

CAN INTEROPERABILITY BETWEEN DISCIPLINES BE IMPROVED BY ADDING PHASING INFORMATION USING STANDARDISED CODING?

Efraim Ljung¹ and Mikael Viklund Tallgren

Architecture and Civil Engineering, Chalmers University of Technology, Sven hultins gata 8, Gothenburg, 41260, Sweden

With the increase of digitalisation in the construction industry, the need for structuring and classifying data is imperative. Due to the fragmentation and specialisation of the industry, digitalisation risks leading to a disconnect between the involved disciplines' different classification systems, impeding the interoperability of data transfer between disciplines. Thus, there is a need to explore how to capture the communication of data between different disciplines, leveraging the possibilities of multiple variables interconnect classifications of different disciplines. We applied a two-stage qualitative study focused on a specific part of a project, consisting first of interviews with practitioners and then a workshop with classification experts. We examined the use of standardised information in communication between disciplines. The main findings show that there are standards that support multiple properties that allow interconnections between disciplines; however, the currently used standards lack these possibilities. Thus, this paper contributes to the field through showing how the implementation of such a standard can solve challenges with interoperability and communication between disciplines.

Keywords: Building Information Modelling; ISO/IEC 81346; classification systems; interoperability; project-data communication

INTRODUCTION

The construction industry has seen a significant transformation with the advent of digital technologies, leading to an exponential increase in data across all phases of construction. Concurrently, the industry has become more specialised and fragmented, creating silos between various disciplines. This has resulted in project information becoming discipline specific with a decrease in knowledge of other disciplines' information needs (Cerezo-Narváez *et al.*, 2020; Mohd Nawi *et al.*, 2014). This has led to the development of discipline-specific digital tools, classification systems, and file formats that are often incompatible. The emergence of Building Information Modelling (BIM) has been transformative in addressing this challenge, centralising information, and enabling multi-stakeholder collaboration.

However, differences in classification systems and data structures between disciplines continue to hamper interoperability and effective communication. A key challenge is the lack of a unified approach to classifying and structuring data across disciplines,

¹ efraim.ljung@chalmers.se

leading to loss of information and miscommunication (Bavafa, 2014). Thus, there is an increased need to coordinate across more project information sources (Wang *et al.*, 2015). In recent research, a standards-based classification is shown to ensure platform neutral data exchange throughout the lifecycle of the construction, however in a limited context (Puust and Liias, 2023). Drawing on existing standards, especially those in Sweden, some well-established ones are for example the BSAB-system and its replacement the CoClass system.

A comparison between international standards such as Uniclass 2015 and OmniClass® shows significant differences in structuring principles compared to CoClass even though all three comply with ISO 12006-2:2015. Since CoClass is the only one of the three also complying with ISO/IEC 81346, it provides a consistent and unambiguous way to classify building elements (Eckerberg, 2019; Royano *et al.*, 2023). Furthermore, if different breakdown structures can be integrated, clearer roles and responsibilities emerge and the likelihood to reach project goals increases through more representative schedules and budgets (Cerezo-Narváez *et al.*, 2020). A deeper common understanding of the needs of the different disciplines within the project organisation (Dainty *et al.*, 2004), enables the adoption of more standardised coding and decoding practices, enhancing overall efficiency and effectiveness of project (Sonnenwald, 1996).

This paper explores the potential of leveraging standardised coding using ISO/IEC81346 in BIM classifications to enhance interoperability and improve communication across disciplines. By examining the current state of BIM classifications and data structures, as well as conducting a two-stage empirical qualitative study, the research identifies opportunities to utilise multi property coding to bridge the gap between disciplines and enable more effective collaboration. The main question asked is:

- Can the implementation of a standardised classification system improve communication efficiency and data interoperability among disciplines in commercial construction projects during the design and construction phases?

A two-staged qualitative study was used to first gather insights into how information and classification is approached in practice through interviews and then a workshop to examine how information could be systematised to leverage the benefits of a standardised classification system.

METHOD

An initial survey of the literature was done to review the role of standards in the communication of project information between disciplines. A two-staged qualitative study was designed to study and understand how systematisation and structuring of information occurs during design documentation and are transferred to the construction phase.

Object of the study

A project for which a shared taxonomy of the project locations and production process had been created was selected as suitable for exploring the role of classifications of information transfer between disciplines. The project was an ongoing design and construction of an apartment block consisting of three buildings (132 apartments) with a subsurface garage, see Figure 1A. The total gross area is 15872 sqm. One building is 5 floors, one is 16 floors, and one is divided into a lower part with 7 floors and a higher part with 9 floors.

A stakeholder analysis was done to identify stakeholders during schematic design (SD), design development (DD), and construction documentation (CD) phases. Table 1 summarises the number of participants and disciplines directly involved during different stages of the project, showing almost a doubling from one phase to another.

Table 1: Amount of people and disciplines involved in different stages.

| | SD | DD | CD |
|--------------------------|----|----|----|
| Responsible participants | 16 | 32 | 54 |
| Disciplines involved | 13 | 24 | 38 |

The Interviews

A semi-structured interview approach was used (cf. Kvale, 1996), leaning towards more open-ended questions and freedom for the interviewees to elaborate on specific topics. This provided a nuanced picture of the ISO/IEC81346 classification standard and the Swedish CoClass classification system and their theoretical usage.

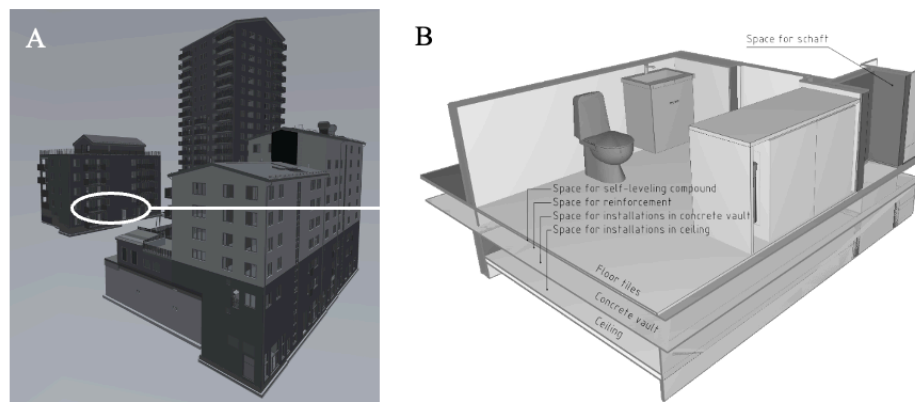


Figure 1: To the left, the three buildings of the project, with the selected area highlighted, to the right, the selected area as a 3D section

To focus the interviews and delimit the scope, a small, targeted detail of the project was selected, see Figure 1A and B. The reason for this selection was that it involved many disciplines over the three construction phases: Framing, Infill walls and Finishes. The focus was the area between two bathrooms situated above one another, henceforth named the bathroom vault. The area stretches from the ceiling of the bathroom below to the finished floor tiles of the bathroom above, as illustrated in Figure 1B.

Out of the 24 disciplines and 32 participants directly involved in DD, 12 individuals from 12 disciplines were interviewed detailed in Table 2. The questions were formulated to get the interviewees to, in their own words, describe their responsibilities and areas of work. The aim was to catch the information they needed, how they communicated their produced information, how this was systematised, and how their area was intended to be produced in practice. Each interview lasted around one hour, and was mainly conducted face-to-face, apart from three interviews where Microsoft Teams was used. The interviews were transcribed verbatim and coded and categorised with regards to three aspects taken from the ISO/IEC 812346 standard: the functional, locational, and product aspects and then paired with a fourth aspect, the construction process onsite.

Table 2: Interview Participants, their experience, their abbreviation, and their affiliation

| Discipline | Work life experience | Projects | Abbr | Affiliation |
|--|-------------------------|----------------------|------|---------------------|
| Architect | Not Collected | Not Collected | A | Inhouse Consultant |
| Acoustic Engineer | 14y as AE | >20 in DD | AE | External Consultant |
| Supervisor & Digitalization coordinator production | 15y (5y as ALD) | 0 in DD (3 in CD) | ALD | Contractor |
| Digitalization coordinator design | 6y as DCD | >10 in DD | DCD | Contractor |
| Structural Engineer | 42y as SE | >20 in DD | SE | Inhouse Consultant |
| Cost Engineer/Manager | 26y (10y as CE Manager) | >20 in DD | CE | Contractor |
| Site Manager | 23y (14y as SM) | 2 in DD 5 in DD | SM | Contractor |
| Project Manager | 20y (8y as PM) | (>5 in CD) | PM | Contractor |
| Project Engineer | 15y (5y as PE) | Not Collected | PE | Contractor |
| Design Manager | 42y (8y as DM) | >10 in DD | DM | Contractor |
| Scheduler | Not Collected | Not Collected | SC | Contractor |
| MEP Engineer/Manager | 12y (7y as MEP Manager) | >20 in DD | MEP | External Consultant |

The Workshop

To find out how the ISO/IEC81346 classification system was used for the targeted detail of the project, a workshop was held with experts/specialists. The focus of the workshop was to systematise and categorise the targeted detail with regards to the ISO/IEC81346 classification system according to the three identified systems of the bathroom vault: the loadbearing system, the plumbing system, and the spatial system together with the aspect of the construction process. The participants of the workshop were two external consultants specialised in the ISO/IEC81346 classification system, who also facilitated much of the workshop. From the project organisation and the construction company, two cost engineers, one scheduler, one structural engineer participated. Additionally, there were two middle management representatives, one digital strategist and one process developer.

The workshop lasted four hours and started with a brief review of the ISO/IEC 81346 standard and a general overview of the systematisation of both documented and undocumented information about the loadbearing system, the plumbing system, and the spatial system. Based on the analysis of the interviews, the systems were identified and exemplified in structures according to functional, locational and product aspects as well as the construction process.

The workshop was situated in a tele-conference room with three participants online, the rest situated around one big table. The workshop was centred around the big

display with one of the consultants documenting the discussions of the structuring directly in a PowerPoint document visible for all participants. The second consultant documented the agreed upon structure more permanently in excel.

FINDINGS

Reviewing the project documentation for the SD and DD phases, the amount of information that was produced can be sorted in three main categories: the size of the 3D model, i.e. the IFC model; the number of drawings and schemas; and the number of Documents and Descriptions. A summary is provided in Table 3.

Table 3: The three designers, with three main categories of information and size or number of documents

| | IFC model (Mb) | | Drawings, Schemas (no. docs) | | Documents, Descriptions (no. docs) | |
|-----|----------------|-----|------------------------------|----|------------------------------------|----|
| | SD | DD | SD | DD | SD | DD |
| A | 90 | 132 | 23 | 32 | 0 | 3 |
| SE | 4 | 6 | 2 | 49 | 1 | 1 |
| MEP | 45 | 134 | 6 | 32 | 1 | 2 |

The amount of data and increase in size between SD and DD indicates an increase in detail of the documentation. The interviews suggested that extensive experience and disciplinary knowledge are required to interpret drawings and descriptions at a SD level, highlighting the need for a common vocabulary connecting the disciplines. This is amplified during DD, where the designers produce a wider variety of documents compared to the SD phase, with content depending on the stakeholder recipient. As seen in Table 1, the increase in participants, almost doubling, follows with the size and number of documents produced in SD and DD phases, respectively as seen in Table 3. While not all the developed project vocabulary was used, the interviewees stressed that a uniform use of location designation in projects is paramount for effective project communication. Furthermore, A, SE and MEP saw the need to calibrate the level of detail of their documentation verbally with intended recipients. These agreements were hardly ever systematised or documented for future use. This highlights the importance of systematisation to create prerequisites for interoperability.

Functional Systems

The interviews show that early on, A focused on setting the overall apartment layout for the project using standardised solutions. Layouts for several standardised bathrooms had been developed internally within the company to meet regulations as well as common internal requirements. During the SD phase, the layouts were adjusted to specific project requirements. A explained that this adjusted layout formed the basis for the coordination and communication with other disciplines concerning the bathroom vault, as shown in Figure 1B.

The SE stressed that the responsibility for the building's load-bearing system went beyond just the bathroom vault. So, SE needed to take the whole level into account when designing the load-bearing system. However, the bathroom definition was included in the vault separating the two levels. SE explained that experience and 'gut feeling' were relied on to intuit how the construction of the floor structure would be affected by other disciplines' tasks such as those of A, AE, and SM, which required coordination of e.g., the space for shafts and installations, see Figure 1B. One such

coordination was exemplified in the project's ventilation system, which required access for service inside the apartment. Thus, the ventilation, partly located in the suspended ceiling also needed to be coordinated with A. The interviews also stressed that most disciplines possess information that is not modelled or formally documented, but rather communicated verbally or by rough sketches between disciplines.

3D Objects and Product Systems

In addition to information about the object's function and location, the project contract stipulated requirements that the designers' data must also contain. Such properties described in the BIM-manual combined with properties from the project vocabulary such as deliverables, construction scope and a BSAB-codes were demanded to be added to the objects. Additionally, properties that enable sorting to fit the other disciplines involved were also required. These are properties that the designers do not primarily need for their own work, but which they acknowledged facilitated communication with other disciplines.

The layout-system, load-bearing system, and the different MEP-systems were modelled as objects in 3D, often coinciding with specific products. The interviews evidenced that the resulting model visualisation provided a visual understanding and helped the designers with the 3D coordination and constructability checking. However, such controls need to be clearly and precisely communicated. As a project control measure, the PM specifically mentioned the monitoring of requirements in the contract in contrast to what was documented so as not to exceed the budget.

Production System

To understand the connection between design and construction, the project used deliverables and production scope to describe the construction process. SC together with SM developed the project-specific structure for deliverables and production scope from a company-wide general structure. SM used this systematisation in drawings and documents to colour-code how the project should be sequenced to provide an overall understanding of the execution that better described the construction process.

Furthermore, SC emphasized that the schedule is based on the deliverable structure; however, the detailed schedule included activities in the vernacular of the workers, ensuring readability for those using the schedule. Finally, the interviews aimed to capture how the discipline described the execution sequence of the selected part of the project. The respondents used simpler activity descriptions rather than deliverables to explain the execution sequence of the bathroom vault.

The workshop helped create an understanding amongst the participants of how the system aspect of ISO/IEC 81346 could enable storing information in properties, thus enabling a more systematic coordination of the systems involved. The interviews showed clearly that disciplines commonly think they refer to the same aspect of objects, but the ambiguity of the vocabulary used creates different meanings within different disciplines. The use of a classification system such as ISO/IEC 81346 contributes to a common understanding of common denominators through a structured systematisation. The workshop focused mainly on finding a structure for the four aspects defined: Function, Location, Product and Construction process. The workshop resulted in three structures, exemplified in Figure 3. 'The prefixes, =, + and

- denote which aspect the classification refers to. The fourth aspect, the construction process, was discussed, but not fully classified.

Workshop Findings

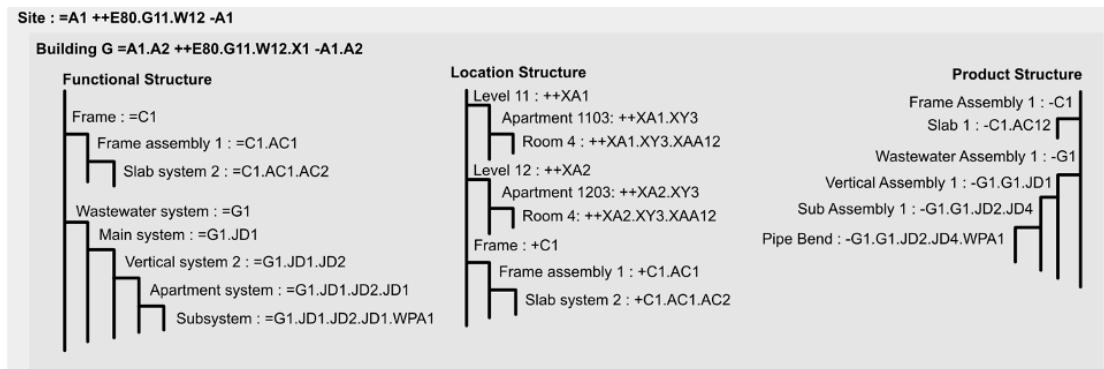


Figure 3: Example of ISO/IEC compliant classification of the slab and a drainpipe in the bathroom, according to three aspects

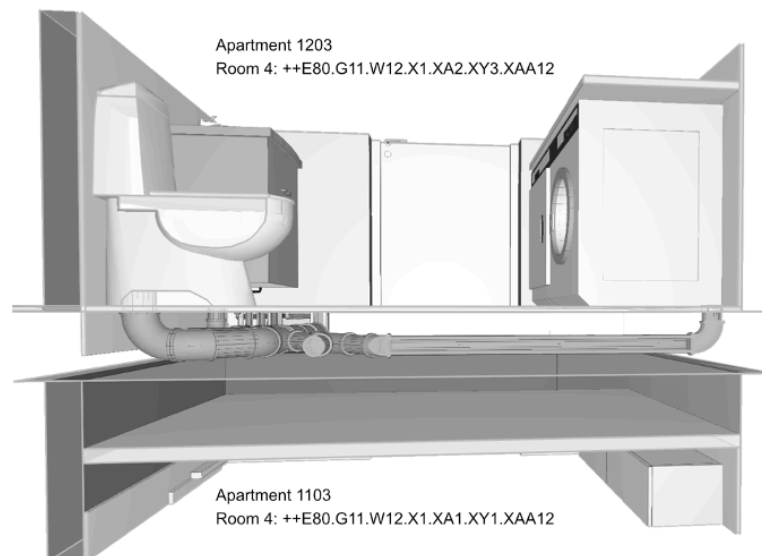


Figure 4: The reference designation for the two bathrooms

The workshop also showed that the existing structure of the location connected to the building were easy to directly transfer to a fully classified structure by adding the reference designations, (RD), stipulated through the standard. An example of the full RD for the bathrooms of Apartment 1103 and 1203 is seen in Figure 4. The RD follows the logic Site.Building.Level.Apartment.Room, where the Site is described by E80.G11.W12; Building by X1; Level by XA1; Apartment by XY1; and Room by XAA12. The numbers are merely indexes used per hierarchical level in the standard and carry no deeper meaning. This reduces the ambiguity of the classification, but also abstracts the meaning of the classification. It becomes clear that the systematisation is there to help us encompass and understand the structure of the system, while the specific RD code is for the data interoperability between software.

Figure 5 illustrates how the wastewater subsystem and assembly for room 3 in apartment 1203 casted in the decking between the bathrooms is classified. The resulting RD-codes can thus be stored in the objects as properties for each aspect. The full classification takes on all three aspects: function, location, and product and connects the load bearing system and the wastewater system. Thus, when describing

different products one can view them as assemblies or as specific products, i.e. the pipe bend. However, the function and location for both the assembly and the pipe bend are the same. This creates an implicit dependency between the product and the function on a property-level, which means that the specific product cannot be changed without ensuring the functionality of the assembly. This solves the design coordination of the stated problem but does not fully handle the construction phase process aspect.

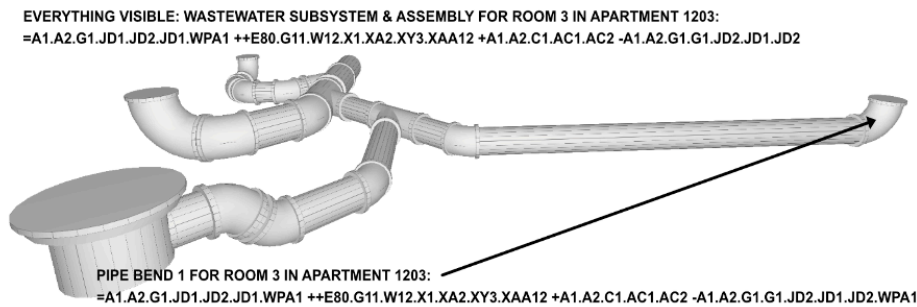


Figure 5: The wastewater subsystem and assembly, and a specific product, the Pipe bend of the system defined

A preliminary systematisation of the construction process was discussed, starting with the site and then buildings, and then using deliverables and construction scopes as major and minor sub-divisions. These aspects have no corresponding tables in the ISO/IEC 81346 standard, but the structure to describe the selected part of the project with a construction process aspect is exemplified in Figure 6.

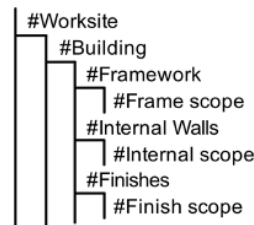


Figure 6: Part of the suggested systematised structure for the selected part of the case project

Framework and Internal Walls and Finishes denote three separate deliverables, and Frame scope, Internal Scope, and Finish scope separate construction scopes. Hence, the construction process aspect can catch dependencies with other aspects in a similar way as with functions and product aspects. Thus, the connection between design and construction can preserve data and facilitate communication and coordination across disciplines and phases.

The workshop showed that the implementation of a standardise classification system, such as exemplified in ISO/IEC 81346, enables the data interoperability among disciplines, it also creates a structure that facilitates the coordination of data and ensures that disciplines can use different aspects and still catch the same object in the model.

CONCLUSION

The findings indicate that while the project employed a specially developed shared taxonomy, only location-related vocabulary was used in the interviews. This suggests

that the construction-process vocabulary is not sufficiently established or familiar to foster practical, cross-disciplinary construction knowledge. The location vocabulary, used as properties in the models, served to systematise each discipline's processes, while the construction-process vocabulary did not achieve this. Thus, the level of detail of the documentation at each stage (SD and DD) and the extent of additional information required through verbal communication or sketches was chiefly based on experience.

The workshop on structuring systems in the bathroom vault demonstrated the value of ISO/IEC 81346 in helping participants structure their systems and understand interdependencies without additional verbal communication and sketches. The method of describing connections within the bathroom vault aligned with the interviewees' execution processes. Defining the construction scope within a deliverable became easier when relationships between products were clearly defined. The 3D coordination, previously limited to modelled objects, can now be extended to coordinate all interdependencies, enhancing areas such as constructability, estimation, purchasing, and construction process monitoring.

We conclude that implementing a standardised classification system, such as ISO/IEC 81346, which breaks down information into interdependent systems stored in multiple properties, improves both communication efficiency and data interoperability within and between the design and construction phases, as evidenced by our study limited to the bathroom vault. The constrained scope and disciplines allowed this systematisation within a 4-hour workshop. Future research should investigate if these results scale to larger project scopes, examining the effects on communication efficiency and data interoperability. Further exploration is also needed to fully systematise the construction process based on ISO/IEC 81346, focusing on RD that distinctly describe the principal parts of the construction process.

REFERENCES

- Bavafa, M (2014) Towards interoperability in the UK construction design industry computing in civil and building engineering, *In: Proceedings of the 2014 International Conference on Computing in Civil and Building Engineering*, 528-535.
- Bryman, A and Bell, E (2011) *Business Research Methods 3rd Edition*, Oxford: Oxford University Press.
- Cerezo-Narváez, A, Pastor-Fernández, A, Otero-Mateo, M and Ballesteros-Pérez, P (2020) Integration of cost and work breakdown structures in the management of construction projects, *Applied Sciences*, **10**(4), 10041386.
- Dainty, A R J, Ison, S G and Root, D S (2004) Bridging the skills gap: A regionally driven strategy for resolving the construction labour market crisis, *Engineering, Construction and Architectural Management*, **11**(4), 275-283.
- Eckerberg, K (2019) *CoClass - Informationshantering för byggd miljö, 1st edition*, Svensk Byggtjänst.
- Industrial Systems, Installations and Equipment and Industrial Products (2022) *Structuring Principles and Reference Designations - Part 1: Basic Rules, IEC 81346-1:2022*
- Kvale, S (1996) *InterViews: An Introduction to Qualitative Research Interviewing*, London: SAGE Publications.
- Mohd Nawi, M N, Baluch, N and Bahauddin, A Y (2014) Impact of fragmentation issue in construction industry: An overview, *MATEC Web of Conferences*, **15**, 1-8.

- Puust, R and Liias, R (2023) Structuring BIM-related construction data through a standards-based classification system, *In: Proceedings of the 2023 European Conference on Computing in Construction and the 40th International CIB W78 Conference*.
- Royano, V, Gibert, V, Serrat, C and Rapinski, J (2023) Analysis of classification systems for the built environment: Historical perspective, comprehensive review and discussion, *Journal of Building Engineering*, **67**, 105911.
- Sonnenwald, D H (1996) Communication roles that support collaboration during the design process, *Design Studies*, **17**, 277-301.
- Wang, R, Zhong, D, Zhang, Y, Yu, J and Li, M (2015) A multidimensional information model for managing construction information, *Journal of Industrial and Management Optimisation*, **11**(4), 1285-1300.