ITcon
www.itcon.org - Journal of Information Technology in Construction - ISSN 1874-4753

A HOLISTIC APPROACH TO INFORMATION REQUIREMENTS: INTEGRATION OF LEVEL OF INFORMATION NEED AND INFORMATION DELIVERY SPECIFICATION

SUBMITTED: December 2024
REVISED: April 2025
PUBLISHED: May 2025
EDITOR: Yang Zou, Mostafa Babaeian Jelodar, Zhenan Feng, Brian H.W. Guo
DOI: 10.36680/j.itcon.2025.030

Elif Akbas, M.Sc.
RWTH Aachen University, Aachen, Thyssen Schachtbau GmbH, Mülheim a.d Ruhr, Germany
elif.akbash@rwth-aachen.de

Marzia Bolpagni, Dr.
Northumbria University, Newcastle, United Kingdom
marzia.bolpagni@northumbria.ac.uk

André Borrmann, Professor
Technical University of Munich, Munich, Germany
andre.borrmann@tum.de

Stefan Boeykens, Dr.
D-studio, Mechelen + KU Leuven, Leuven, Belgium
sb@dstudio.be, stefan.boeykens@kuleuven.be

Martina Mellenthin Filardo, M.Sc.
Bauhaus-Universität Weimar, Weimar, Germany
martina.mellenthin.filardo@uni-weimar.de

Liu Liu, M.Sc.
Computing in Engineering, Ruhr University Bochum, Bochum, Germany
liu.liu-m6r@rub.de

Jakob Beetz, Professor
Design Computation Chair, RWTH Aachen University, Aachen, Germany
beetz@dc.rwth-aachen.de

SUMMARY: *Digitalization and automation in the construction industry improve the efficiency of information management. For automated information management systems, it is crucial to establish standardized and well-structured information requirements. Recently, various methods have been developed to specify project requirements, addressing different aspects of the projects, with some overlap in certain areas. This paper examines standardized, machine-readable methods, such as the Information Delivery Specification (IDS) and Level of Information Need (LOIN) XML schema, focusing on their integration. Both methods use XML schemas; however, LOINXML covers a broader range of aspects, while IDS mainly focuses on alphanumerical requirements. Although there is some overlap in the alphanumeric content between the two schemas, their structures and applications differentiate them. The primary objective of this research is discovering the integration possibilities of these methods by analyzing their data templates and standards, with the aim of providing holistic approaches for efficient information management. There is potential to integrate the two schemas, however challenges remain due to the differences in the schemas and their scopes, limiting to cover all the aspects through integration.*

KEYWORDS: *Information Management, Information Requirement, Building Information Modelling, Information Validation, level of information need, Information Delivery Specification.*

REFERENCE: *Elif Akbas, Marzia Bolpagni, André Borrmann, Stefan Boeykens, Martina Mellenthin Filardo, Liu Liu & Jakob Beetz (2025). A holistic approach to information requirements: Integration of level of information need and information delivery specification. Journal of Information Technology in Construction (ITcon), Special issue: 'Construction 5.0', Vol. 30, pg. 731-744, DOI: 10.36680/j.itcon.2025.030*

1. INTRODUCTION ON INFORMATION REQUIREMENTS

Building Information Modeling (BIM) plays a crucial role in Architecture, Engineering and Construction (AEC) industry (Kumar, 2021). This collaboration requires specification of requirements to ensure interoperability between stakeholders (Cavka et al., 2017). The Industry Foundation Classes (IFC) is a vendor-neutral international data standard for sharing and exchanging information (Borrmann et al., 2018). In the construction sector projects tend to have diverse information requirements, which introduces difficulties to information validation and standardization. Various methods have been developed to specify information requirements (Tomczak et al., 2022) by different organizations as the International Organization for Standardization (ISO), the European Committee for Standardization (CEN) and buildingSMART International. Amongst those initiatives there are the level of information need (LOIN) based on ISO 7817-1 and the Information Delivery Specification (IDS) by buildingSMART International that aim to standardize machine-readable structures of information requirements (ISO, 2024b; buildingSMART International, 2024). Additionally, the Information Delivery Manual (IDM) introduced by buildingSMART International, based on ISO 29481-1, establishes a repeatable, standardized process for BIM projects (ISO, 2016).

In the context of a software ecosystem, having inconsistent data can result in mistakes that are difficult to identify. Such inconsistencies can cause significant problems, including incorrect data interpretation, errors in project execution, and increased costs due to rework and delays (Honnappa, Padala, 2022).

Currently, there is a gap in the literature regarding the implementation of LOIN and IDS, along with confusion around their relationship. Some may perceive the two initiatives as being equal, despite their distinct purposes and scopes. This paper aims to investigate how the two initiatives are related to each other and discuss how to overcome possible overlaps by exploring the challenges and possibilities to create a consistent data flow and avoid repetition.

2. BACKGROUND AND RELATED WORK

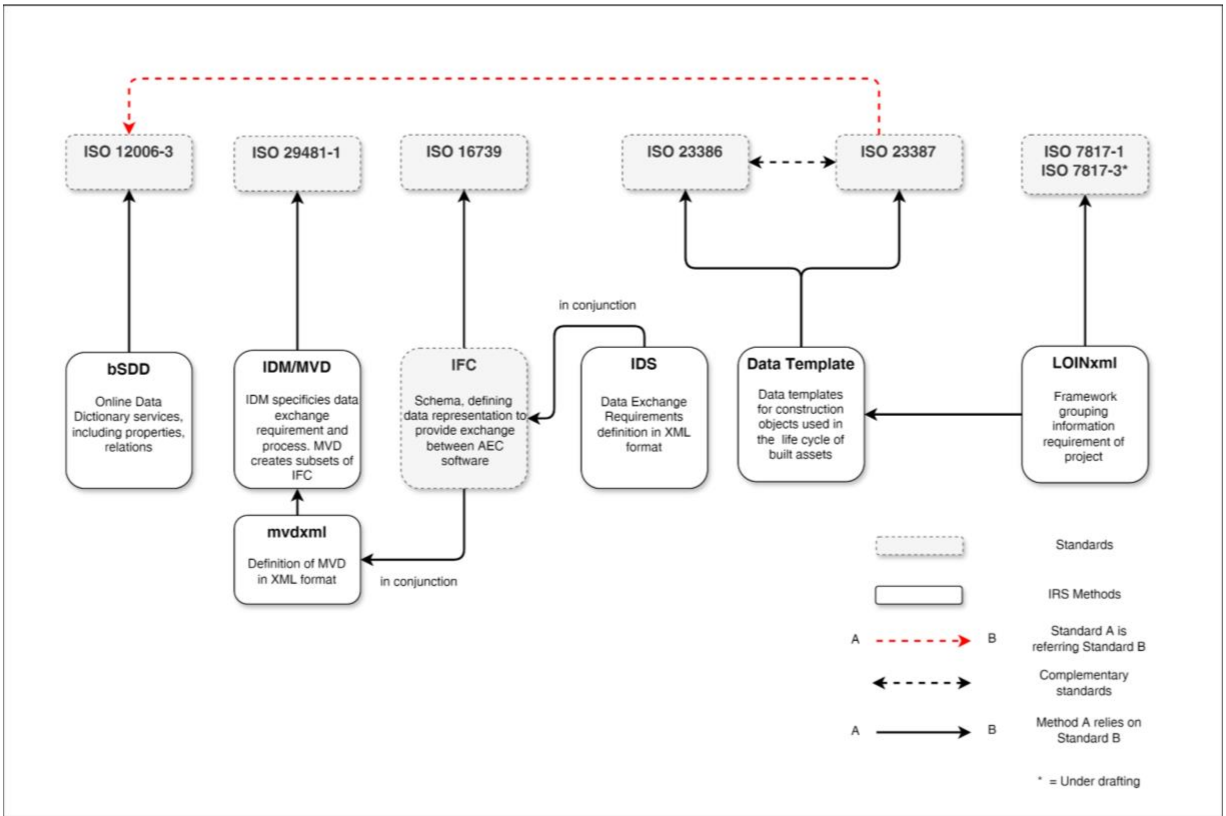


Figure 1: Standards and Methods.

2.1 Information Delivery Specification (IDS)

Information Delivery Specification (IDS) is developed by buildingSMART International, with version 1.0 released in June 2024 (buildingSMART International, 2024). Its purpose is to separate software certification implementation from validation processes (Tomczak et al., 2022). IDS provides an XML-based schema to define project requirements for the use case of checking project deliverables. The IDS consists of specifications such as *Applicability* and *Requirement*, which function as filters and definitions of requirements (buildingSMART International, 2024). It includes the facets *material*, *requirement, entity, partOf, classification, attribute and property*. *Applicability* and *Requirement* are defined through a combination of these facets. It is possible to define different requirements, *Applicability* and *Requirement* can consist of different facets as shown in figure 2 in example 1 and example 2. In example 1, Applicability is populated with *Entity* and *Property* facets, while *Requirement* is populated with the *Attribute* facet. In example 2, *Property* and *Attribute* facets populate *Applicability* and *Requirement*, respectively.

2.2 Level of information need schema (LOINXML)

Level of information need was introduced in ISO 19650-1 (ISO, 2018) to specify information requirements when dealing with information management using BIM. In ISO 19650-2 (ISO, 2020) it is defined as a part of the Exchange Information Requirements (EIR). Within CEN/TC 442, the European Standard EN 17412-1 on concept and principles related to the level of information need (CEN, 2020) was developed and in 2024 it became an international standard as ISO 7817-1. It governs the application of the level of information need framework and defines both the necessary prerequisites and the information requirements, split across *geometrical* and *alphanumerical requirements* and *documentation* (ISO, 2024b, Oliveira et al., 2024). Various techniques have been introduced to define information requirements (Bolpagni and Ciribin, 2016). Even though there is no official acronym for level of information need, in this paper we refer to the framework as "LOIN" which provides a comprehensive framework, covering many aspects such as *geometrical information, alphanumerical information, and documentation* (ISO, 2024b). Currently, a joint working group within ISO/TC 59/SC 13 and CEN/TC 442 has been established to develop a schema of the framework in ISO 7817-1 as part of the upcoming standard ISO 7817-3.

The LOIN schema is being developed as an XML-based schema and it will be referred in this paper as "LOINXML". The schema aims to include the data template mechanism defined in ISO 23387, which is in turn aligned with ISO 23386 (data dictionaries) and therefore with ISO standard series 12006, at least to describe the alphanumerical information requirements.

2.3 Integration Information Requirement Specification Methods

Over time, several information requirement specification methods have been introduced and according to Tomczak et al., (2023), IDS is considered as one of the most beneficial methods for checking information requirements. However, with the existence of numerous methods and standards (e.g. Model View Definition (MVD), IDM, buildingSMART Data Dictionary (bSDD), IDS, LOIN), there could be opportunities for extensions and integrations. This section mainly focuses on a literature review of integration of LOINXML and IDS, with the exploration of IDS extension to have a better understanding on extension of the XML schemas.

When it comes to the extension of the IDS, there is research focusing on expanding IDS by using XLink for the geometrical validation (Kremer, Beetz, 2023). XML Linking Language (XLink) is a syntax to create links between XML schemas and extend their scopes (Smith et al., 2016). Although IDS by itself incorporates IFC entities, XLink extension enables the creation of a connection between schemas in IDS (Kremer and Beetz, 2023). The IDS, aligning it with the ISO standard 16739 (Industry Foundation Classes, IFC), is utilizing the XLink method to connect with external data sources to broaden the scope of the schema (Kremer and Beetz, 2023). This capability facilitates connections with data dictionaries such as the bSDD, enabling the creation of links between diverse data sources (buildingSMART International, 2024).

To explore the integration possibilities between LOIN and IDS, related research is examined, that related shows there is LOIN ontology development which is linking IDS facets with LOIN for encapsulation of Information Container for Linked Document Delivery (ICDD) (Liu et al., 2023).

Another study investigates workflow to utilize XML-based information requirement in a modelling enviroment within Archicad (Mellenthin Filardo et al., 2023). As a continuation of this work, the second study provides a practical example of the industrial application of both LOINXML and IDS, where it was tested by importing both LOINXML- and IDS-based requirements into Archicad to incorporate information requirements during the planning phase (Mellenthin Filardo et al., 2024). Another study by Gragnaniello et al., (2023) presents an approach to optimize information management in Structural Health Monitoring (SHM), using LOIN and IDS to ensure data consistency.

There are studies on IDS and LOINXML concerning expansion of the schema and integration with current software solutions in the industrial applications, respectively. However, since IDS has recently been published and LOINXML is still in development, there is limited research in this area.

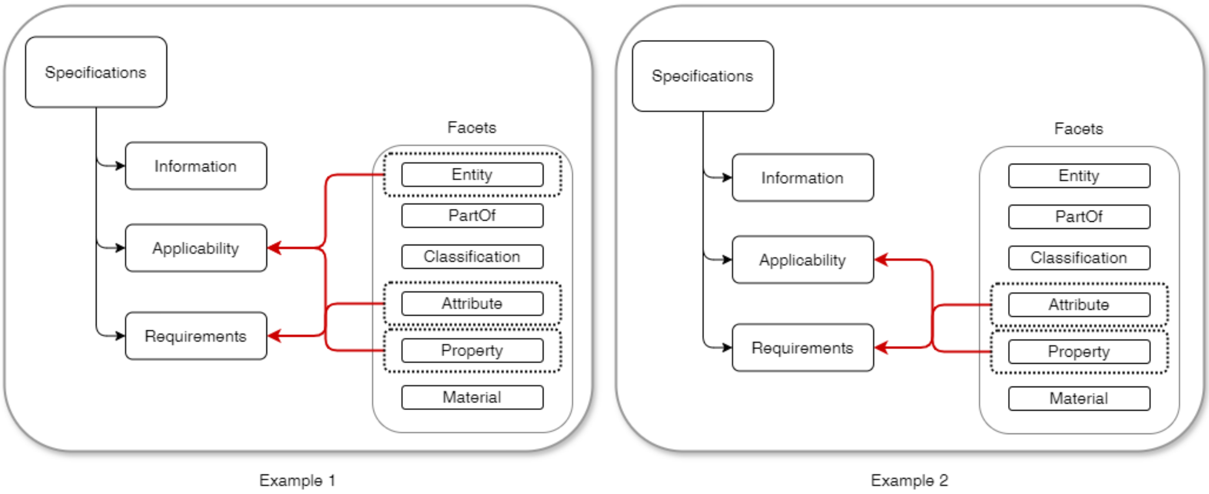


Figure 2: Different Combinations of IDS facets.

3. METHODOLOGY

Initially, the methodology of this research focuses on posing research questions on exploring the integration of LOINXML and IDS and addresses challenges in terms of data interoperability (Figure 3). The concept development begins with analyzing schemas.While both LOINXML and IDS aim to facilitate interoperable solutions, they differ in their scope. IDS mainly covers two cases in BIM workflow: defining information requirements and IFC validation (Fischer et al., 2024). On the other hand, LOINXML with its broader scope including aspects such as *geometrical information, alphanumerical information, and documentation* provides holistic understanding of the information requirements.

To understand integration possibilities and develop mapping concept, both schemas, expressed in XML/XSD, along with their parent and child elements, have been examined. Reference data templates and standards which they are relying on are analyzed as illustrated in figure 1. LOIN is relying on ISO 23387 which specifies principles for data templates (ISO, 2024b) while IDS utilizes ISO 16739 which contains the IFC schema (ISO, 2024a). Example schemas provided by buildingSMART International (2024), and a restricted GitHub repository created by CEN/TC 442 working group are used for the test purposes.

After analysis and defining mapping concepts, the LOIN - IDS Converter tool (figure 7) is proposed as a solution to achieve seamless integration. The tool is designed to propose a user-friendly interface to make it accessible to a wide range of users and to accommodate a variety of use cases. Converter functionalities are tested with the LOINXML and IDS examples provided by CEN/TC 442 working group and buildingSMART International (2024), respectively.

As a final step, to demonstrate the industrial application of the tool and show integration possibilities with other used validation tools in the industry, the tool has been integrated with Desite MD Pro, a validation software by Thinkproject. This integration can be considered as an initial example for the industrial application highlighting the possibilities of the integration of the tool within existing validation softwares.

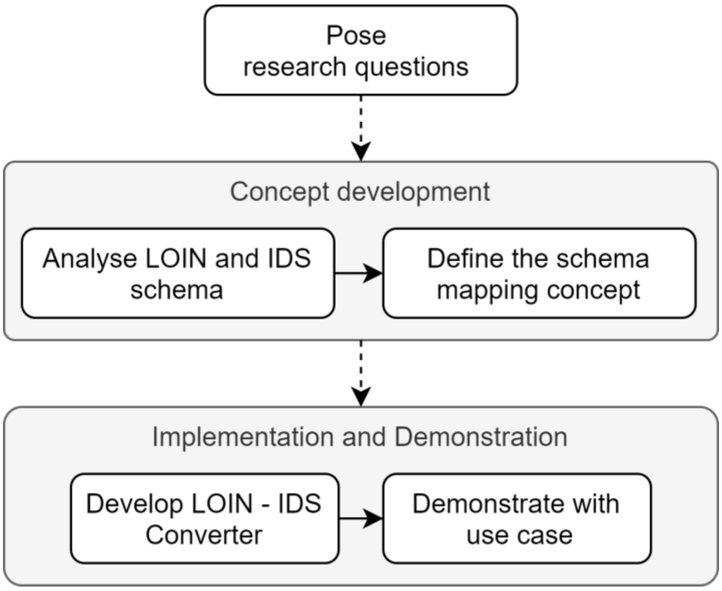


Figure 3: Methodology.

4. INTEGRATION OF IDS AND LOINXML

As LOIN framework and IDS are starting to be adopted more and more in academia and industry (Hentour et al., 2024; Oliveira et al., 2024), there is a need to better understand their integration to advance the processes and avoid repetition of the work. Thus, an integration between IDSxml and LOINXML is proposed in this paper.

IDS only covers alphanumerical information, while LOINXML addresses more aspects (geometrical information, alphanumerical information and documentation), and thus a wider scope (Figure 4). However, both schemas rely on different standards and technical descriptions (Tomczak et at., 2023).

Both approaches propose an XML-based definition of information requirements with varying scopes and constraints, which can result in inconsistencies between schemas both with end users and implementers in the industry. The relations between the standards and schemas is shown in figure 1. As this research mainly focuses on IDS and LOINXML integration, other standards and methods are out of the scope for this article, which can be part of future work. After analysing the current two schemas independently, this chapter will further explore the mapping concept and their integration.

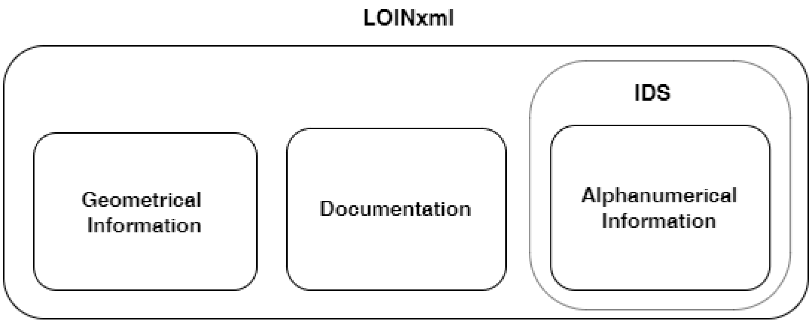


Figure 4: LOINXML Scope and Intersection with IDS Scope.

4.1 Analysing of the schemas

For a better understanding of the LOIN-IDS integration, a comparison of both schemas is undertaken. As illustrated in figure 5, LOIN has a broader scope than IDS. For example, IDS does not define which documents a client might require from a delivery team (designer, contractor etc.), while the required information can be assigned with documents in LOIN. In addition, IDS does not define what the geometry of a building or an object should have, while LOIN provides the terms to specify the detail, location, dimensionality, appearance and parametric behaviour of the geometrical representation. Due to its structure, LOIN contains standardized data for project requirements, and it overlaps with IDS in terms of only *alphanumerical information requirements*. IDS does not fully encompass those from LOINXML.

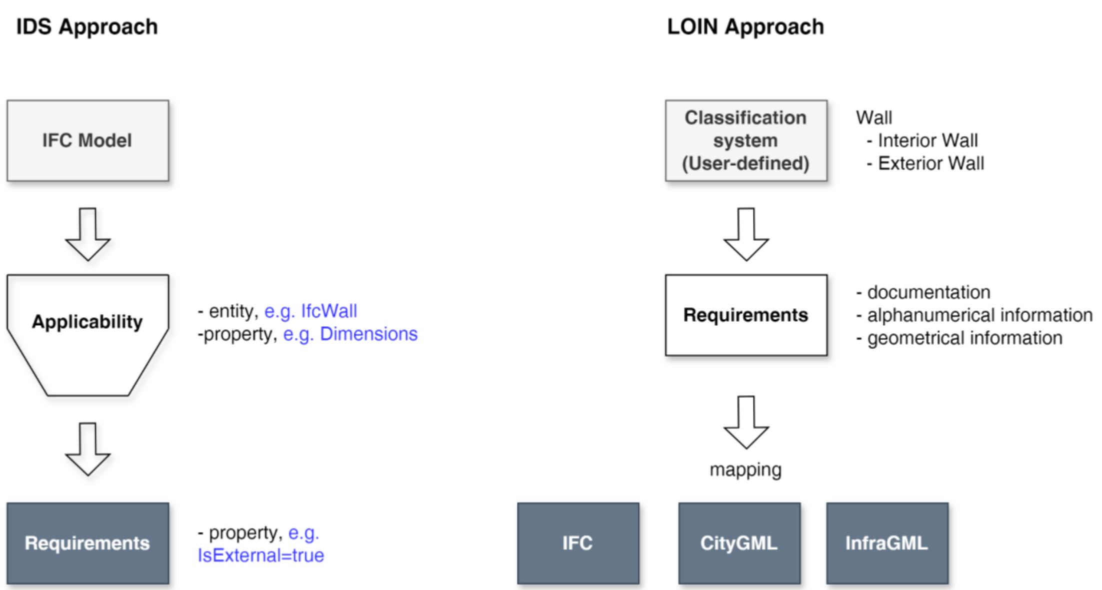


Figure 5: IDS Approach - LOIN Approach (adopted by the author, based on publicly available information).

Furthermore, IDS relies on IFC classes to define objects, whereas the LOINXML schema is designed to support different object libraries as shown in figure 5. Therefore, a complete conversion of the object defined with LOIN to IDS might not be successful. As BIM projects are widely delivered in different industries (buildings, civil infrastructure, energy infrastructure etc.) and the IFC schema does not provide every type of object, the IFC extension needs to be further considered in the LOIN and IDS integration. There are various studies on how to expand the IFC schema for example IFC 4.1 introduced alignment expressions for infrastructure, while IFC 4.2 further expanded including bridge structures and defined a separate spatial hierarchy for infrastructure including entities like *IfcFacility* and *IfcFacilityPart* (Zadeh, Atkin, and Kelly, 2018; Yu et al., 2023).

Gaps in the scope of the IFC schema represent a broader issue not only for the IFC schema but also for IDS, and LOINXML, when the IFC schema is used. In practice, a common workaround is using *IfcBuildingElementProxy* for objects that lack predefined IFC classes. Prior to the IFC 4.3 introduction, bridge elements were represented with architecture-related entities such as *IfcSlab* or *IfcBuildingElementProxy* (Yu et al., 2023). However, this method might cause potential errors and data interoperability issues between bridge-specific BIM applications (Park et al., 2020; Won et al., 2022). Although this provides a representation, it is not a best practice as it can reduce semantic precision and needed granularity.

Given the narrow scope of IDS and the associated limitations of modelling using IFC, this research explores the one-way integration of LOINXML and IDS, with the aim of creating IDS from LOINXML. While LOIN contains more comprehensive, standardized data for project requirements across geometrical, alphanumerical and documentation aspects, IDS can facilitate requirements definition based on IFC schema.

4.2 Mapping Concepts

The nature of IDS requires a more adaptable linking mechanism. The IDS schema is designed to accommodate various requirements that depend on the specifics of each project. This flexibility allows for the creation of tailored requirements with different combinations of facets as illustrated in figure 2. Figure 6 shows how different combinations of facets in IDS create various specifications, and how these specifications can align with elements in LOINXML. In IDS - Example 1, the *Applicability* is created using an *Entity* such as door, while the *Requirement* is created with an *Property* for example dimensions. In IDS - Example 2, both the *Applicability* and *Requirement* are created using *Entity* such as door and *Attribute*, which can be the fire rating associated with a door, respectively.

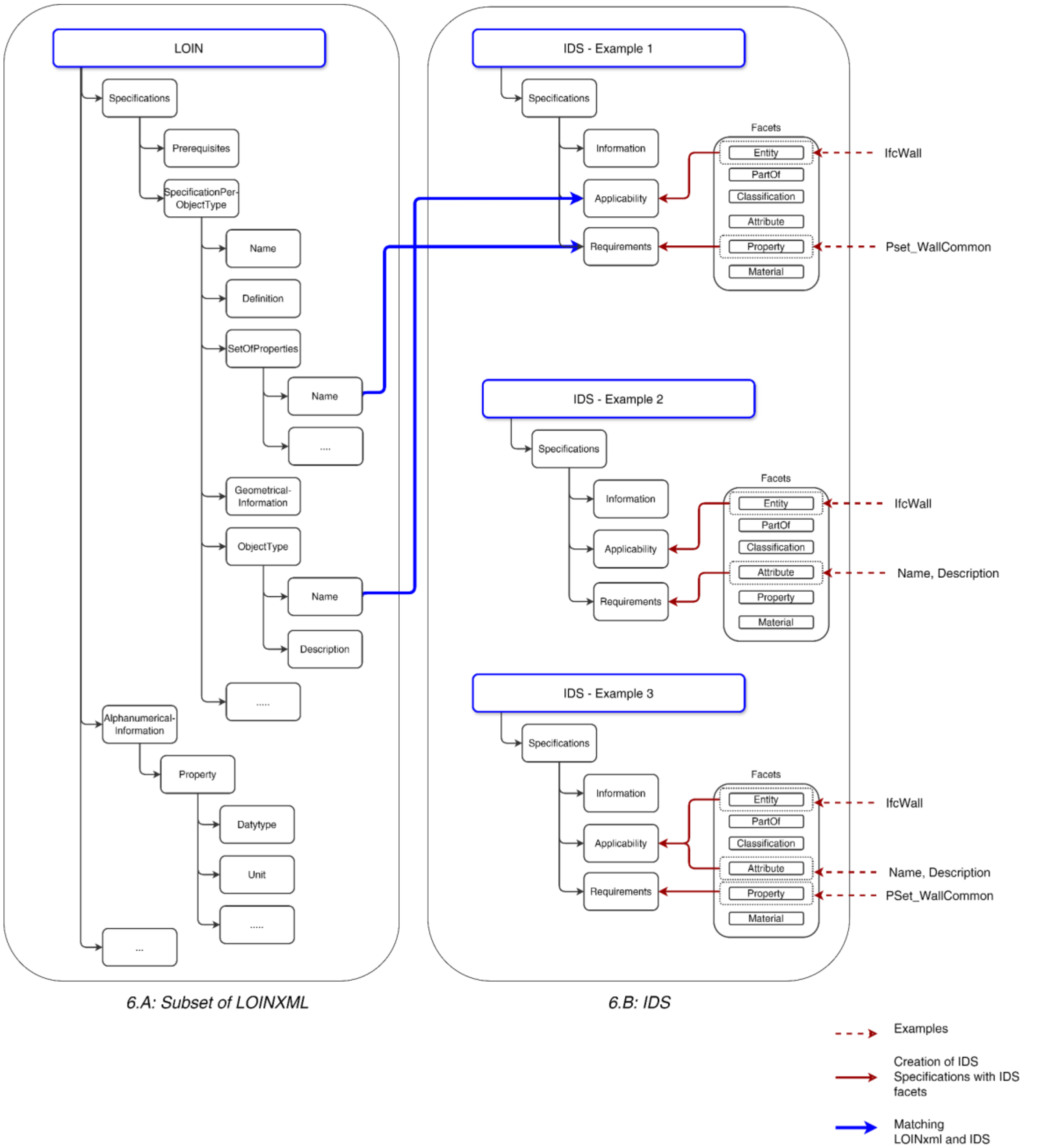


Figure 6: Mapping LOINXML and IDS with different combinations of facets. 6.A: Subset of LOINXML. 6.B: IDS schema.

On figure 6.A, a subset of the LOINXML is illustrated by the author, and the example schema sourced from the LOINXML (CEN/442, 2024) restricted-access GitHub repository. On the figure 6.B, IDS, which is published in the GitHub repository by buildingSMART International (2024) serves as the basis for this figure and it is illustrated by the author. In the first example in figure 6.B, the *Entity* facet such as "IfcWall" generates an *Applicability* which aligns with the *ObjectType* in LOINXML which can be simply expressed as "Wall" in LOINXML, and the *Property* facet which can be "PSet_WallCommon" or a custom defined property set generates *Requirements* which matches the *SetOfProperties* in LOINXML. In the second example, the *Applicability* aligns with the *ObjectType* as the first example, but this time, the *Requirements* are generated as an *Attribute* facet, which matches one of the attributes of the *ObjectType* in LOINXML such as "Name" or "Description".

In the provided examples, the *entity* facet from IDS is mapped with the *ObjectType* from LOINXML. Both IDS and LOIN can refer to objects to which a specification applies. Within IDS, users can use the *entity* facet in both the *applicability* and the *requirements*, which must point to a valid entity from the IFC schema, although the user may use any chosen string to name the *specification* or *requirement*. Alternatively, other facets may be used, such as *classification*, to set the *applicability* of the *specification*. In LOINXML, any breakdown structure can be used to identify objects. This may be the IFC schema, as with IDS, but could also be a classification system or any other chosen breakdown structure.

In both cases it becomes difficult to refer to objects for which no equivalent entity is available in the IFC schema for IDS and LOINXML or in the chosen breakdown structure for LOINXML. In IDS, alternative facets could be applied, such as the *classification* facet, or one can fall back on a higher-level or abstract class from the IFC schema to refer to the applicable entity.

5. LOINXML – IDS CONVERTER

To achieve successful integration, LOIN – IDS Converter is designed as a part of this research as shown in figure 7 and it is available in GitHub (Akbas, 2024) and was initially developed as a MSc Thesis by *RWTH Aachen University*. The tool is built using JavaScript, an XML library and Flask web application framework, along with other libraries. The main idea behind the converter is to show that it is possible to match elements between the two schemas from LOINXML to IDS.

To be able to match schemas, the first step is mapping non-matching entities and descriptions between the schemas to define differences. Non-matching entities should be transformed into each other. Moreover, the adaptable structure of the IDS should be addressed. The conversion mechanism must allow generation of different IDS scenarios based on project requirements as shown in figure 7 with LOIN-IDS converter.

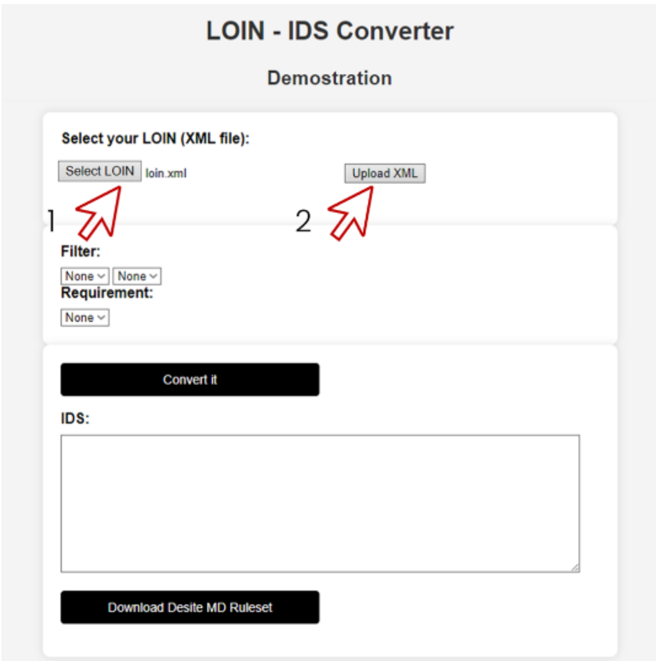


Figure 7: LOIN – IDS Converter Interface.

5.1 Implementation

Regarding the tool functionality, upon uploading a LOINXML file into the converter, dropdown menus are updated based on the data pulled from the file (step 1 and 2, figure 7). In this way, two key modules of IDS schema: *Applicability* and *Requirements* can be generated (step 3 and 4, figure 8). Once data is in there, users can click "Convert it" (step 5, figure 8) to create corresponding IDS schema. In LOINXML, elements are interlinked through a unique ID. *Properties* and *SetOfProperties* are linked, and *Data types*, *Units* are associated to *Properties*. When "Upload XML" is triggered by the user, *PropertySets*, related *Properties* and linked *Data types* are queried through the schema with unique IDs.

The converter is not designed to support every type of element in LOINXML. Currently, it is tested with *ObjectType*, *Property*, *SetOfProperty* with their child element *Name* and *Data types* of elements from LOINXML as an initial step to test integration possibilities. Future research may include other child elements such as *Definition and* Unit to expand the scope of the integration.

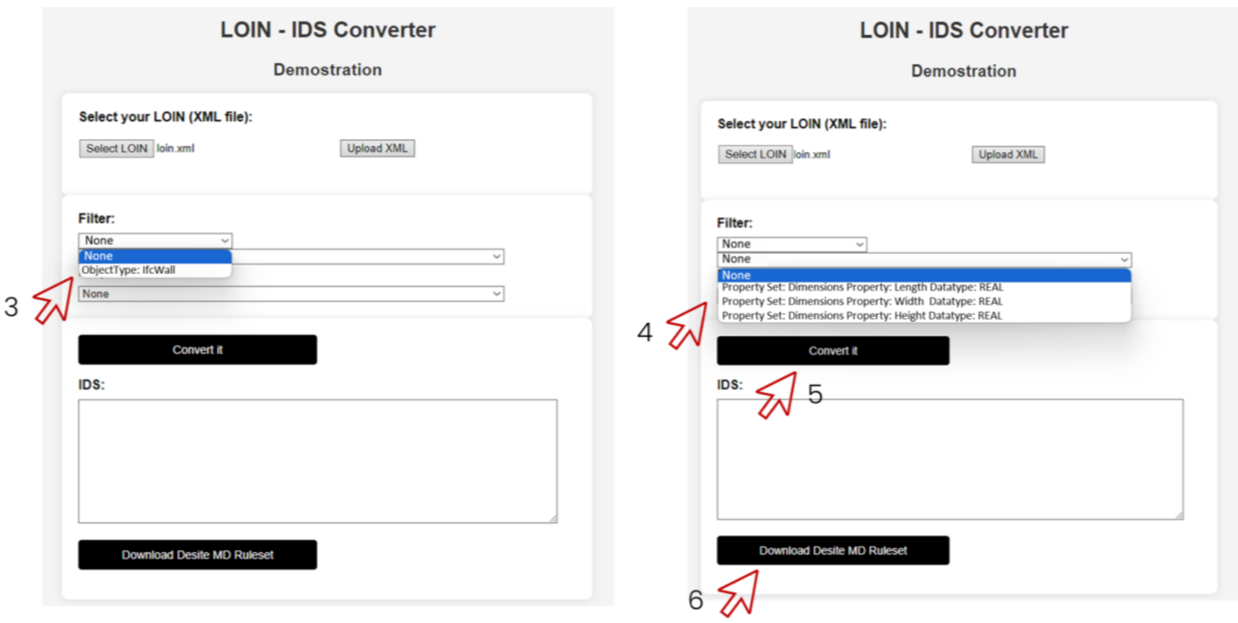


Figure 8: LOIN – IDS Converter Interface.

The implementation also addressed two challenging issues: units and data type representations. In IDS, units for numerical measure values are defined using the International System of Units (SI) (buildingSMART International, 2024). Each unit is a combination of the seven fundamental SI base units and expressed as seven dimensional exponents. LOINXML uses definitions provided by ISO 23387, which is aligned with ISO 23386, and also use SI units. When integrating LOINXML and IDS, alignment of the units should be considered.

Data types in IDS are based on the available data types from the IFC schema. They are typically numeric (e.g., integer, double), textual, an enumeration (also listed as strings) or logical (Boolean). Facing validation with IDS, the data types from the IFC schema are strictly defined for the attributes and the standard properties, thus an IFCTEXT is not an IFCBOOLEAN. LOINXML makes use of the data type definitions in ISO23387, which also provides extensive mechanisms to define the physical quantity, the dimension and the units. The data types are not restricted to the data types from the IFC schema. In the implementation, the conversion for the data types is realized with the conversion table which basically aligns data types in both schemas if LOINXML is not using data types from IFC schema.

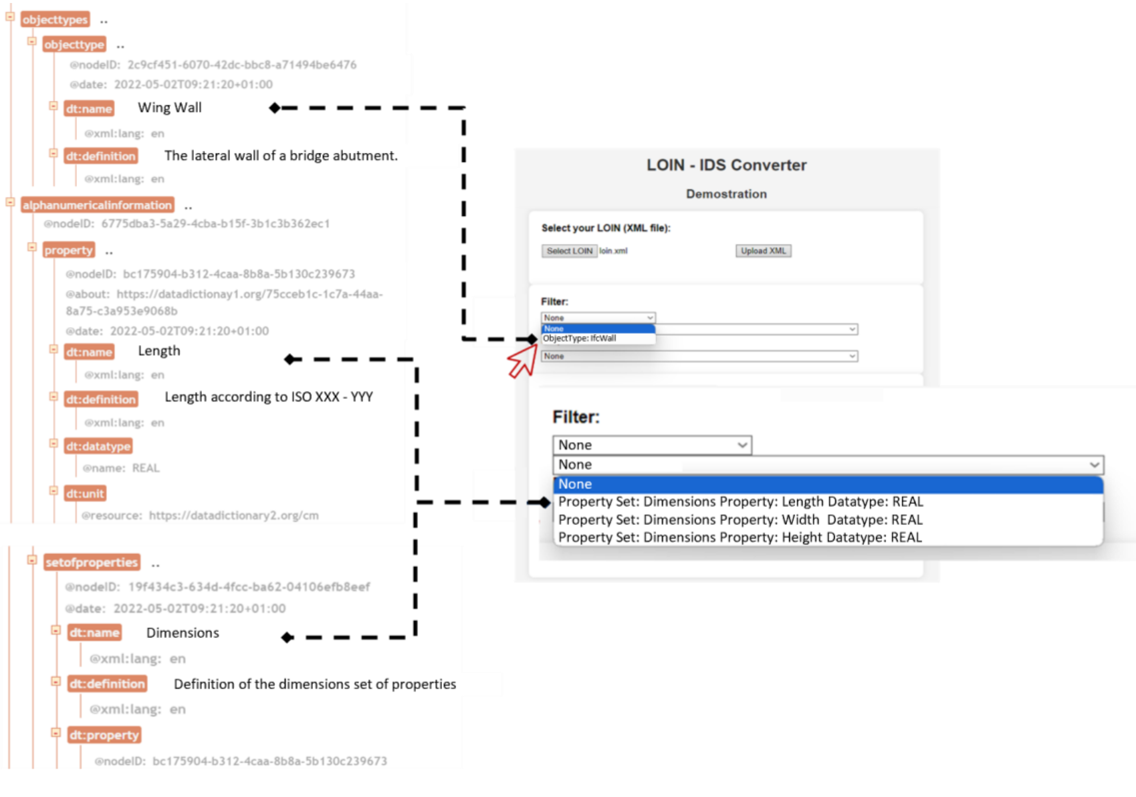
5.2 Use case: Integration with Validation Tools

Having machine readable requirements enables automatic validation (Pauwels et al., 2024) which can speed up the validation process. To adopt a holistic approach, a tool has been developed to generate IDS from LOINXML, with the second stage which is creation of a ruleset to use in model validation software from the IDS. On the figure 9.A, LOINXML schema is illustrated by author with Code Beautify (n.d.) and the schema (CEN/TC 442, 2024), maintained in a restricted-access GitHub repository, served as the basis for this figure. Figure 9.B is showing how the schema appears on the tool after it is uploaded. Therefore, the user can define the *Applicability* which is named as “Filter”.

As a next step, the tool is tested in Desite MD Pro, which is one of the Thinkproject products, widely used software in Germany for information validation to show industrial application and potential use cases for this type of converter. Desite MD Pro enables users to create rulesets in XML format and allows uploading external files (Thinkproject, 2024). As it is shown in figure 8 step 5, after converting files to IDS, it is possible to create a Desite MD Pro rule set out of IDS by clicking “Convert Desite MD Ruleset”. Additionally, it is possible to use Desite MD Pro interface to generate rules which is repetitive and time-consuming workflow. In figure 10.A, a filter list has shown, which needs to be generated manually one by one. Similarly, the requirements need to be generated individually under the corresponding filters.

Desite MD Pro rulesets are aligning with IDS in terms of structure. Therefore, to avoid duplicated work and provide a holistic workflow, Desite MD Pro ruleset is generated with the LOIN-IDS Converter tool and imported to the software. At the same time, a manual rule set (rule set 1, figure 11) has been generated to compare with the results of the rule set generated by the tool (rule set 2, figure 11). As it is shown in figure 11, both rule sets detected 56 objects and all of them validated.

Additionally, many other software tools and online platforms such as BIMCollab Nexus + Zoom, Solibri Office, BIMQ, ACCA usBIM.IDS, LastBIM and Blender extension Bonsai which are not tested part of this paper offer similar functionalities, enabling the conversion of IDS into rulesets to support various workflows.



9.A: LOINxml visualization *9.B: LOIN – IDS Converter*

Figure 9: Drop down menu options in LOIN - IDS Converter generated by using data from LOINXML. 9.A: LOINXML Schema Visualization. 9.B: LOIN - IDS Converter.

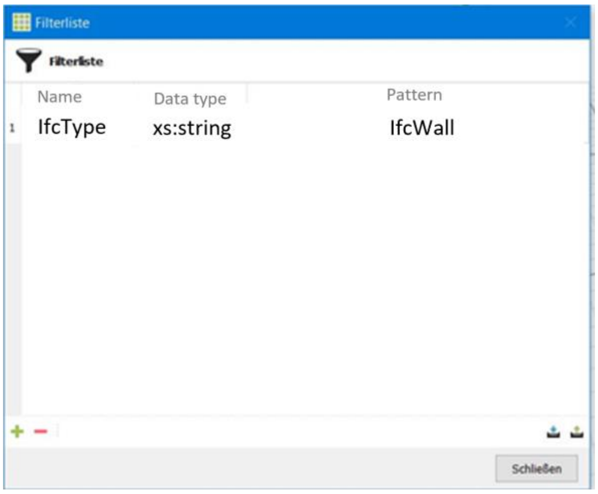


Figure 10: Desite MD Pro - Rule set creation interface.

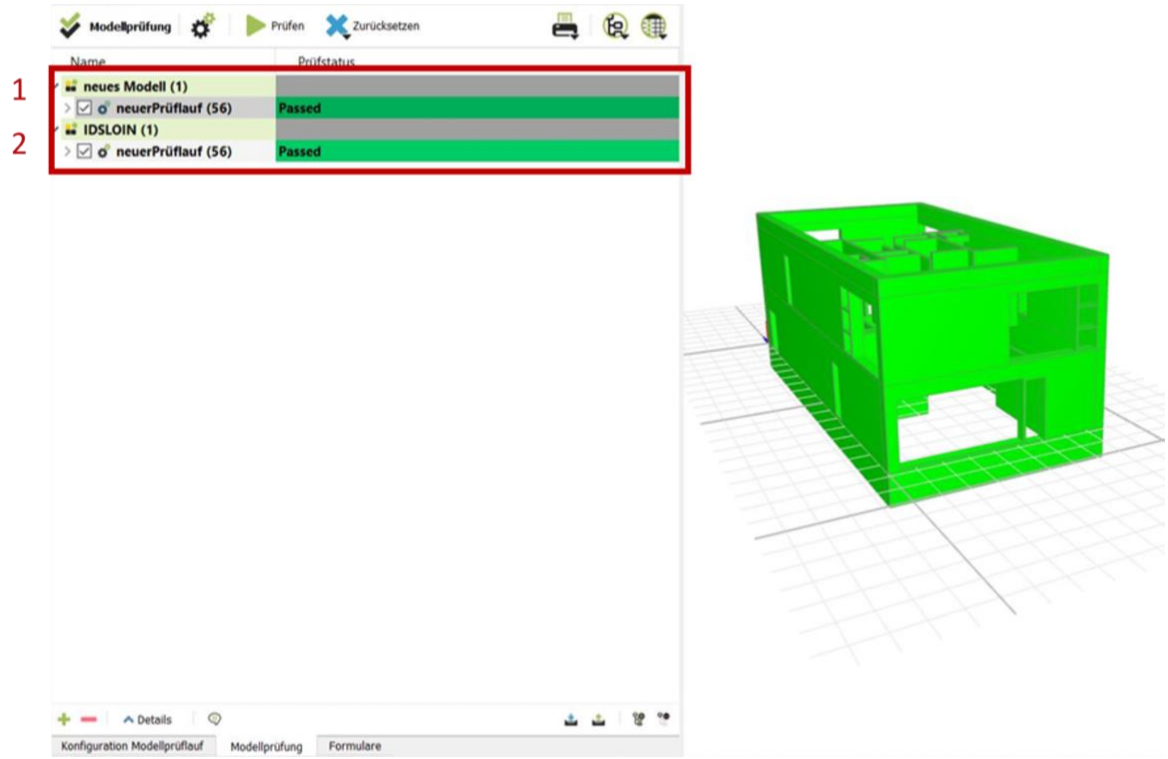


Figure 11: Desite MD Pro - Model validation.

6. CONCLUSION AND FUTURE WORK

This research shows that the LOIN framework according to ISO 7817-1 and IDS developed by buildingSMART International have overlapping scopes regarding the definition of alphanumerical information requirements. LOIN has a wider scope than IDS as it also includes *geometrical information* and *documentation* as well as prerequisites, in addition to *alphanumerical information requirements*. Moreover, LOINXML is intended to support other schemas beside IFC, and it is linked to data dictionaries through ISO 23386 and ISO 23387 (ISO, 2020b; ISO, 2020c), while IDS is based on IFC according to ISO 16739. The two schemas are still under development and changes might still occur, however there is already a need to integrate them as different tools are integrating IDS, and projects are requesting the LOIN framework as part of the ISO 19650 series to define the level of information need as part of the exchange information requirements.

This paper has identified and discussed the main challenges in performing such an integration. To overcome such constraints, the IDS-LOIN converter tool has been developed and results are verified with Desite MD Pro. The tool shows that an integration is currently possible. Some of the identified integration challenges can be handled with conversion tables. The tool is currently based on a subset of elements from the IDS and LOINXML schema; future work should be done to test the tool with the full schema and to integrate possible future developments of both schemas. Moreover, since both schemas are still evolving, the converter's features can be expanded according to updates. Future work on LOINXML - IDS integration may face limitations due to updates in both standards which may require adjustment to maintain compatibility. Additionally, larger or more complex projects may require more complex integration as the volume of data increases, and this complexity should be taken into consideration. In addition, current work can be integrated with other research focusing on IDS extension (Kremer and Beetz, 2023) or LOINXML integration with specific authoring software (Mellenthin Filardo et al., 2023; Mellenthin Filardo et al., 2024) to create seamless pipeline in information requirement specification and validation workflows. The conversion between IDS and LOINXML can avoid redundancy and ensure data consistency when IFC is used in projects.

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