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STRUCTURING BIM-RELATED CONSTRUCTION DATA THROUGH A STANDARDS-BASED CLASSIFICATION SYSTEM

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Abstract

Various software platforms do have their own unique ID system to enable information sharing. *OpenBIM* has been developed to fill the gap to share the data in between various platforms, but it has its own limitations. To enable unified, platform-neutral, human- and machine-readable information sharing in between any IT-system, modern classification-based data structuring method is developed. The current paper aims to give an overview of the recently developed international classification system and about the issues the teams have tackled with.

Introduction

In *building information management* (BIM) the key attention has been emphasized to the word ‘information’. Most common construction classification systems have been developed well-before the BIM-based workflows. Information can be seen as structured data that generates a value for a stakeholder throughout the construction lifecycle. Therefore, the structuring of data has become a key topic in the digitalization of the construction sector. Mainly due to the need to keep the data flow uninterrupted, increase the efficiency in data exchange, reducing the rework need and enabling an efficient data reuse. Data interoperability can be seen in two domains: (a) geometrical and (b) alphanumerical information. The information split in between those domains should be defined through a level of information need (EN 17412-1, 2020). It is expected that geometrical and alphanumerical information relates to each other in the same data structure (OpenBIM data, BIM data, BIM model). However, in some cases this connection can be at least partly departed to enable to attach/connect information at later steps. Several unique ID systems have been developed which can be for internal use only (like software original formats) or introducing some universal ID like global unique ID (Niknam & Karshenas, 2017) for information sharing. The downside of such universal IDs is that those are not machine- or human readable. To overcome this limitation, construction classification systems can be used for generation of that unique ID. For example, for top level information comparison, *UniFormat / MasterFormat* with stated limitations by the authors have been defined to understand the resource use in building construction (Guven et al., 2022). The importance of construction classification is growing. Construction projects are international and when generating data, more automated processes are to be introduced to assure more reliable decision making, keeping in mind the whole lifecycle of construction entities.

Construction classification systems can be seen as an additional layer to structure the construction-related information in building information models. Various, well-known classification systems are used to present some part of the construction lifecycle. This has enabled the isolated use of various classification systems at the same time to overcome the limitations of one specific classification system. Therefore, it is quite common that in many countries multiple classification systems are in use which normally do not talk with each other (have been developed based on different reference designation systems). This enables possible data-drops and continuous rework-need to ensure the structured data flow in between construction stages and/or to ensure the data flow connectivity to various IT-systems. As those, various, in-use classification systems have been developed following different principles, the data needs to be reclassified several times during the construction lifecycle. Because of that it is hard to keep the data connected in between construction stages and keep the connection or origin of the data in the context of building information model. Keeping the data connected becomes more important if we need to go back and make some changes to our original design data (in form of an update) and reestablish the link in between various IT-systems. To overcome the limitation by using multiple classification systems, a unified classification system should be developed that enables the most valuable use-cases for the construction lifecycle. The construction lifecycle can be easily visualized through EN ISO 12006-2 (2020) standard (Figure 1).

European standard EN ISO 12006-2 divides the construction result on any given built space to various classes which do have three main groups: (a) construction result; (b) construction process and (c) construction resource. There are some classification systems that take ISO 12006-2 structure in use but in a limited manner, mainly focusing onto the top part (Figure 1, green boxes). Examples of such classification systems are *Danish CCS* and *Swedish CoClass*. Recently, *Construction Classification International* (CCI) has been made available by the non-profit organization of *Construction Classification International Collaboration* (CCIC, https://cci-collaboration.org/). CCI shares the similarities with *CCS* and *CoClass*, as all those classification systems do use EN/ISO/IEC 81346 standard series as the basis to define the main classification groups.

In the following section we look how CCI has been defined and extended (CCI-EE) to help to define the structured, BIM-related, information in a platform-neutral manner.

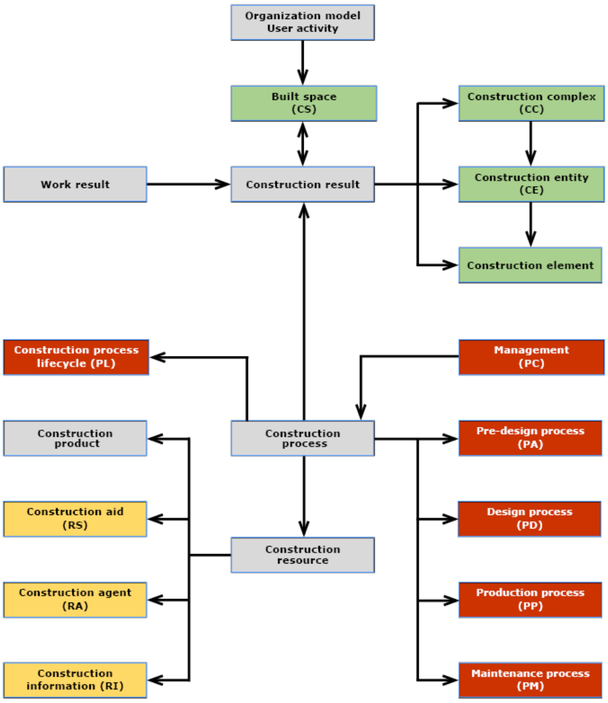

Figure 1: Classes for a built environment as defined in EN ISO 12006-2

Methodology

Methodology is divided into four key parts: (1) the description of CCI that defines the core part for the current development (Figure 1, green boxes); (2) the description of CCI-EE that has been also previously defined for Estonian market and includes classification codes for all other EN ISO 12006-2 classes (Figure 1, yellow and red boxes); (3) the development of standard-based types/subtypes for CCI / CCI-EE classification tables and (4) the proposed unique reference designation system that combines previous parts together to be used for the structuring of BIM-related information in platform-neutral format.

CCI as a core classification system

CCI has been defined by CCIC. Currently it covers 4 tables from the main structure of EN ISO 12006 (Figure 2, green boxes) from which the *Construction element* is substituted into three sub-classes according to EN IEC / ISO 81346 standard series: *Functional system*, *Technical system* and *Construction component*. EN IEC / ISO 81346 standards are referred as base standards from where the classification groups have been taken over. Other "green boxes" (*Built space*, *Construction complex*, *Construction entity*) are also filled in according to the same standard series. Table 1 lists the CCI core tables and referenced standards. CCI core tables enable to classify a construction component's (ex. a window) main function, its belonging into a technical (ex. wall) and functional (ex. wall system) system as well as to assign it to a specific construction entity (ex. laboratory building) in the construction complex (ex. education complex). CCI core tables are meant to be used for any type of construction domain (buildings, bridges, roads etc.). As CCI tables are standards-based, those can be used on its own for a more general classification in where, for example, projects across different countries (or in between various clients) needs to be compared, summarized.

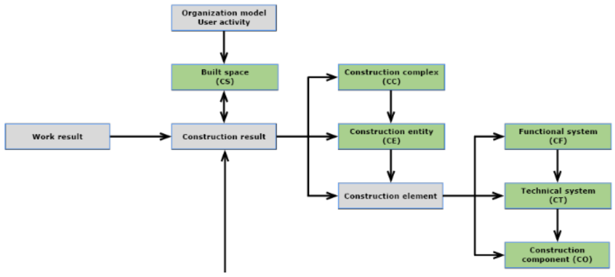

Figure 2: Classification tables covered by CCI

Therefore, it enables a basic data structuring without a unique ID capability for general purpose workflows (for filtering data based on a specific function of the component but without pointing to one specific component instance on itself). This is not the limitation of the CCI core tables, on the contrary, those give freedom to build on top of it to extend the use-cases of a classified construction data.

Table 1: CCI core tables and connected standards

CCI core table	Standard
Built space	EN IEC 81346-2
Construction complex	ISO 81346-10
Construction entity	ISO 81346-10
Functional system	ISO 81346-12:2018
Technical system	ISO 81346-12:2018
Construction component	EN IEC 81346-2:2020

To enable the more specific referencing and move towards platform-neutral unique ID concept, CCI core classification codes are extended with appropriate types and subtypes which are partly based on the examples given in the EN IEC / ISO 81346 standard series but divided according to a reference standard in this work. Before we describe the methodology used to define types and/or subtypes, it is obvious that CCI core tables are not describing the whole construction lifecycle. Therefore, the next section will focus onto the definition of other EN ISO 12006-2 classes that are needed to describe the whole construction lifecycle.

CCI-EE as an extension to the CCI core

CCI-EE has been developed for Estonian market as the open-source extension to CCI with the following key purposes: (a) to enable the classification of the whole lifecycle of the construction; (b) to have a unified classification framework in where current but isolated local standards are merged into EN ISO 12006-2 classification framework and (c) to set the basic rules for *reference designation system* (RDS) for machine- and human readable construction data (CCI-EE, 2021). CCI-EE RDS part enables to start using a unique ID concept through a classification framework, but it has some limitations. In later sections those limitations are to be removed through the introduction of types/subtypes. Most of the CCI-EE additional parts (Figure 1, yellow/red boxes) are also standards-based to enable *across the borders use* or at least to consider the starting point for additional developments (Table 2). Although some references are Estonian local standards (marked with the acronym EVS, Table 2), those are available in CCI-EE tables also in English (https://ehituskeskus.ee/cci/cci-ja-excel-tabelid/). Having additional tables, as defined by *Construction resource* and *Construction process*, we are now enabling lifecycle-based information management. Some of those tables are generated based on currently used, isolated standards (ex. *Maintenance process*). It is important to note that usually it is not possible just to copy one standard that refers to some specific use-case into a lifecycle-based classification framework.

Table 2: CCI-EE additional tables and connected standards or source

CCI-EE table	Standard / source
Construction process lifecycle	ISO 15686-10
Management	Occupational qualification standards
Pre-design process	EVS 932 Construction design documents
Design process	EVS 932 Construction design documents
Production process	EVS 885 Classification of construction costs + Technical specifications of road works
Maintenance process	EVS 807 Management and maintenance of facilities
Construction aid	Proposed by CCI-EE workgroup
Construction agent	Proposed by CCI-EE workgroup
Construction information	EN/ISO standards, IFC 4.3, ETIM 8.0

Doing that it may enable it to use separately but more importantly it is not connected to other parts of the classification framework. For example, if in a copied standard there are separate terms/divisions for asset names that do not align with CCI core tables or those are at different detail levels, it causes confusion. Instead, double naming should be removed, and the copied standard should be shaped according to other tables which then enables the connected use of a modern classification framework.

There is one table that largely differs from the others, *Construction information*. Instead of having a single classification code to be used with a particular asset, it lists common properties which can be used to generate data templates for a given asset at some asset's lifecycle stage. Listed properties (currently over 8000) are generated from common EN / ISO standards, IFC (*Industry Foundation Classes)* property sets, ETIM feature codes and those are matched together as much as possible. All properties do have a reference code (similarly to other tables) that can be used for information sharing in a platform-neutral way. Figure 3 draws an example property which relates to *thermal conductivity*. Firstly, properties are divided into key property groups from where the first letter of reference code (two letters, three numbers) is generated. Second letter is for ordering only. Numbering value (three numbers) is then ranging from 001-999 with a possibility to add properties in between if additional use-cases should be needed. As some properties are directly related to EN / ISO standards, not all of them are carried over into CCI-EE sub-table. Properties that tend to have more value, in terms of information sharing from the planning stage till asset management, are added. Properties that are required by default in some kind of standard compliance process (to produce according to a standard) are not included, instead, this compliance is normally added to the information exchange through a property that simply refers to that standard(s).

Level 1	Level 2	Level 3	Term (EN)	Definition (EN)	Reference	Unit/Format	IFC property name	ETIM Feature ID
A?			Administrative properties	terms (properties) regarding administrative characteristics (incl address, classification system/code, naming, data transfer related properties etc.)	CCI-EE			
B?			Acoustic properties	terms (properties) regarding sound-generating or sound-affecting ability	CCI-EE			
C?			Chemical (incl biological) properties	terms (properties) regarding chemical or biological content/relation	CCI-EE			
D?			Electrical and signal tehcnology related properties	terms (properties) related to electrical or signal technology	CCI-EE			
E?			Energy and thermal capacity related properties (incl	terms (properties) regarding capacity or purpose of managing energy, thermal capacity, temperature	CCI-EE			
	ET		Properties that start with letter	terms (property names) are based on a given	CCI-EE			
		ET430	Thermal conductivity	thermal property that indicates the ability of a material to conduct heat (K-value)	EN ISO 10077-1	W/m K	ThermalConductivity	EF020017
		ET435	Thermal conductivity (EN	thermal conductivity (EN 12664)	EN 12664:2001	W/(m.K)		EF013881
		ET440	Thermal conductivity (90/90)	thermal conductivity (90/90)	EN 1745:2020	W/(m.K)		EF010338
		ET445	Thermal conductivity (lambda 10, dry, stone)	thermal conductivity (lambda 10, dry, stone)	EN 1745:2020	W/(m.K)		EF014659
		ET450	Thermal conductivity temperature derivative	thermal conductivity temperature derivative	IFC		ThermalConductivityTemperatureDerivative	
F?			Environmental properties	terms (properties) regarding environmental impact	CCI-EE			
G?			Fire related properties	terms (properties) regarding capacity or purpose of protection against fire	CCI-EE			
H?			Fluid/gas related properties	terms (properties) regarding capacity or purpose of handling fluids/gases	CCI-EE			
J?			Light related properties	terms (properties) regarding capacity or purpose of handling light	CCI-EE			
K?			Mechanical properties	terms (properties) regarding capacity or purpose of handling mechanical forces	CCI-EE			
L?			Location and position related properties	terms (properties) related to location and position	CCI-EE			
M?			Length, size and weight related properties	terms (properties) related to length, size or weight	CCI-EE			
P?			Product and production related properties	terms (properties) related to a product and production, including product composition, its type/shape or its surface	CCI-EE			
Q?			Quality related properties	terms (properties) related to quality (incl data/measurement errors)	CCI-EE			
S?			Health and safety related	terms (propetries) concerning health and safety	CCI-EE			
T?			Time related properties	terms (properties) related to time	CCI-EE			
V?			Documentation and presentation related properties	terms (properties) related to documentation and presentation	CCI-EE			
X?			Cost related properties	terms (properties) related to cost	CCI-EE			
Z?			Maintenance properties	terms (properties) related to maintenance	CCI-EE			

Figure 3: Example property and its connections

Although properties are common way to extend some universal classification code (through attached data templates), having a property for a type or subtype, leaves less opportunities to automate the inclusion of data templates. It also leaves less details to filter some base elements/components or assets in a digital database. For example, if we investigate CCI core table, *Construction component*, *Paving* is given with a single code, *NCA* with a definition of “*finishing object of a pavement*”. Without starting to define it through a property set (data template) we can introduce types/subtypes for that paving component that extend the classification table. As such we have a lot more valuable information already at our base data structure which enables to carry out more specific information exchange. Those types/subtypes can be also defined through standards that help to take those into use in across borders (but those can be also client/project-based). In the next section the extension through the introduction of types/subtypes is given.

Standard-based types/subtypes

Having predefined types/subtypes in classification tables is not a new thing. For example, *Uniclass* and *CoClass* kind of use the same philosophy. The key difference with the CCI-centric view is how those types/subtypes are divided in between classification codes. In general, it can be divided into two main groups: (a) division based on distinctive examples given in standards from where CCI / CCI-EE tables are generated and (b) based on the classification code definition, appropriate standards and/or guidelines are used to generate types/subtypes. For example, Figures 4-5 list examples for option (a) and (b) respectively from *Construction components* table.

AT850_TypeDesignation	Term (EN)	Definition (EN)	Examples (EN)	Source
R##$$	**Restricting object**	**object for restricting or stabilising**	**kind of object flowing and kind of constraint**	**CCI**
RQ#$$	**Local climate stabilising object**	**restricting object of the local environment**	**kind of effect and method applied**	**CCI**
RQA$$	Insulation	local climate stabilising object by restricting a thermal or sound transmission	brick lining, frost insulation layer, antifreeze insulation, sound attenuation, sound insulation, thermal insulation, frost protection, air	CCI
RQA10	Thermal insulation	insulation for thermal transmission	frost insulation layer, frost protection insulation, frost	CCI-EE/R
RQA20	Sound insulation	insulation for sound transmission		CCI-EE/R
RQA21	Air sound insulation	sound insulation through air		CCI-EE/R
RQA22	Step sound insulation	sound insulation through solid objects		CCI-EE/R

Figure 4: RQA10, RQA20 are types for a classification code of RQA (Insulation) which comes directly from CCI core examples (according to standards, Table 1)

Note that examples given in reference standards could be either a type or a subtype. In Figure 4, a type is given with the first number and its subtype with the second number. In some cases, one standard or standard series may give types/subtypes for various CCI core classification codes. For example, EN ISO 10318-2 can be used to define types/subtypes for CCI component classification codes *RQB Membrane* (*separation layer, filtration layer, drainage layer, barrier layer, protection layer, surface erosion control layer, stress relief for asphalt interlayer*) but also for *UMB Reinforcing mesh* (*reinforcement layer*). This is done because the key function for some membranes is different, and it should belong to another classification group. Having well-defined types/subtypes enables us to further differentiate components/elements in building information model and help to automate to assign a more specific data template with characteristic properties for that specific type/subtype. In this research a common ground for types/subtypes is searched which covers different construction domains (ex. buildings, bridges, roads). Those are filled in according to the need of real case-studies (see a discussion chapter). In general types/subtypes may cover just one client or be project specific. To be able to cover different domains, types/subtypes should be built up in a such a way that those are not too detailed, otherwise the 2-level numbering schema may become a limiting factor (the reason for selecting 2-level numbering is explained in the next section).

AT850_TypeDesignation	Term (EN)	Definition (EN)	Examples (EN)	Source
N##$$	**Covering object**	**object for enclosing partly or fully another object**	**kind of method**	**CCI**
NC#$$	**Finishing object**	**covering object by finishing structures**	**kind of object to**	**CCI**
NCA$$	Paving	finishing object of a pavement	pavement, street pavement, ground grating, wearing course, road pavement,	CCI
NCA20	Flexible permanent surface course			EN 13108 EVS 843 (p 116)
NCA21	Asphalt concrete	asphalt in which the aggregate particles are continuously graded or gap-graded to form an interlocking structure	AC (AC 8 surf; AC 12 surf; AC 16 surf; AC 20 surf; ...)	EN 13108-1 EVS 843 (p 116) EVS 901-3
NCA22	Asphalt concrete for very thin layers	asphalt for surface courses with a thickness of 20 mm to 30 mm, in which the aggregate particles are generally gap-graded to form a stone to stone contact and to provide an	BBTM (BBTM 4; BBTM 8; BBTM 10; ...)	EN 13108-2
NCA23	Soft asphalt	asphalt in which the aggregate particles are continuously graded or open-graded to form an interlocking structure with soft bitumen grades not harder than 250/330	SA (SA 4; SA 8; SA 16; ...)	EN 13108-3
NCA24	Hot rolled asphalt	dense, gap graded bituminous mixture in which the mortar of fine aggregate, filler and high viscosity binder are major contributors to the performance of the laid	HRA (HRA 30/14F; ...)	EN 13108-4
NCA25	Stone mastic asphalt	gap-graded asphalt mixture with bitumen as a binder, composed of a coarse crushed aggregate skeleton bound with a mastic	SMA (SMA 8; SMA 12; SMA 16; ...)	EN 13108-5 EVS 901-3
NCA26	Mastic asphalt	voidless asphalt mixtures with bitumen as a binder in which the volume of filler and binder fills the volume of the remaining	MA (MA 8; MA 12; ...)	EN 13108-6 EVS 901-3
NCA27	Porous asphalt	asphalt prepared so as to have a very high content of interconnected voids which allow passage of water and air	PA (PA 8; PA 12; PA 16; ...)	EN 13108-7 EVS 901-3
NCA28	Asphalt for ultra-thin layers	asphalt for surface courses with a thickness of 10 mm to 20 mm, in which the aggregate particles are generally gap-graded to form a stone to stone contact and to provide an	AUTL (AUTL 10; ...)	EN 13108-9

Figure 5: NCA20 as a type of paving with appropriate subtypes (NCA21-NCA28) which are directly defined through EN 13108 standard series

Having real case-studies from different domains helps to define a better structure for types/subtypes. It is also good to keep in mind that having a predefined type/subtype is not to meant to substitute the need of a property set. Therefore, types/subtypes should be not defined based on material-centric views (having a different type for different material-groups like wood, concrete, metal etc.) as such information can be assigned later through a data template. In some cases, material-centric view can be still used if the selection of a material is a key concern. For example, from the environment perspective, we may have types for a column (CCI component code: ULD) or beam (CCI component code: ULE) based on a material group or construction method (prefabricated, cast-in situ). In summary, types can be generated based on various needs and be applicable only for one project or for a specific domain. Also, in this article we are focusing onto component examples, same approach is applied to other CCI and CCI-EE tables to extend classification codes through the introduction of types/subtypes. In the next section, we look how CCI core, CCI-EE extension and its types/subtypes are used to build up a unique ID for any digital asset for platform-neutral information exchange.

Reference designation system to form a unique ID

Reference designation (RD) can be defined as *an identifier of a specific object formed with respect to the system of which the object is a constituent, based on one or more aspects of that system* (EN IEC 81346-1, 2022). *Reference designation system* is therefore a way how we build up a unique reference ID to some asset which enables to exchange information through that unique ID. Unique ID concept can be viewed in many, currently available, forms like *global unique identifier* (GUID), *global trade item number* (GTIN), bar code, personal identification number, WIN code or in form of some specific IT/software-platform ID value. All those examples are machine readable but typically not human readable and most importantly those miss the context into where the given object belongs to. In the construction industry the object's context plays an important role as this enables location-based analysis. CCI core tables give the context to the construction component. In addition, CCI-EE extends the context which relates to construction resource and/or construction process. This relationship is well discussed in EN ISO 12006-2 as described previously. To enable to generate a machine- and human readable code, some *reference designation system* (RDS) should be agreed/defined. Although the RDS can be viewed from different perspectives (being project-, country- or client based), having a common schema helps to build a unified ID system for various purposes. For example, to be able to say that a window (construction component) belongs to some wall (technical system) which builds up a wall system (functional system) in a specific building, we need some prefix signs to merge those codes together as in Figure 6.

DD.B.AD.QQA

<University building>.<Wall system>.<Wall construction>.<Window>

Figure 6: Simple example in where different classification codes (from CCI core tables) are separated by a punctuation

The previous example is purely derived from CCI core tables (Figure 1, green boxes) + using some applied RDS schema. To enable more specific division and a unified RDS structure, additional punctuations are needed (for example, to enable to easily differentiate the construction element part and location part). EN IEC 81346-1 gives us a selection of those distinctive prefix signs which are summarized in Table 3.

Table 3: Prefix signs to build up a common RDS

Prefix sign	Description
=	when relating to the function aspect of the object
-	when relating to the product aspect of the object
+	when relating to the location aspect of the object
%	when relating to the type aspect of the object

In addition to prefix signs and to enable to include type/subtype recognition, agreed numerical part is attached to all letter codes. ISO 81346-12 shows examples with just 1-level as well as 2-level numbering parts. It is recommended by EN IEC 81346-1 that both, letter- and numbering parts are kept as short as possible with up to 3 letters and 3 numbers. In CCI core tables / CCI-EE additional tables the letter codes are up to 3 letters. For that reason, for CCI-EE RDS, 2-level numbering code is applied (except for properties, in where 2-level letter code + 3-level numbering code is used). As shown in CCI-EE guidance (CCI-EE, 2021) this forms a RDS structure and the example given in Figure 6 becomes more specific which now accounts a type and/or ID value for all given table codes (Figure 7).

+DD01-B01.AD01.QQA01%QQA10

<University building>.<Wall system>.<Wall construction>.<Window>

Figure 7: Simple example in where prefix signs are introduced to break up the ID code based on location(+), product(-) and type(%) part

At the time of publishing CCI-EE RDS guidance, both the type and ID aspect were considered only within construction component. And all other codes (ex. technical system, functional system, construction entity) were using just 2-level numbering part to enable a type or ID based naming structure. As follow-up of this research, this approach is now extended which enable to define types/subtypes also for other classification tables and having an ID number for that specific type. Using a % prefix also in other parts makes the reading (either with machines or by humans) a way more complicating. Instead of that, the numbering part is extended or simply to say 2+2 numbering schema is used in where first 2 numbers refer to type and 2 following numbers to an ID value of that type (Eckerberg, 2019). An example given in Figure 7 becomes a basis to define asset's unique ID with the possibility to add additional table codes once required. Figure 8 enables to identify a specific component that relates from certain component type and relates to a specific type of a technical/functional system as well as into a building (Figure 8).

+DD1001-B2001.AD3001.QQA01%QQA10

<University building>.<Wall system>.<Wall construction>.<Window>

Figure 8: Simple example where type and ID numbering values are introduced along with each classification code

Selected RDS systems can vary from client to client or country to country. It can be broken down based on prefix signs (from the locations of +, -, %). Location aspect can be seen in two different ways: (a) as the point of installation in a system (marked with a single +) and (b) as the of installation within spaces (marked as ++). If we continue that same simple example as shown in Figure 8, we broke down the long code into several lines (Figure 9). RDS that has been broken down into several lines can be more easily understood through a property value that will be used by some software/IT platform. Location aspect is quite often the top level to recognize something and is common to all or at least for a large group of components (ex. all windows that belong to the same building). In some cases, it makes sense to show the component's connection to a specific location locally. In our example we might refer to a window in some specific room (built space). An example where a window belongs to some specific cabinet (but still being in that same technical/functional system) is shown in Figure 10.

+D2001.DD1001
<Education or science complex>.<University building>

-B2001.AD3001.QQA01%QQA10
<University building>.<Wall system>.<Wall construction>.<Window>

Figure 9: Various parts are broken down into multiple lines from the significant prefix

As the proposed RDS is using type number as well as an ID number within that component type class, it forms an extra ID system for elements which are usually maintained based on a room from where those can be found. In another words, we might quite easily run out of ID values (01-99) if there are a lot in some specific wall.

-B2001.AD3001.QQA01%QQA10/++BAA1001
<University building>.<Wall system>.<Wall construction>.<Window>/++<Cabinet>

Figure 10: Referencing to a window in some specific room (built space)

To define and to enable different filtering possibilities, that ID is user-based and on user-decision how she/he divides it in between specific classification tables if it ensures the unique ID string for all digital assets in each construction entity. A common suggestion is that a component's ID (if assigned to a room) runs based on that room (for example, if there are three windows in that specific room and those are all with the same type, an ID part becomes 01, 02 and 03). ID for technical systems change once it forms a separate technical system (ex. two separate cooling supply systems at first floor). ID for functional systems change once it forms a separate functional system within that same type (ex. cooling systems at first and second floor). Proposed ID-mechanism has a user-definable freedom and according to a project (scale of a project), various divisions are possible. In the next section a discussion is initiated to show example use-cases how the unique ID concept has been applied in different platforms to enable platform-neutral information exchange.

Discussion for future case studies

To enable the unambiguous information exchange, different software uses their own unique ID system. For example, when we investigate building information modelling packages, various ID systems are used which are auto-generated and therefore not machine- or human readable outside that package.

Example: Autodesk Revit

Autodesk Revit is commonly used software in architectural, structural, and technical systems domain. *Revit* is using *UniqueId* as well as *ElementId* to reference its objects uniquely. Both are auto generated and used for internal use only. There is an extra possibility for information exchange to have a *GUID* also in IFC file structure (IFC - *Industry Foundation Classes*), but this is by default an extra ID (*IfcGUID*) which does not match with *UniqueId* (Figure 11). Although, *IfcGUID* can be saved into a property, extra workflows are needed to have *ElementId* or *UniqueId* visible in a project. It is also important to note that *ElementId* is only unique per project file.

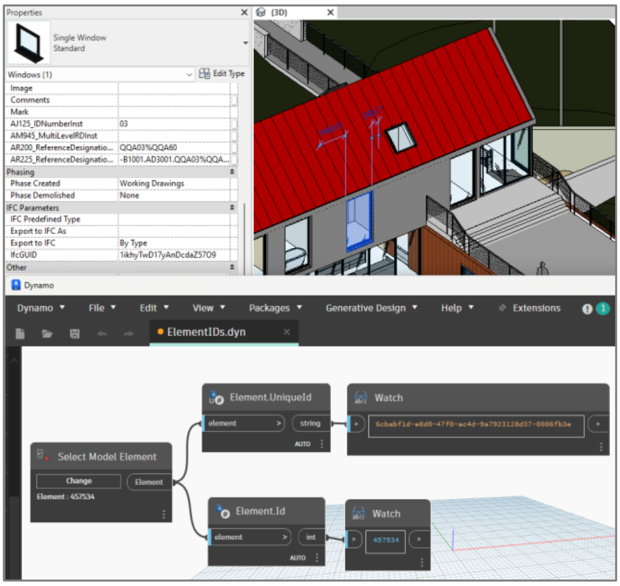

Figure 11: Default ID systems used in Revit (ElementId, UniqueId, IfcGUID)

CCI-EE-based unique *reference designation system* (RDS) can solve this issue and have a unified, both machine- as well as human readable ID system. It can be introduced through project properties. As some properties can be type-based, and some are instance-based, different property locations can be used (*Type Properties* dialog, Figure 12, *Properties palette* – Figure 13).

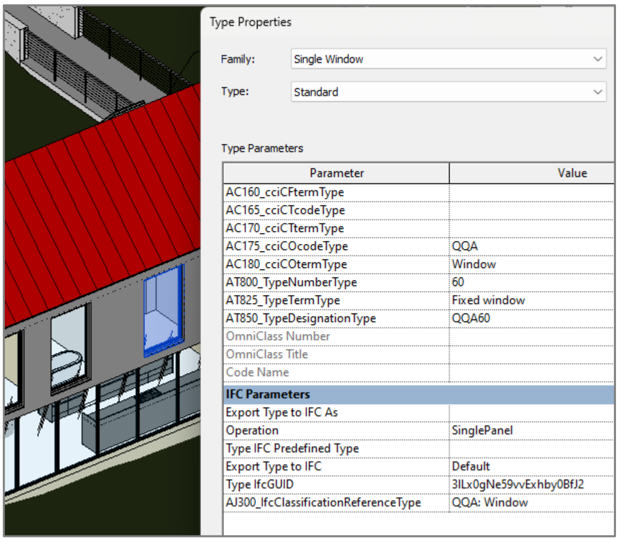

Figure 12: CCI-EE RDS example in form of shared parameters to state type-related properties

Figure 13 lists a property that shows a unique ID for selected window (according to CCI-EE RI table, it is named as *AR225_ReferenceDesignationSet,* in short just *AR225*). As described in the methodology part, it includes references to technical/functional system, but a building code is broken into project information section. This *AR225* value can be used for any kind of exchange requirements or mappings to other systems.

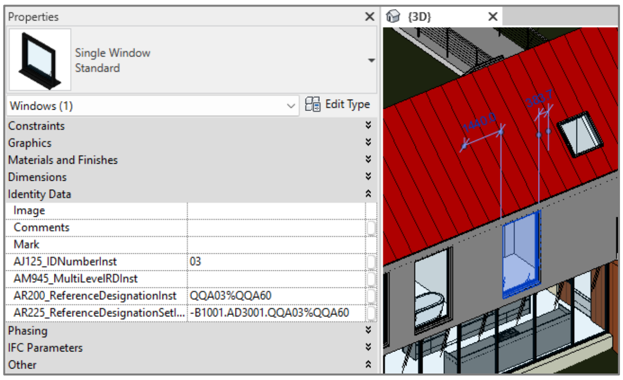

Figure 13: CCI-EE RDS example in form of shared parameters to state instance-related properties

As we see in the next example, same parameter names can be used in different software packages and therefore we generate a platform neutral way to share data. Although we used a building as an example in *Autodesk Revit*, same can be done for any object that we have in *Autodesk Revit*, is it a building-centric or infrastructure-centric component (ex. bridge abutment, noise wall etc.). Additionally, once we generate those type/instance properties, those can be used in any form (exported formats). For example, we can simply export a *COBie* compliant *MS Excel* sheet to have CCI-EE RDS-based ID-s in table format (*COBie Type > Name = AR200*; *ExtIdentifier = AR225* etc., see Figure 13). We can also use any other table-based exports which can be used as a basis to attach various data-templates.

Example: Autodesk Civil 3D

Autodesk Civil 3D is *AutoCAD*-based civil engineering product for infrastructure projects. As it is *AutoCAD*-based, the unique ID is in form of a *Handle* which is auto-generated value and unique only in along one drawing file. Figure 14 shows a handle for a corridor model's top surface, paving surface.

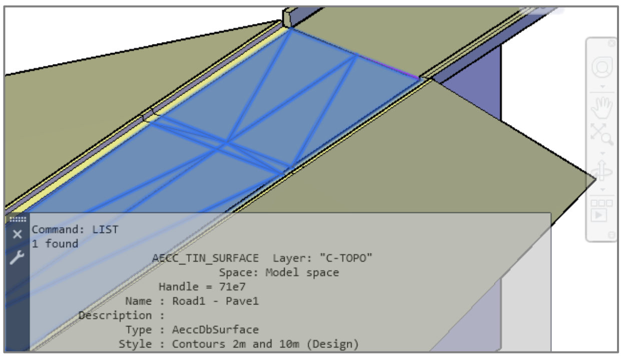

Figure 14: Handle (71e7) shown for a picked element (surface)

Similar issues as with an example of *Autodesk Revit*. As the *Handle* is auto-generated it is not machine- and/or human readable without *Autodesk Civil 3D* drawing database. The value can be listed in *Properties* palette and exported into data exchange package but once again, the context is missing and therefore it is difficult to connect additional information based on just that value. CCI-EE-based unique *reference designation system* (RDS) can solve this issue and have a unified, both machine- as well as human readable ID system. It can be introduced through *Property Sets* and therefore we can use the same group of properties as introduced in *Autodesk Revit* to ensure platform neutral data sharing (properties are classified through a CCI-EE property name as 2-level letter code + 3-level number code). Figure 15 shows the same surface selected with CCI-EE based RDS system gathered into one data template called *A010_Administrative*. The importance of having a unified structure to divide properties is discussed earlier and further discussions left for the future.

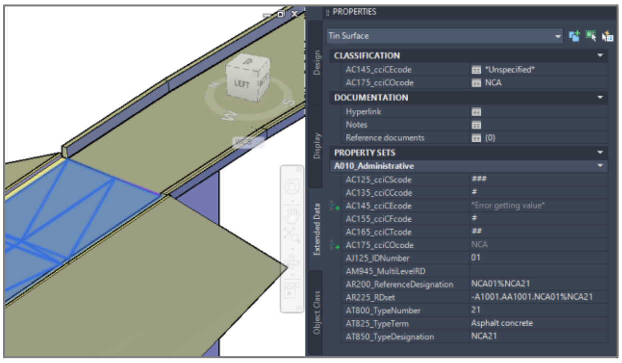

Figure 15: AR225 property connects a selected surface to a technical and functional system which altogether generates a unique ID for that component

Property sets in *Autodesk Civil 3D* can be exported in various formats (through *.ifc, *.csv, *.xlsx etc.), therefore we can gather same or similar information into a unified database as our properties are standardized which is difficult to achieve with multiple IDs at the same time (as we have to match those several times against some IT-system and those values are hardly machine- and/or human readable).

Different use-cases for applying CCI-EE based RDS system

Depending on the exchange requirements or a specific use case we might use those classification codes with or without reference designation system specifics. For example, when the exchange is done through an IFC, it enables to use *IfcClassificationReference* for more general referencing (ex. CCI code/term). This enables CCI-based filtering in federated data models (client-wide, project-wide) which could be enough for general planning studies (incl. building permit). In *Autodesk Revit* we can use a common property *AJ300* to include a general CCI code/term in form of *Code: Term* (see Figure 12). In *Autodesk Civil 3D* we can use *Classification Definitions* (available through *Style Manager*) to export defined values into *IfcClassificationReference* structure. And when additional information is needed those are added through property sets. Classification system can be taken into use at several detail levels. Modern software packages do have tools available to apply any type of classification system and automated workflows can be also taken into use (in *Autodesk Revit – BIM*

Interoperability Tools and *Dynamo*; in *Autodesk Civil 3D – Autodesk Standardized Data Tool* and *Dynamo*). Therefore, tools are available to start structuring the data across various platforms.

The CCI-EE based RDS system is currently tested in two key pilots: (a) at *TalTech Campus* where assets in as-built models are aligned according to CCI-EE RDS and used to pilot to connect that data with other IT-systems that are currently in use for facility management studies; (b) at *Estonian Transport Administration*, where a sample road project is classified through a CCI-EE based RDS system and connected to a current bill of quantities tables to automate model-based use-cases. Both pilots enable to develop further the current CCI-EE RDS system that is valid for different domains and can be scaled to similar clients/projects.

Conclusions

The research showed a unique way to define data structuring method for building information models (related data) through a standards-based classification system. This ensures a platform neutral data exchange with unique ID capabilities for all assets throughout the lifecycle of the construction. As different platforms do use various, internal ID systems, in a collaborative project it is hard to keep the data connected, especially when different ID-systems are not machine and/or human readable to enable connected workflows. *Construction Classification International* (CCI) has been recently published by CCIC as standards-based classification system. It gives a common way to declare a built environment as stated in EN ISO 12006-2. In addition to the classification of a construction result (component, construction entity etc.), classification can also incorporate construction process and construction resource which has been defined through Estonian extension to CCI as CCI-EE. As such, the developed framework, which aligns to EN ISO 12006-2, can be used to define the *reference designation system* for a platform neutral information exchange with unique ID capability (incl *uniform resource identifier* which will be discussed in future studies). The current research was limited to show CCI core tables in relation to unique ID. CCI-EE in general incorporates also other parts (*construction process*, *construction resource*) to extend the ID for additional use-cases. Whether it is wise to add it into models directly or connect at later stage (in a common data environment) should be discussed according to project requirements.

Data availability

Software templates used in this study are available at: https://flowbim.ee/cci-ee-context.

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