients. For healthcare facilities, the CSI Master Format has a series of sections specifically dedicated to the HVAC in healthcare facilities. For green building, there are environmental performance requirements that cover topics, such as indoor air quality and sustainable design the integration of BIM with MasterFormat has allowed professionals to achieve greater efficiency especially in healthcare commercial building construction projects.

2.3.4.1. Purpose and application scope

The purpose of this format is to assist the user to organize information into distinct groups when creating contract documents and to help the user searching for specific information.

When it comes to the advantages of MasterFormat, first and foremost, it is all about improved communication and interaction between different project teams. For example, MasterFormat – primarily is used for communication between the design and construction teams.

Not only does it allow all members of the team to organize specific sections of construction documentation using the universal coding system, but it also facilitates communication and coordination between project owners, contractors, architects, and suppliers. The entire purpose is to save time on the organization of documents.

Moreover, today, many industries including the construction industry is widely using "Building Information Modeling (BIM)," which can use MasterFormat to improve data interoperability and improve adoption of BIM. The MasterFormat is thus a sophisticated system, which you can use for the organization of different project documents including:

MasterFormat is a standard filing system used for written project information, it likewise provides a list of titles and numbers for the construction requirements as well as other associated activities of industrial and commercial building projects.

For example, if it is an elementary school in New York or a hospital in Los Angles. The interesting thing is that MasterFormat helps almost all disciplines involved in designing, constructing and operations of buildings.

MasterFormat also helps architects and contractors who work on renovations to easily collect the data they may require in the future. It is also very important for professionals who want to use building information modeling. MasterFormat is continuously adopted by more and more modeling software systems.

Lastly, the integration of BIM with MasterFormat has allowed professionals to achieve greater efficiency especially in healthcare commercial building construction projects.

Advantages:

- Manufacturers will often publish specifications for their products based on MasterFormat
- MasterFormat provides the overall organizational structure that makes pulling sections from different sources possible
- Design team may pull specifications from multiple sources based on MasterFormat
- Improved communication between project group (design and construction teams)

MasterFormat classification can be used in different types of project documents, such as:

- Design specifications
- Project manuals
- Drawings
- Facility management and maintenance
- Cost data applications
- Building information modeling

2.3.4.2. Flexibility and customization (tables)

This classification system has a hierarchical structure that is divided into groups and subgroups. It is organized in an enumerative manner.

Today, there are over 40 divisions in the MasterFormat – including electrical, safety, and integrated building systems that help in the organization of construction information. For instance, Division 23

focuses on HVAC systems and requirements as well as Division 28 and 33 covers electronic safety and utilities respectively.

Each MasterFormat number and title defines a “section” arranged in “levels”. The main collections of related construction products and activities are level one titles or “divisions. Each division is made up of level two, level three, and often level four numbers and titles gradually specifies more detailed area (CSI and CSC, 2004).

MasterFormat has fifty division, some of them are shown in Figure 8 below.

- Division 00 - Procurement and Contracting Requirements
- Division 01 - General Requirements
- Division 02 - Existing Conditions
- Division 03 - Concrete
- Division 04 - Masonry
- Division 05 - Metals
- Division 06 - Wood, Plastics, Composites
- Division 07 - Thermal and Moisture Protection
- Division 08 - Openings
- Division 09 - Finishes
- Division 10 - Specialties
- Division 11 - Equipment
- Division 12 - Furnishings
- Division 13 - Special Construction
- Division 14 - Conveying Equipment
- Division 21 - Fire Suppression
- Division 22 - Plumbing

Figure 9. Example of MasterFormat divisions

Groups are not numbered, but are divided into Subgroups. Subgroups are not numbered, but are divided into numbered Divisions [4].

Divisions are the top Level (Level 1) in the hierarchy of the classification system. The Divisions include sets of numbered Titles (Levels 2-4). In a project manual application, the titles are called Sections that specify "work results"(Levels 2-4) [4].

Work results are permanent or temporary aspects of construction projects achieved in the production stage or by subsequent alteration, maintenance, or demolition processes, through the application of a particular skill or trade to construction resources [4].

2.3.5. CESSM4 – "Civil Engineering Standard Method of Measurement"

The Civil Engineering Standard Method of Measurement, fourth edition was published in 2012. It is sponsored by the Institution of Civil Engineers and the Civil and the Civil Engineering Contractors Association. The main purpose of this classification system is to explain in greater detail the various measurement rules and the principal objectives for a Bill of quantities. References to the British Standards have been removed, making the method more applicable to a global audience.

2.3.5.1. Purpose and application scope

CESSM4 is used for works of civil engineering when a client provides the design that has been completed by the client's designer and it is an important part of construction tenders.

CESMM4 sets out a procedure for the preparation of a Bill of Quantities for civil engineering works, for contracts based on traditional 'measure & value' principles. The Bill of quantities enables tenders to be prepared efficiently and can be used to value work completed once the contract has been let.

Work Classification is the core of CESMM4 where work commonly encountered in civil engineering contracts. The Work Classification determines the unit of measurement that shall apply to each item.

The object of CESMM4 is to set up the procedure according to which the Bill of Quantities shall be prepared, priced and the quantities of work listed.

CESMM4 is contract neutral and National standard neutral. It can be used in any form of contract that includes quantities or approximate quantities such as NEC, FIDIC (Fédération Internationale des Ingénieurs-Conseils) and ICC (Infrastructure Conditions of Contract). This may include:

- lump sum contracts with variable quantities where any decrease or decrease may occur
- contracts where the final quantities are determined after work has been done
- target contracts where target price is compared with the actual cost in order to determine eventual profit or loss

CESMM4 defines:

- how work is to be divided into separate items in the Bill of Quantities

- the information to be given in item descriptions
- the units in which the quantities against each item are to be expressed
- how the work is to be measured for the purpose of calculating quantities

CESMM4 does not cover items such as mechanical or electrical engineering work, or complex building work. It provides a simple building works class which cannot be used in complex building projects.

For instance, when it comes to a 50 million euros railway station refurbishment in a large city center, comprising complex roof replacement, giant atrium, refurbished platforms, CESMM$ would not be the right choice to deal with the building work of such a project.

2.3.5.2. Application of the work classification

The work classification divides work commonly encountered in civil engineering contract into 26 main classes, shown in Figure 6. Each class comprises up to three division which classify work. Each division comprises a list of up eight descriptive features of work.

Class A:	General items, 14
Class B:	Ground investigation, 18
Class C:	Geotechnical and other specialist processes, 26
Class D:	Demolition and site clearance, 30
Class E:	Earthworks, 32
Class F:	In situ concrete, 38
Class G:	Concrete ancillaries, 42
Class H:	Precast concrete, 46
Class I:	Pipework – pipes, 48
Class J:	Pipework – fittings and valves, 50
Class K:	Pipework – manholes and pipework ancillaries, 52
Class L:	Pipework – supports and protection, ancillaries to laying and excavation, 56
Class M:	Structural metalwork, 60
Class N:	Miscellaneous metalwork, 62
Class O:	Timber, 64
Class P:	Piles, 66
Class Q:	Piling ancillaries, 70
Class R:	Roads and pavings, 74
Class S:	Rail track, 78
Class T:	Tunnels, 84
Class U:	Brickwork, blockwork and masonry, 90
Class V:	Painting, 94
Class W:	Waterproofing, 96
Class X:	Miscellaneous work, 98
Class Y:	Sewer and water main renovation and ancillary works, 100
Class Z:	Simple building works incidental to civil engineering works, 104

Figure 10. CESMM4 classes

Based on contractor experience and scope of work (mostly infrastructure projects such as metro lines, dams, railways, high ways, tunnels, ...) below are listed the most used categories:

- Class E – earth works

Earthwork depths are measured from the Commencing Surface, which shall be stated in item descriptions where this is not the Original Surface (Rule A4), but Rule A4 also provides that the Excavated Surface shall be identified in item descriptions where this is not the Final Surface.

The bill compiler needs to be aware of any circumstances in the contract where excavation is expressly required to be carried out in stages, as an item for each stage shall be given according to Measurement Rule M5. The phrase expressly required could refer to a clause in the specification, to a requirement on a drawing or to a specific preamble where a particular sequence of work is required.

Where excavation begins below the Original Surface, the Commencing Surface shall be stated:

-This could be an Excavated Surface or

-The Final Surface.

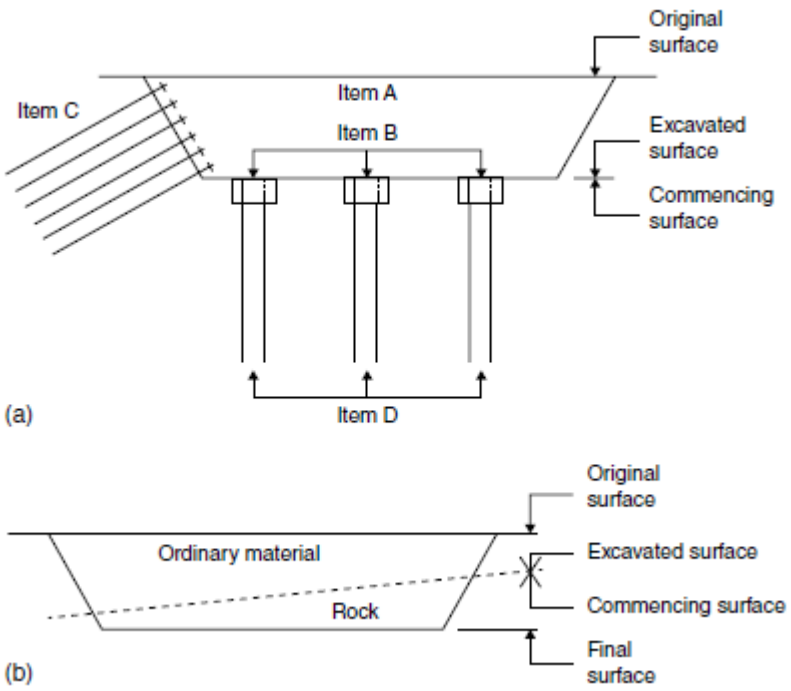


Figure 11. CESMM surfaces – 2. (a) Surfaces relating to items of work and (b) surfaces relating to ground conditions

Quite frequently, in practice, there will be an interface between different classifications of excavation. There may, for instance, be a general excavation, or a cutting for a road, where there is also a structure, such as a bridge, gantry foundation or retaining wall which has a foundation to be excavated. The bill compiler needs to make a decision on how to measure the work so that tenderers may be clearly informed as to what to price (Williams, 2016).

- Class F – in situ concrete

Concrete features are described in the Third Division by thickness, except that columns, beams and steel casings are described by cross-sectional area. In each case, there is no requirement to state the precise thickness or cross-sectional area.

Thicknesses of concrete in Class F are given in ranges and are not precise thicknesses. Therefore, similar work in the same location would be aggregated into one item provided the thickness of the various items is in the chosen range of thicknesses. The same principle applies to concrete components whose thickness varies but nonetheless remain within the dimension range (e.g. a tapering wall).

- Class H – precast concrete

Precast concrete is chiefly concerned with the supply and fixing of large concrete units manufactured off-site, such as bridge beams, bridge deck slabs, subways, culverts, etc. Precast concrete units are defined as cast other than in their final position (Rule D2), but where concrete items are precast on-site, Definition Rule D3 determines that they shall be measured as in situ concrete where:

-The reason for precasting is not to obtain multiple uses of formwork.

-The nature of the work is characteristic of in situ concrete albeit the cast unit has to be moved

into its final position.

- Class I – pipework- pipes

The three divisions of Class I provide for the provision, laying and jointing of pipes, including those described as not in trenches, and for excavation and backfilling of pipe trenches.

The whole point of the CESMM approach is to alert tenderers to risk, so that appropriate allowances can be made in the tender.

Different types of pipework, in different locations, will affect access requirements, working methods, choice of plant, temporary works and output of the drainage gang. The bill complier must exercise considerable judgement in deciding how to comply with Rule A1, as the method of measurement provides no guidance.

- Class M – Structural metalwork

Class M is the repository of fabricated structural steelwork where fabrication is measured separately from erection. Both are measured in tonnes, and both are categorised as members for bridges, members for frames and other members.

- Class P – Piles

Bored or driven piles are reinforced and filled with in situ concrete, and preformed piles areprecast off-site. Groups of bored/driven piles (i.e. the same type/materials, diameter/cross section and location) are required by Measurement Rule M2 to be billed as follows:

- An item for the number of piles.

-An item for the concreted length.

- An item for the total depth bored or driven.

- Class R – Roads and pavings

Class R includes roads, runways and other paved areas as well as kerbs, light duty pavements, traffic signs and road markings.

- Class S – rail track

Rail track work is highly industrialised and mechanised, and there is a variety of track laying methods available, depending upon the length of track required, its access, location and complexity in terms of diamond crossings and turnouts, etc.

Rail track work involves both new track laying and work to existing track. For new rail track work, materials are often provided by the employer, delivered to site, hence the separation of supplying from laying for new track work in Class S.

- Class T – tunnels

Class T: Tunnels excludes pipe laying by pipe jacking, thrust boring and the like which is measured under Classes I–L. 'Cut and cover' tunnels are measured under Class E, Class F and other appropriate classes of the method of measurement. The level of risk in tunnelling operations is recognised in CESMM4, and a considerable burden of financial risk is retained by the employer: Both temporary and permanent support shall be measured (Rule M1); this is quite different to other classes where the contractor is deemed to include earthwork support.

Supports and stabilisation also includes a measured item for forward probing, whereas the risk of determining prevailing ground conditions lies with the contractor in other classes

Work in compressed air shall be so described as an additional description to relevant items (Rule A1 refers).

Ground freezing, jet grouting, chemical grouting, cement grouting and other soil stabilisation methods are not measured in Class T, or elsewhere, but may be provided for via a provisional sum for defined work in Class A (Williams, 2016).

2.3.5.3. Coding and numbering of items

It can be used to:

- crate unique reference codes for all measured items
- code measured items where there is no appropriate feature in the Work Classification
- code measured items where there is no applicable division in the Work Classification
- provide a unique code for measured items with additional descriptive features that would otherwise be indistinguishable from similar items
- identify individual items in the bill of quantities, if desired

Coding system in the CESMM4 is alphanumeric with a reference letter identifying the class of work to which the item belongs. An example of how to the coding system works is given in Figure 12.

Code H 1 3 6 identifies an item as

class	H	precast concrete
first division	1	beams
second division	3	length 7–10 m
third division	6	mass 5–10 t

Figure 12. CESMM4 coding system

The letter corresponds to the class in the Work Classification in which the item occurs and the digits give the position of the item in the first, second and third divisions of the class.

Code numbers may be used to number the items in the Bill of Quantities, the items within the Bill of Quantities being listed in order of ascending code number

2.3.6. POMI (Principles of Measurement – International)

Most standard methods of methods of measurement are sector specific, focusing on either building or civil engineering work. POMI is prepared by BCIS (Building Cost Information Service) a subsidiary of RICS (Royal Institution of Chartered Surveyors).

2.3.6.1. Purpose and application scope

POMI can be used for all sorts of building and engineering work, including demolitions, piling, dredging, railway work, …

The item description requirements of POMI are simple that a non-library-based software package could be used to create a bill of quantities.[3]

Figure 10. shows types of project where POMI has been commonly used according to RICS 2011 Principles of Measurement (International) Survey Report.

Project category	Nr	%	
Buildings	322	76.3	
Building maintenance	3	0.7	
Infrastructure	43	10.2	
Mining	1	0.2	
Mixed	49	11.6	
Petro-chem/Oil+Gas	3	0.7	
Unspecified	1	0.2	
Totals	442	100	

Figure 13: Projects where POMI has been used

Objects of POMI are listed as follows:

- To assist in the accurate preparation of tenders, by providing for measurement of quantities

Disadvantages of POMI:

- Should be more comprehensive to avoid double meaning

- Doesn't provide required information in detail
- Insufficient accuracy and specification of measurement

2.3.6.2. Flexibility and customization (tables)

POMI consist of 20 pages of measurement rules, comprising Section GP: General Principles, Section A: General requirements and 15 measured Work Sections. The measured Work Sections are subdivided into:

Section	Title
B	Site Works
C	Concrete Work
D	Masonry
E	Metalwork
F	Woodwork
G	Thermal and Moisture Protection
H	Doors and Windows
J	Finishes
K	Accessories
L	Equipment
M	Furnishings
N	Special Construction
P	Conveying Systems
Q	Mechanical Engineering Installations
R	Electrical Engineering Installations

Figure 14. POMI classes

Description of items – general rules are as follow below:

- Items which are required to be enumerated. or for which an item is required, shall be fully described.
- Items which are to be measured by length or depth shall state the cross-sectional size and shape, girth or ranges of girths or such other information as may be appropriate; for items of pipework it shall be stated whether the diameter is internal or external.
- Items which are to be measured bv area shall state the thickness or such other information as may be appropriate
- Items which are to be measured by weight shall state the material thickness and unit weight if appropriate (for example, ductwork).

2.3.7. Other classifications systems

There are other classification systems that are not the main subject of this dissertation. Below you can find a list of those classification systems:

- New Rules of Measurement 1 and 2 - is part of the suite documents that make up the RICS New Rules of Measurement
- CoClass – is a Swedish classification system for the built environment
- CCS – is a Danish classification system for the bult environment
- TALO 2000 – is a Finnish classification system
- NS 3451/TFM – id a Norwegian classification system

3. INFORMATION EXCHANGE BETWEEN DIFFERENT CLASSIFICATION SYSTEM

Information exchange is one of the main challenges in construction projects nowadays. Different project stages have different purposes and requirements, through the project lifecycle many problems occur due to lack of communication. The main problem occurs when the wrong information is received what cause waste of time and has an impact on the cost accordingly.

In this chapter is described how to improve information exchange workflow. the main goal is to make bridge between different project participants. One of the solutions is to use proper classification system, but which one is the right one? The best answer to this question is to create relations between classification system. Classification system can be described as a language for the construction industry and to achieve consistent information exchange we must somehow translate classification system A into classification system B.

For example, a designer create model and use classification system A for the purpose of design and a general contractor receive the model from designer but the contractor needs classification B for the purpose of cost estimation. Reclassifying model consumes a lot of time which is crucial in a project management and causes delays. Solution would be to have common data base and to establish relations between different classification systems which allow contractor to translate easily classification system A into classification system B.

3.1. General principles

Interoperability between different classifcation systems is based on data bases. Following the specific protocol or workflow between databases and softwares for 4D BIM is possible to increase automation in terms of data excnahge. Each participant in the project use different classification system based on their needs.

To connect one classification system to another the first step should be to setup a data(base) model. The big step in connectin data bases is to create relations between classification systems. It should be taken into account that not all classification systems use the same number of levels to structure data internally. Keeping this in mind, while creating relations between classifications main focus should be on what are the user needs. Based on the need and requirements the connection shall be established.

Figure 15. shows simple CROW diagram (schema) whereby the connections are established. Classification system A has direct links to classification system B. It can be seen when linking OmniClass table 21. with UniFormat classification.

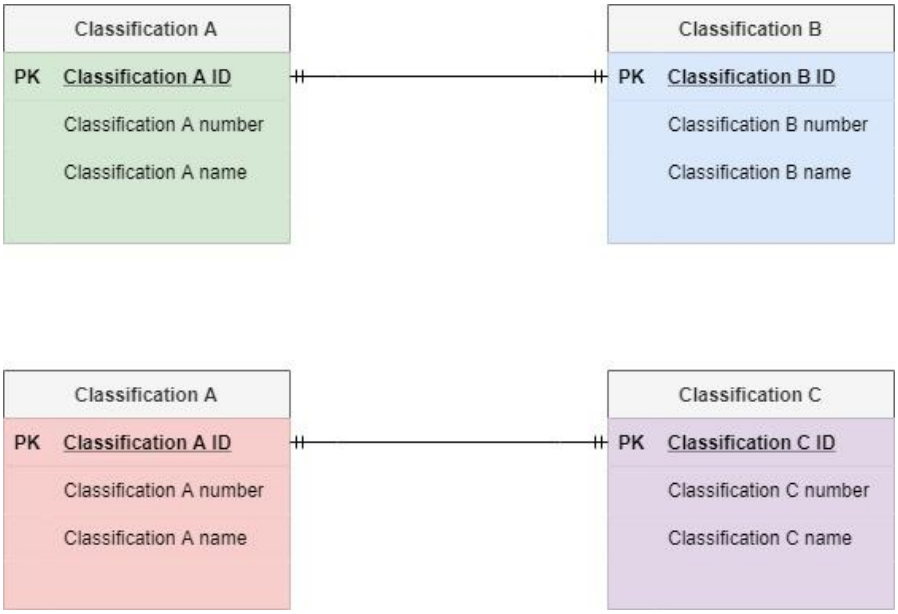


Figure 15. Relations between classifications

Next step in achieving successful data exchane is to create unio table which connects together all classification systems under unique ID, as shown in Figure 16. For example, ID wall would comprise all the codes from different classification systems.

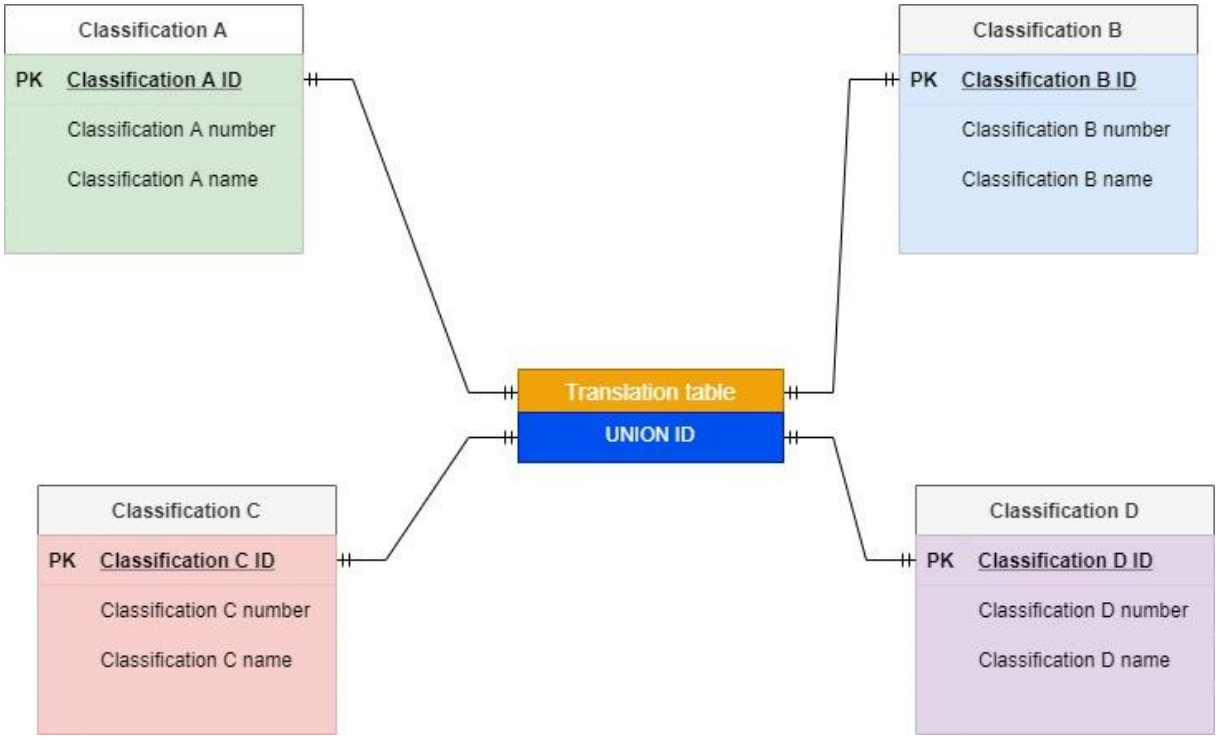


Figure 16. Union table

In some cases there is no direct relation. The relation should be customized depening on many factors such as project stage, type of project, company's internal rules, etc. In that case is recommended to not create relations in great detail using subdivisions. It is good to keep it simple and use just first levels of classifications to find relation. Later on, this relation may be customized depending on the project requirements.

Figure 17. shows union table with connected classification systems. This example is for the purposes of thesis. If a company participate on a different types of projects, it is necessary to create their own relations and populate data based on a specific project needs.

ID	Uniclass	OmniClass	MasterFormat	UniFormat	CESMM4	POMI
Floors	EF_30_20	21-03 20 30 30	09 63 43	C2030.30	Z 4 1 1	J3.1 1
Walls	EF_25_10	21-02 20 10 20	04 21 13.23	B2010	U 1 2 1	D2.1
Windows	EF_25_30	21-02 20 20 20	08 50 00	B2020	Z 3 1 1	H2.1
E. Doors	EF_25_30	21-03 10 30 10	08 10 00	B2050	Z 3 1 3	H1.1
I.Windows	EF_25_30	21-03 10 30 10	08 50 00	C1020	Z 3 1 1	H2.1
I. Doors	EF_25_30	21-03 10 30 10	08 10 00	C1030	Z 3 1 3	H1.1

Figure 17. Exmple of database with custom relations

Element ID	UniClass	OmniClass	MasterFormat	UniFormat	CESSM4	POMI	ID
379250	EF_25_30	21-02 20 20 20	08 50 00	B2020	Z 3 1 1	H2.1	Windows
380236	EF_25_30	21-02 20 20 20	08 50 00	B2020	Z 3 1 1	H2.1	Windows
380324	EF_25_30	21-02 20 20 20	08 50 00	B2020	Z 3 1 1	H2.1	Windows
381616	EF_25_30	21-02 20 20 20	08 50 00	B2020	Z 3 1 1	H2.1	Windows
382147	EF_25_30	21-02 20 20 20	08 50 00	B2020	Z 3 1 1	H2.1	Windows
382264	EF_25_30	21-02 20 20 20	08 50 00	B2020	Z 3 1 1	H2.1	Windows
382296	EF_25_30	21-02 20 20 20	08 50 00	B2020	Z 3 1 1	H2.1	Windows
385127	EF_25_30	21-02 20 20 20	08 50 00	B2020	Z 3 1 1	H2.1	Windows
385128	EF_25_30	21-02 20 20 20	08 50 00	B2020	Z 3 1 1	H2.1	Windows
385129	EF_25_30	21-02 20 20 20	08 50 00	B2020	Z 3 1 1	H2.1	Windows
385130	EF_25_30	21-02 20 20 20	08 50 00	B2020	Z 3 1 1	H2.1	Windows
385131	EF_25_30	21-02 20 20 20	08 50 00	B2020	Z 3 1 1	H2.1	Windows
385132	EF_25_30	21-02 20 20 20	08 50 00	B2020	Z 3 1 1	H2.1	Windows

Figure 18. Example of assigned multiple classifications to the elements

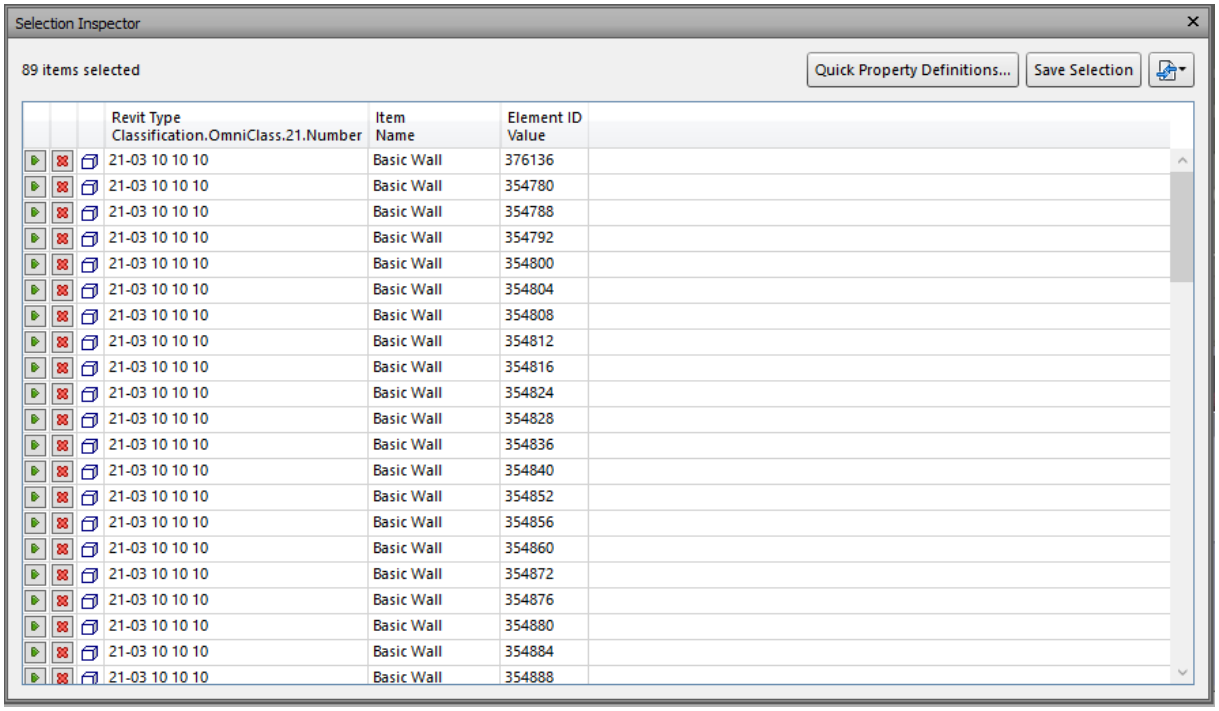
3.2 Interoperability – using multiple classifications in BIM models

This chapter describe procedure data exchange between database and coordination software. For the purposes of thesis, Navisworks has been used. Data manipulation is the important factor in BIM interoperability. A designer sends BIM model to the general contractor for the purpose of 4D modelling and cost estimation. Often happens, the model is not fully populated with necessary data and information. The designer used Classification system that can't be used for the 4D modelling and creating WBS accordingly. To avoid creating WBS from the scratch following procedure may be used to facilitate WBS developing and cost estimation.

Process of customizing data may be as following workflow described in the next figures:

Elements without assigned proper classification are extracted from the model and exported to Excel which is shown in the figures 19. and 20. For example, for preliminary cost estimation an estimator uses Uniformat instead of UniClass and the designer used UniClass in the model. Therefore, the estimator

would export data to Excel and add Uniformat classification or more classifications which is shown in the figure 21.



Revit Type Classification.OmniClass.21.Number	Item Name	Element ID Value
21-03 10 10 10	Basic Wall	376136
21-03 10 10 10	Basic Wall	354780
21-03 10 10 10	Basic Wall	354788
21-03 10 10 10	Basic Wall	354792
21-03 10 10 10	Basic Wall	354800
21-03 10 10 10	Basic Wall	354804
21-03 10 10 10	Basic Wall	354808
21-03 10 10 10	Basic Wall	354812
21-03 10 10 10	Basic Wall	354816
21-03 10 10 10	Basic Wall	354824
21-03 10 10 10	Basic Wall	354828
21-03 10 10 10	Basic Wall	354836
21-03 10 10 10	Basic Wall	354840
21-03 10 10 10	Basic Wall	354852
21-03 10 10 10	Basic Wall	354856
21-03 10 10 10	Basic Wall	354860
21-03 10 10 10	Basic Wall	354872
21-03 10 10 10	Basic Wall	354876
21-03 10 10 10	Basic Wall	354880
21-03 10 10 10	Basic Wall	354884
21-03 10 10 10	Basic Wall	354888

Figure 19. Preparing elemnts for exporting to excel

1	Classification.OmniClass.Table21	Item	Element ID
2	21-03 10 10 10	Basic Wall	376136
3	21-03 10 10 10	Basic Wall	354780
4	21-03 10 10 10	Basic Wall	354788
5	21-03 10 10 10	Basic Wall	354792
6	21-03 10 10 10	Basic Wall	354800
7	21-03 10 10 10	Basic Wall	354804
8	21-03 10 10 10	Basic Wall	354808
9	21-03 10 10 10	Basic Wall	354812
10	21-03 10 10 10	Basic Wall	354816
11	21-03 10 10 10	Basic Wall	354824
12	21-03 10 10 10	Basic Wall	354828
13	21-03 10 10 10	Basic Wall	354836
14	21-03 10 10 10	Basic Wall	354840
15	21-03 10 10 10	Basic Wall	354852
16	21-03 10 10 10	Basic Wall	354856
17	21-03 10 10 10	Basic Wall	354860
18	21-03 10 10 10	Basic Wall	354872
19	21-03 10 10 10	Basic Wall	354876
20	21-03 10 10 10	Basic Wall	354880
21	21-03 10 10 10	Basic Wall	354884
22	21-03 10 10 10	Basic Wall	354888
23	21-03 10 10 10	Basic Wall	354892

Figure 20. Excel data exported from Navisworks

Figure 21. shows spreadsheet linked with data base. Drop-down menu pop-up and user can select proper classsification based on elements.

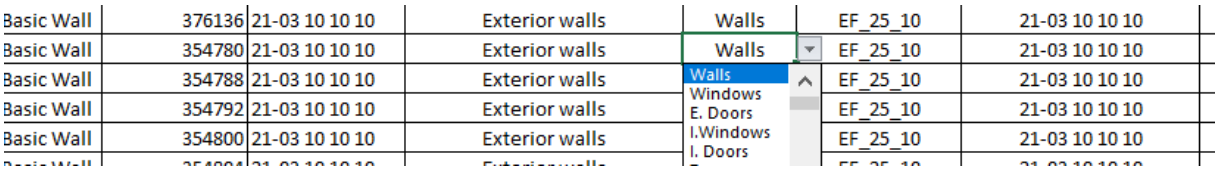
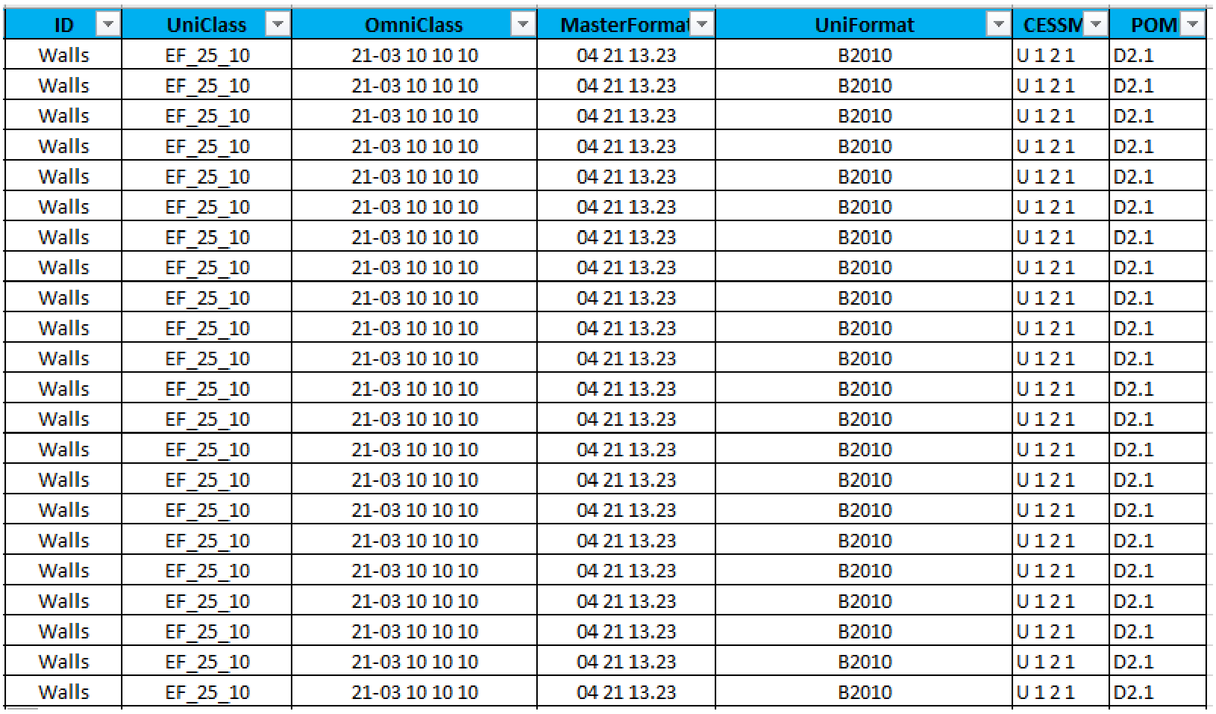


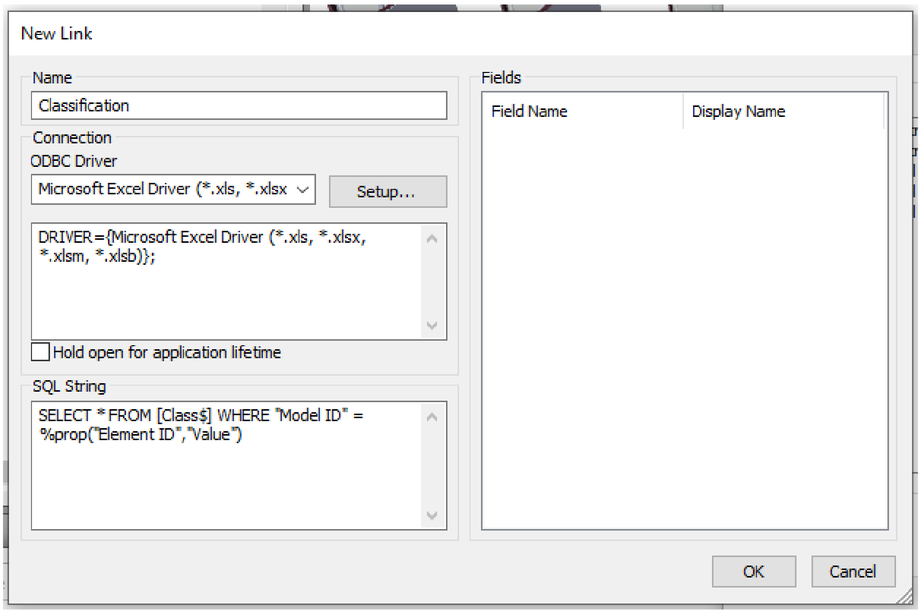
Figure 21. Assigning multiple classifications



ID	UniClass	OmniClass	MasterFormat	UniFormat	CESSM	POM
Walls	EF_25_10	21-03 10 10 10	04 21 13.23	B2010	U 1 2 1	D2.1
Walls	EF_25_10	21-03 10 10 10	04 21 13.23	B2010	U 1 2 1	D2.1
Walls	EF_25_10	21-03 10 10 10	04 21 13.23	B2010	U 1 2 1	D2.1
Walls	EF_25_10	21-03 10 10 10	04 21 13.23	B2010	U 1 2 1	D2.1
Walls	EF_25_10	21-03 10 10 10	04 21 13.23	B2010	U 1 2 1	D2.1
Walls	EF_25_10	21-03 10 10 10	04 21 13.23	B2010	U 1 2 1	D2.1
Walls	EF_25_10	21-03 10 10 10	04 21 13.23	B2010	U 1 2 1	D2.1
Walls	EF_25_10	21-03 10 10 10	04 21 13.23	B2010	U 1 2 1	D2.1
Walls	EF_25_10	21-03 10 10 10	04 21 13.23	B2010	U 1 2 1	D2.1
Walls	EF_25_10	21-03 10 10 10	04 21 13.23	B2010	U 1 2 1	D2.1
Walls	EF_25_10	21-03 10 10 10	04 21 13.23	B2010	U 1 2 1	D2.1
Walls	EF_25_10	21-03 10 10 10	04 21 13.23	B2010	U 1 2 1	D2.1
Walls	EF_25_10	21-03 10 10 10	04 21 13.23	B2010	U 1 2 1	D2.1
Walls	EF_25_10	21-03 10 10 10	04 21 13.23	B2010	U 1 2 1	D2.1
Walls	EF_25_10	21-03 10 10 10	04 21 13.23	B2010	U 1 2 1	D2.1
Walls	EF_25_10	21-03 10 10 10	04 21 13.23	B2010	U 1 2 1	D2.1
Walls	EF_25_10	21-03 10 10 10	04 21 13.23	B2010	U 1 2 1	D2.1
Walls	EF_25_10	21-03 10 10 10	04 21 13.23	B2010	U 1 2 1	D2.1
Walls	EF_25_10	21-03 10 10 10	04 21 13.23	B2010	U 1 2 1	D2.1
Walls	EF_25_10	21-03 10 10 10	04 21 13.23	B2010	U 1 2 1	D2.1
Walls	EF_25_10	21-03 10 10 10	04 21 13.23	B2010	U 1 2 1	D2.1
Walls	EF_25_10	21-03 10 10 10	04 21 13.23	B2010	U 1 2 1	D2.1

Figure 22. Succesfully assgined multiple clasifications

Once the data is set out, further step is to retreat data back to Navisworks. Figure 23. shows how to link back data from Excel.



Name: Classification

Connection

ODBC Driver: Microsoft Excel Driver (*.xls, *.xlsx

```
DRIVER={Microsoft Excel Driver (*.xls, *.xlsx,
*.xlsm, *.xlsb)};
```

☐ Hold open for application lifetime

SQL String

```
SELECT * FROM [Class$] WHERE "Model ID" =
%prop("Element ID","Value")
```

Figure 23. Naviswork interface to link excel data

Figure 24. shows a new property tab which comprise data about assigned classifications which can be used now in creating schedules, cost estimation, etc.

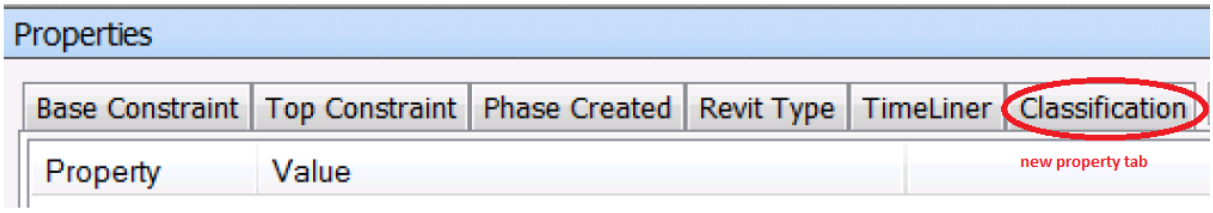
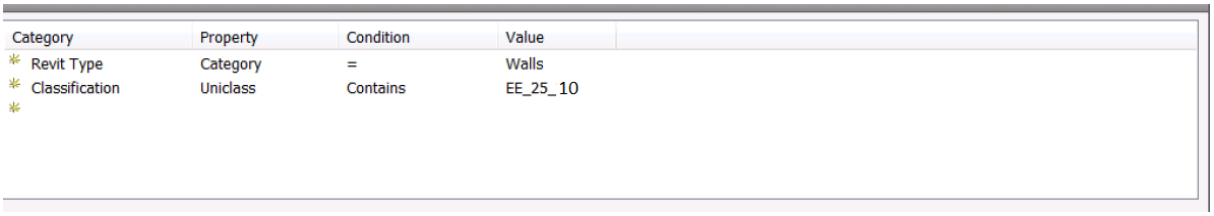


Figure 24. Shows new property tab



Category	Property	Condition	Value
Revit Type	Category	=	Walls
Classification	Uniclass	Contains	EE_25_10

Figure 25. Clasification data

Figure 25. shows example of using newly assigned classification.

4. BENCHMARKING CLASSIFICATION SYSTEMS

Classification systems are diverse grouping systems of elements, work results, products, etc. One element can be classified by different points of view. If we look at the element Wall, in preliminary design and estimations, it is not defined many parameters such as type of element, material etc. At construction stage, the same wall must have included all the details and parameters in order to be built. Following previous example, it can be concluded that not all classification systems are suitable to any project stage or project type.

4.1. Comparison of classifications systems

Table 3. show comparison between different classification systems based on benchmarking criteria such as purpose, project stages, grouping principles, application scope, flexibility and customization.

It can be seen that classification systems cannot be observed as a one group with different classification names. Each classification system was developed for the different purposes such as material specification, element classes, work results. Furthermore, it can be seen relation between some classification systems. As shown in the table 1., MasterFormat may be called extension of UniFormat and both of the classification systems are included in OmniClass as a table 21 and table 22. OmniClass is aligned with ISO 12006-2020 as well as UniClass. Thus, a connection between these classifications system can be established. Comparing the CESMM$ and POMI with the above mention classification systems, there is no direct link between them. The link may be established just as a guide and support to change more efficiently one classification system into another.

Table 3. Benchmarking table

Benchmarking criteria	**UniClass**	**OmniClass**	**Uniformat**	**Master format**	**CESMM4**	**POMI**
Purpose	organizing library materials and structuring product literature and project information	Organization , sorting and retrieval of product information for all objects in the built environment in the project life cycle.	For arranging constructio n information , organized around the physical parts of a facility	A master list for organizing construction work results, requirements , products and activities..	the preparation of a Bill of Quantities for civil engineering works, for contracts based on traditional 'measure - value' principles	a uniform basis for measuring bills of quantities for works of construction
Project stages	All aspects of design and constructio n process	throughout a facility's life cycle	schematic design phase, preliminary project description s	Preconstructi n stage	Tendering, preconstruction	Tendering pre - construction
Grouping pirnciple	faceted	faceted	hierachical	hierarchical	hierarchical	hierarchical
Tables/groups	12	15	1	1	1	1

Application scope	Various types of projects	provides a classification structure for electronic databases and software, enriching the information used in those resources	elements for a range of building types and constructio n related to buildings	it enables the entire project team to store, retrieve, assess, and share essential information in a common filing system	it explains in greater detail the various measurement rules and the principal objectives for a Bill of Quantities, infrastructur projects	Mostly used in building projects
Flexibility and customization	allows information about a project to be defined from the broadest view to the most detailed	covers all forms of construction, vertical and horizontal, industrial, commercial and residential.	It can be extended with Master format, linked with the OmniClass table 21	linked with the OmniClas table 22	Contract neutral	It doesnt cover building elements in such great detail
Stakeholder/ sponsors	Constructio n Project information and NBS	CSI and CSC	CSI and CSC	CSI and CSC	The Institution of Civil Engineers	RICS Business Services Limited

4.2. Mapping between classification systems

Mapping between classification systems is inevitably messy. One might except most objects within a class to have a 1:1 mapping, but many will not. Many variations may occur due to different structure and concept. Some tables have different depths of detail (e.g., one table stops at “clay bricks” and another one 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. “loadbearing bricks”). These classification differences are compounded by terminological difficulties ((International Construction Information Society, 2017)

An example is shown in figure 26. And 27. Those tables illustrate an object type per class that is common to the various classification tables.

Element	Omniclass number		Uniclass number
	table 21	table 22	table EF
Floor: NW_Finishing_Floor_01	21-03 20 30 30	22-09 63 43	EF_30_20
	Specialty Flooring	Composition Stone Flooring	Floors
Basic Wall: NW_Ext_Brick_001	21-02 20 10 20	22-04 21 13	EF_25_10
	Exterior Wall Construction	Brick Masonry	Walls
WD_2F_BA_001: 240X150	21-02 20 20 10	22-08 52 13	EF_25_30
	Exterior Operating Windows	Metal-Clad Wood Windows	Doors and windows
DO_1F_BA_005: 210X90	21-03 10 30 10	22-08 14 16	EF_25_30
	Interior Swinging Doors	Flush Wood Doors	Doors and windows

Figure 26. Part 1. Mapping between classification systems

Uniformat	Masterfroamt	CESMM4	POMI
C2030.30	09 63 43	Z 4 1 1	J3.1 1
Specialty Flooring	Composition Stone Flooring	Floors, cast in-situ	Floor finishing
B2010.20	04 21 13.23	U 1 2 1	D2.1
Exterior Wall Construction	Surface-Bonded Brick Masonry	Vertical walls thckness 200 mm	Walls
B2020.20	08 52 13	Z 3 1 1	H2.1
Exterior Operating Windows	Metal-Clad Wood Windows	Timber windows	Windows
C1030.10	08 14 16	Z 3 1 3	H1.1
Interior Swinging Doors	Flush Wood Doors	Timber doors	Doors

Figure 27. Part 2. Mapping between classification systems

Uniclass table EF class object in a general way such as floors, walls, etc. Table SS describe at greater level of deatil while MasterFormat defines material of elements. Experts in the various tables might be able to refine this illustrative mapping further.

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5. SOFTWARE SUPPORT

Nowadays, a software plays a significant role in the construction industry. A Classification system are becoming updated and adapted to be compatible with the software. Using classification system codes helps computer to better understand tasks user wants to run. In this thesis the focus is on Autodesk Revit, a BIM software for 3D modelling. As mention in chapter 3., Microsoft Excel is a powerful tool to create databases and is compatible with many software regarding exporting/importing data. In this chapter Excel would not be described because it is not a BIM modelling tool.

5.1. Autodesk Revit

Autodesk Revit comprise tools to incorporate classification systems while modelling. This is a great a benefit which allow modeller to anticipate classification system that would be used at next project stage and input data. That lead to reduced mistakes, time saving and cost saving accordingly.

Object in Revit have predefined parameters to insert classification code. Assembly code parameter is directly connected with UniFormat classification. OmniClass parameters is set out in the objects properties as well, as can be seen in figure 28.

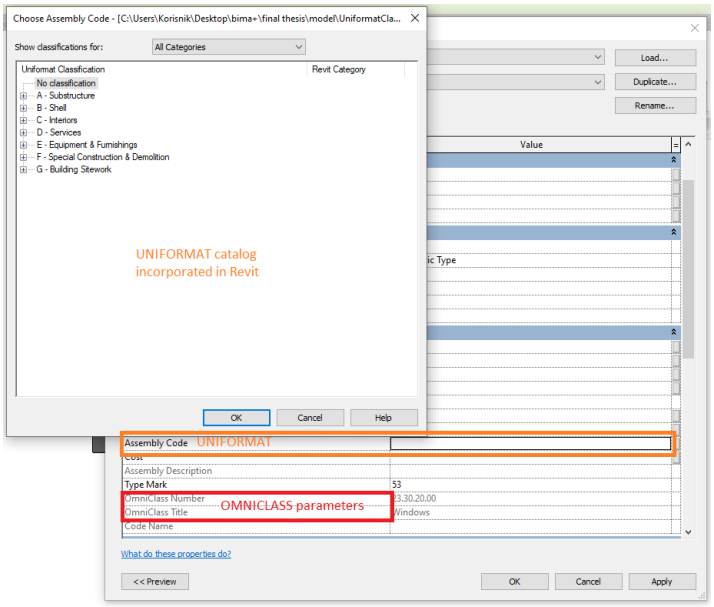


Figure 28. Revit classification parameteres

There is also plug-in for Revit called BIM interoperability tools with incorporated classification systems, listed below:

- UniFormat
- MasterFormat
- UniClass
- OmniClass

This tool alows importing other classification systems as well. Figure 29. Shows user interface of the plug-in. It can be seen that public library comprises previuosly mentiond classification systems.

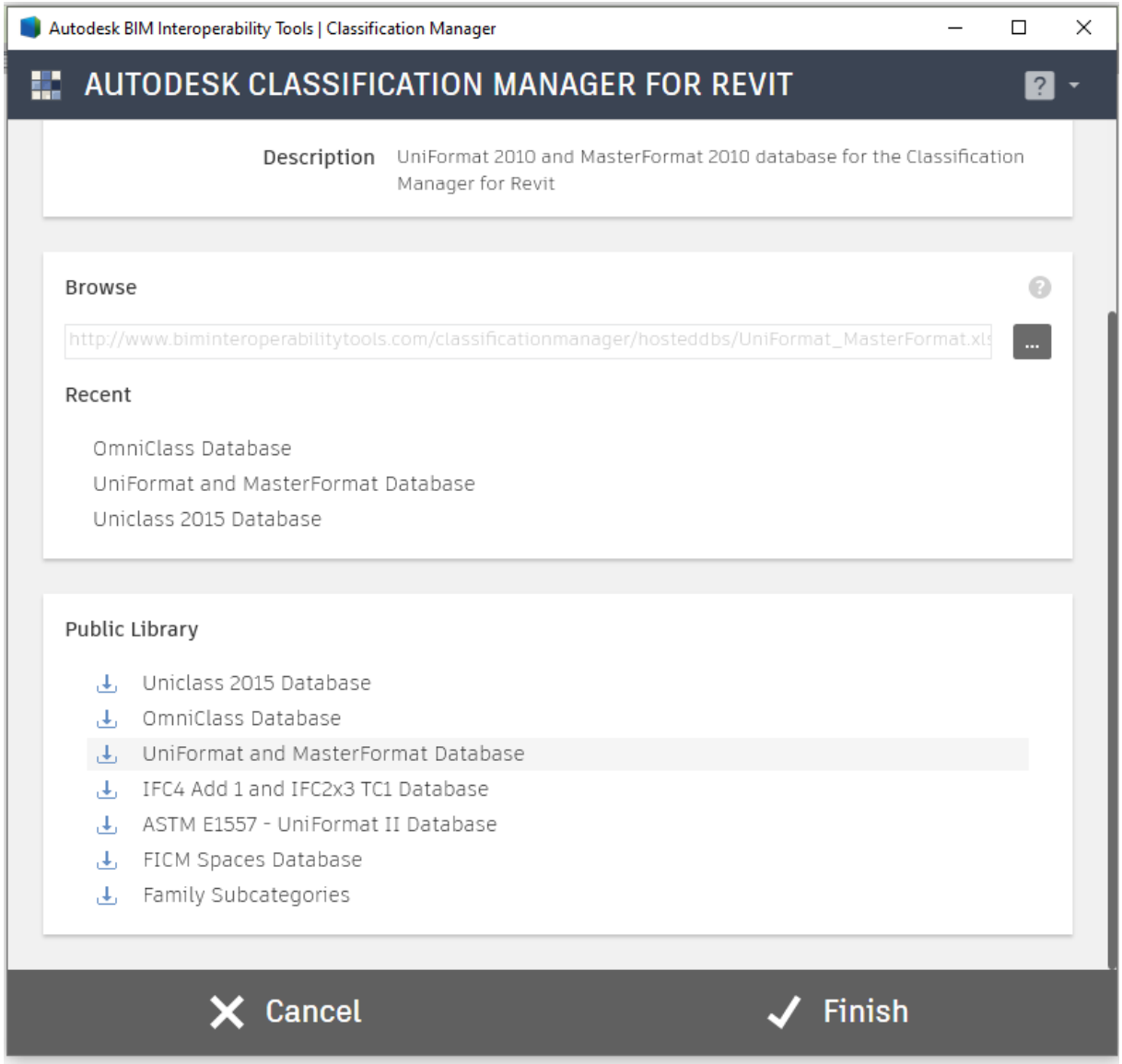


Figure 29. BIM interoperability tool for Revit – user interfacc

As shown in figure 30. the interoperability tools automatically create parameters in the object properties and allow user to automatically assign classification code and description.

Data	
Classification.OmniClass.21.Number	21-02 20 20 10
Classification.OmniClass.22.Number	22-08 52 13
Classification.OmniClass.21.Description	Exterior Fixed Windows
Classification.OmniClass.23.Number	23-17 13 15 23
Classification.OmniClass.22.Description	Metal-Clad Wood Windows
Classification.OmniClass.23.Description	Wood Casement Windows
Classification.Uniclass.Ss.Number	Ss_25_30_95_26
Classification.Uniclass.EF.Number	EF_25_30
Classification.Uniclass.Ss.Description	External window systems
Classification.Uniclass.EF.Description	Doors and windows
Classification.Uniclass.Pr.Number	
Classification.Uniclass.Pr.Description	
Classification.MasterFormat.Description	Metal-Clad Wood Windows
Classification.UniFormat.2010.Description	Exterior Fixed Windows
Classification.MasterFormat.Number	08 52 13
Classification.UniFormat.2010.Number	B2020.20

Figure 30. Automatic creation of classification data by interoperability tool

5.2. Architectural Revit model classification

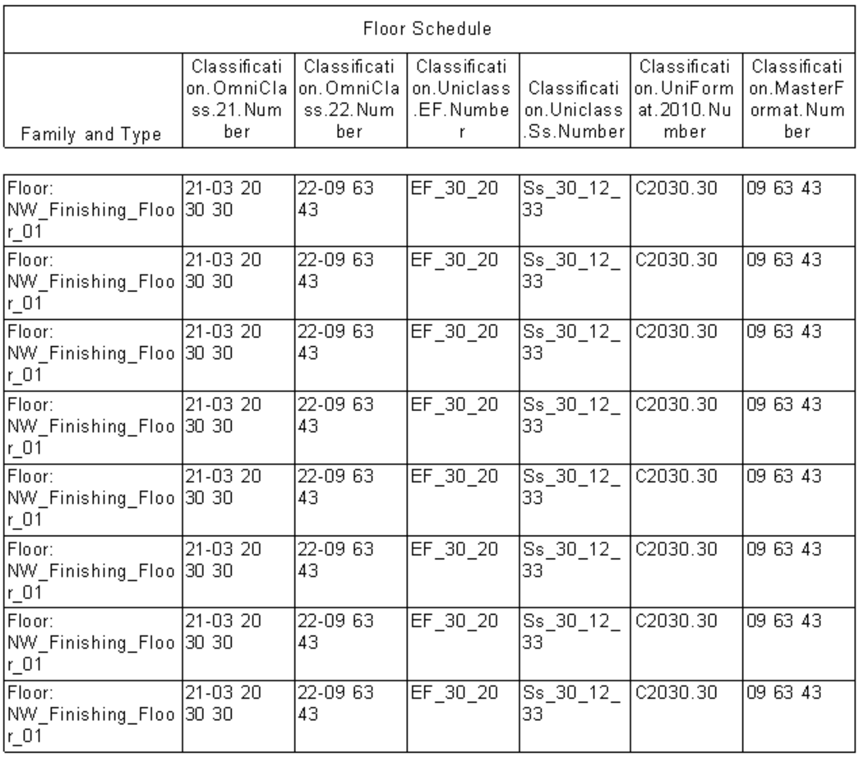
Figure 31. show architectural model I have created during the course semester in Portugal. For the purpose of the thesis multiple classification has been applied to show example of classification in Revit and generating schedule.

Figure 31. Architectural Revit model

Figure 32., 33., 34. Shows multiple classifcations of the architectural model automatically generated in schedule which can be used for further purposes depening on the project discipline nad staage.

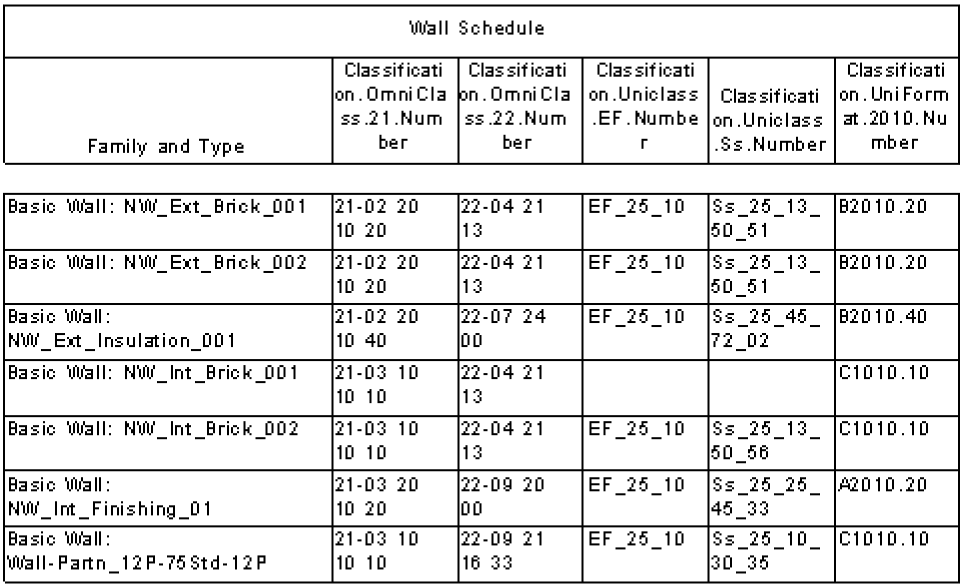
Multi-Category Schedule						
Family and Type	Classification.MasterFormat.Number	Classification.OmniClass.21.Number	Classification.OmniClass.22.Number	Classification.Uniclass.EF.Number	Classification.Uniclass.Ss.Number	Classification.UniFormat.2010.Number
DO_1F_BA_005: 210X90	08 10 00	21-03 10 30 10	22-08 14 16	EF_25_30	Ss_25_30_20_30	C1030.10
DO_1F_BA_005: DO_85x210	08 10 00	21-03 10 30 10	22-08 14 16	EF_25_30	Ss_25_30_20_30	C1030.10
DO_1F_BA_005: DO_210X60	08 10 00	21-03 10 30 10	22-08 14 16	EF_25_30	Ss_25_30_20_30	C1030.10
DO_1F_BA_005: DO_210X80	08 10 00	21-03 10 30 10	22-08 14 16	EF_25_30	Ss_25_30_20_30	C1030.10
Sliding door: DO_SL_80x210	08 16 73	21-03 10 30 25	22-08 16 73	EF_25_30	Ss_25_30_20_77	C1030.25
Sliding door: DO_SL_80x210 2	08 16 73	21-03 10 30 25	22-08 16 73	EF_25_30	Ss_25_30_20_77	C1030.25
Sliding door: DO_SL_90x210	08 16 73	21-03 10 30 25	22-08 16 73	EF_25_30	Ss_25_30_20_77	C1030.25
WD_1F_BA_001: 210x90	08 52 13	21-02 20 20 20	22-08 52 13	EF_25_30	Ss_25_30_20_30	B2020.20
WD_2F_BA_001: 240X150	08 52 13	21-02 20 20 10	22-08 52 13	EF_25_30	Ss_25_30_95_26	B2020.20
WD_2F_BA_001: 240X275	08 50 00	21-02 20 20 10	22-08 52 13	EF_25_30	Ss_25_30_95_26	B2020.20
WD_2F_BA_001: WD_90x90	08 52 13	21-02 20 20 10	22-08 52 13	EF_25_30	Ss_25_30_95_26	B2020.20
WD_2F_BA_001: WD_140x140	08 50 00	21-02 20 20 10	22-08 52 13	EF_25_30	Ss_25_30_95_26	B2020.20

Figure 32. Architectural model classifcation of doors and windows.



Floor Schedule						
Family and Type	Classification.OmniClass.21.Number	Classification.OmniClass.22.Number	Classification.Uniclass.EF.Number	Classification.Uniclass.Ss.Number	Classification.UniFormat.2010.Number	Classification.MasterFormat.Number
Floor: NW_Finishing_Floor_01	21-03 20 30 30	22-09 63 43	EF_30_20	Ss_30_12_33	C2030.30	09 63 43
Floor: NW_Finishing_Floor_01	21-03 20 30 30	22-09 63 43	EF_30_20	Ss_30_12_33	C2030.30	09 63 43
Floor: NW_Finishing_Floor_01	21-03 20 30 30	22-09 63 43	EF_30_20	Ss_30_12_33	C2030.30	09 63 43
Floor: NW_Finishing_Floor_01	21-03 20 30 30	22-09 63 43	EF_30_20	Ss_30_12_33	C2030.30	09 63 43
Floor: NW_Finishing_Floor_01	21-03 20 30 30	22-09 63 43	EF_30_20	Ss_30_12_33	C2030.30	09 63 43
Floor: NW_Finishing_Floor_01	21-03 20 30 30	22-09 63 43	EF_30_20	Ss_30_12_33	C2030.30	09 63 43
Floor: NW_Finishing_Floor_01	21-03 20 30 30	22-09 63 43	EF_30_20	Ss_30_12_33	C2030.30	09 63 43
Floor: NW_Finishing_Floor_01	21-03 20 30 30	22-09 63 43	EF_30_20	Ss_30_12_33	C2030.30	09 63 43

Figure 33. Classification of floors



Wall Schedule					
Family and Type	Classification.OmniClass.21.Number	Classification.OmniClass.22.Number	Classification.Uniclass.EF.Number	Classification.Uniclass.Ss.Number	Classification.UniFormat.2010.Number
Basic Wall: NW_Ext_Brick_001	21-02 20 10 20	22-04 21 13	EF_25_10	Ss_25_13_50_51	B2010.20
Basic Wall: NW_Ext_Brick_002	21-02 20 10 20	22-04 21 13	EF_25_10	Ss_25_13_50_51	B2010.20
Basic Wall: NW_Ext_Insulation_001	21-02 20 10 40	22-07 24 00	EF_25_10	Ss_25_45_72_02	B2010.40
Basic Wall: NW_Int_Brick_001	21-03 10 10 10	22-04 21 13			C1010.10
Basic Wall: NW_Int_Brick_002	21-03 10 10 10	22-04 21 13	EF_25_10	Ss_25_13_50_56	C1010.10
Basic Wall: NW_Int_Finishing_01	21-03 20 10 20	22-09 20 00	EF_25_10	Ss_25_25_45_33	A2010.20
Basic Wall: Wall-Partn_12P-75Std-12P	21-03 10 10 10	22-09 21 16 33	EF_25_10	Ss_25_10_30_35	C1010.10

Figure 34. Classification of walls

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6. CONCLUSION

In summary, this paper has analysed possibilities of advanced BIM interoperability. Need for a data exchange is getting on radar. It can be said that classification system is a “language” in construction industry. With growing BIM concept in the AEC industry, there is need for more frequent using of classification systems because of the codes which allow implementation in a various type of software. In the thesis six classification systems have been analysed. The main focus was to explore possibilities of translation between different classification systems. Comparing different classification systems, it can be concluded that in some cases is not possible to create unique relation between them due to their different structure, purposes and properties but systems can be customized and adjusted to increase efficiency in creating WBS and cost estimations. Example of these cases are linking directly CESMM4 to other classification systems. On the other side there are direct link between UniClass, MasterFromat and OmniClass. OmniClass tables 21. and 22. have incorporated UniFormat and MasterFormat classification. Despite the limitations, the main goal of this document is achieved in terms of developing workflow which can be of great benefit to various the project stakeholders, especially a general contractor. An improvement has been achieved by creating relations between classification systems and their usage in software applications to show proposed workflow. This document can be used as a guidance to develop custom relations depending on the project requirements. Once database is created, it can be populated and customized with more project data that can be used in further projects. In addition, it takes a lot of effort to create a big database that comprise information and classifications from previous project in order to reach full automation which is possible by consistently populating database with a new data. Therefore, Autodesk Revit and its plug-in have shown capacities to handle with multiple classifications. For the purpose of classification architectural model has been used with different types of elements. There are some limitations in order to achieve “equal” classification. Some classification system is more focused on detail specifications while other classify objects in general way. However, it is possible to assign multiple classifications in Revit and create high quality BIM model for further purpose at next project stages. This type of classification (multiple classification) shall be defined in advance and in a collaboration with other project participants. So, the Revit modeller can assign multiple classification based on predefined project requirement at every stage of project. For instance, the modeller has basic information on how object would be built (using first level of classifications). This approach would be of great benefit for a cost estimator or construction company because they don’t start from the scratch. Overall, classification systems play an important role in fast growing digitalization in AEC industry. Project participants, especially general contractors should focus on developing unique classification system which would replace all the existing classifications in order to achieve efficient workflows and full automation level. Building smart organization is working on that solution.

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http://rockwelleng.com/blog/downloads/cesmm/CESMM4.pdf (Accessed: 6 June 2020)

https://www.rics.org/globalassets/rics-website/media/products/data-products/bcis-construction/principles-of-measurement-pomi-english.pdf (Accesed: 25 June 2020)

LIST OF ACRONYMS AND ABBREVIATIONS

BIM	Building Information Modelling
4D	Phase planning
AEC	The architecture, engineering and construction…
WBS	Work breakdown structure
CESSM	Civil Engineering Standard Method of Measurement
POMI	Principles of Measurement (International)