Enhancing Information Requirement Compliance Through Automated Integration in a Modelling Environment

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Abstract. Information requirements for project deliverables are a key component of the Building Information Modeling (BIM) method. Currently, they are defined mostly in a text-based manner with high-effort creation by the information receiver and high-effort interpretation by the information provider, making this process error-prone and highly inefficient. Developments to address the formal checking of project deliverables, such as the standards Information Delivery Specification (IDS) and Level of Information Need (LOIN), are ongoing. This paper proposes the integration of information requirements from standardization into a modelling environment. To that goal, an extension to a popular modelling environment (Archicad) was developed and tested with BIM professionals to validate its suitability for the proposed processual change (preponing the usage of information requirements to also cover the design and planning phase) as well as the coverage of the input information requirements (from LOIN and IDS XML-based files). Results show the successful integration of LOIN and IDS requirements into the modelling environment, their limitations for that use case, as well as feedback from BIM professionals.

1. Introduction

One of the meaningful contributions of the Building Information Modeling (BIM) method consists of the collaboration between stakeholders working on consistent data (Borrmann et al. 2018), usually the so-called BIM models generated as project deliverables. Given the vital role these models play within the methodology, defining the scope of the information to be delivered also plays a vital role. BIM implementation in different countries varies, but in general it is agreed upon the need for requirement definition for the information delivery process (Bolpagni et al. 2022; Tomczak et al. 2022). The BIM implementation plan in Germany requires the definition of information requirements in documents called Employer Information Requirements (EIR) (German Federal Ministry of Transport and Digital Infrastructure 2015). This is reinforced by national guidelines (VDI – Association of German Engineers 2021a, 2021b) and does not contradict the international ISO standard series 19650 (ISO 2018), which defines Exchange Information Requirements. When considering the levels of BIM implementation in Germany, EIR play a vital role, given that a key realization feature of "Niveau 1" is the formal checking of project deliverables (BIM models) for fulfilment of the EIR (Borrmann et al. 2021). If the implementation of the BIM methodology can be understood as part of a digitalization strategy, it is questionable then, that these requirements are to be defined in running text, which are open to interpretation and distributed as PDF files, as investigated previously (Mellenthin Filardo 2019), and confirmed by Tomczak et al. (2022). The focus of the BIM "Niveau 1" on checking has the effect, that research activities also tend to focus on this, resulting in many solutions that focus on the output, not necessarily considering the delivery process itself, as illustrated in Section 2.

This study is set in a series of publications aiming at developing a standard for information requirements that is compatible with the required checking of project deliverables. Its key feature, however, is that it allows information providers to actively use defined information requirements during all phases of a project and especially modelling, meaning that information

requirements have been formalized and imported to the modelling environment, thus making project deliverables EIR-conformant by default. Otherwise, the entire information delivery process continues to be as it is today: A game of Battleship, where BIM models are built 'conventionally' (without EIR), but checked in the most enhanced manners (e.g., automated rule checking based on IDS, SHACL and such). To this goal, information requirement documents were sampled from the industry and analyzed (Mellenthin Filardo 2019). Based on this analysis, the content of EIR was formulated, as proposed in Mellenthin Filardo and Krischler (2020), and an a priori process suggested (Mellenthin Filardo and Krischler 2021), in which machine-interpretable EIR could be integrated in the information delivery process prior to the actual modelling. Through this processual change (allowing information to be compatible with requirements from creation on), error-prone manual efforts and human interpretations can be reduced and finally, iterations within the delivery process of project deliverables can be minimized, given that information requirements, such as properties assigned to entities (among others), are assigned by default. Through this approach, the ultimate goal of EIR-conformity can be increased. Moreover, the (perceived) increased effort associated with the BIM method can be reduced, thus aiding in overall adoption.

To test and illustrate technical limitations of the XML-based input EIR within the modelling environment, a more comprehensive prototype in the form of an Add On was implemented within a popular modelling environment (Archicad 26), as shown in Mellenthin Filardo et al. (2023). To confirm that the proposed processual change, embodied by the Add On implementation, goes in conformity with user needs, and to assess requirements regarding the input, the prototype was demonstrated to BIM professionals. Their feedback was surveyed in an anonymous questionnaire, divided into categories, and used to improve implementation in the Add On, as shown in Section 3. Results are shown in Section 4 and discussed in Section 5.

2. Related Work

2.1 Standardization of Information Requirements

As identified by Bolpagni et al. (2022), standardization in the construction domain has two anchor standard series: ISO 19650 and ISO 12006. The role of information requirements is mainly described in the ISO 19650 standard series (ISO 2018), where the information delivery process is described, including the Level of Information Need (LOIN) approach to describe the information needed in the delivery process. Subsequently, the ISO 7817 standard series for the LOIN (ISO 2024) is being developed (GitHub 2024a), with an XML-based schema for specifying alphanumerical as well as geometrical information, and documentation in addition to prerequisites (purpose, milestone, actors) for project deliverables coming in part 3. The LOIN specification is agnostic, which means it can be applied to various data models (IFC, LandXML etc.). The current version of the XML-based LOIN schema (XSD, XML Schema Definition) uses the structure defined in the ISO 23387 standard for data templates for construction objects for the alphanumerical information, which in turn considers specifications made in ISO 23386 as well as the ISO standard series 12006 (ISO 2020). Through this development, the LOIN alphanumerical information can be used to define properties as well as sets of properties for specific element types (with or without predefined values, datatypes, boundary values, units, symbols, and physical quantities). Given the usage of the data template schema, the current version of the LOIN requirement definition allows external references to data dictionaries as well as classification systems (GitHub 2024a).

Simultaneously, the non-profit organization buildingSMART International, credited with the development of the Industry Foundation Classes (IFC), is developing the Information Delivery Specification (IDS), which allows the definition of information requirements using facet types, already known from the IFC data model, such as entity, attribute, classification, property, material, and parts. These facets can be combined within the XML-based IDS schema through the elements' applicability and requirements (GitHub 2024b). Value constrains can be expressed using regular expression patterns (regex) and restrictions. IDS is intended for formal checking by comparing an IFC and an IDS file through querying.

2.2 Information Requirement Integration

Information requirements are a popular research topic. Tomczak et al. (2022) analyzed available methods for information requirement definition (highlighted as (A) in Figure 1) and partially for automated checking (highlighted as (C) in Figure 1). Among the analyzed approaches are not only the aforementioned LOIN (after part 1 of the norm, without a schema) and the IDS schema, but also conventional spreadsheets, the Information Delivery Manual (IDM) combined with Model View Definitions (MVD), the IfcPropertyTemplate from the IFC data model, data templates (after ISO 23387), as well as approaches from the Linked Data (LD) and Semantic Web community, such as LD+SHACL (Shapes Constraint Language) and data dictionaries. All the compared approaches are technology agnostic. From the compared approaches, all but the LD approach are either standardized or waiting to be. The authors highlight similarities between MVD (primarily a filtering mechanism for the IFC data model aimed at software vendors) and SHACL, given that both allow filtering, validation and inference of data sets as well as integral definition of both semantics and specification. Of the analyzed approaches, only IDM and MVD, LD+SHACL and LOIN address geometry, with LOIN allowing by far the most detailed specification. Further, since the review, the development of the LOIN includes a schema specification that also regards the current data templates schema, combining those approaches. Therefore, the points not covered by the LOIN in this review (certain value constrains, content existence) are supported in the current schema version. The only review criteria not met by the current LOIN schema are, to the best of the authors knowledge, process maps and pattern for value constrains.

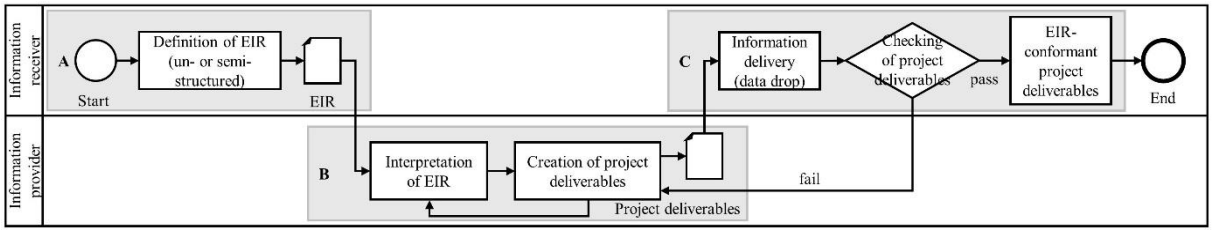

Figure 1: Diagram of the conventional information delivery process, based on the ISO 19650 framework (ISO 2018), and divided into swim lanes. (A) and (C) highlight the focus of related work, while (B) highlights the focus of the proposed research, elucidated in Section 3.1.

In the domain of automated compliance checking, highlighted as (C) in Figure 1, Nuyts, Bonduel an Verstraeten (2024) compared IDS, XSD, JSON (JavaScript Object Notation) schema, Web Ontology Language (OWL) + SPARQL Protocol and RDF Query Language (SPARQL), Semantic Web Rule Language (SWRL+SPARQL), SPARQL and SHACL. The authors analyzed information availability, as well as value, relational, mathematical and conditional constrains (analyzed proprietary solutions excluded). The authors found that only IDS, JSON schema and OWL (+SPARQL) did not cover all of the set criteria, highlighting the

suitability of XSD, SWIRL, SPARQL, and SHACL, the latter one especially. Furthermore, they highlight the need for agnosticism and standardization.

3. Add On Evaluation

3.1 Research Gap, Aim and Requirements

Given the identified gap between areas (A) and (C) in Figure 1, this research focuses on area (B), by proposing a change both in the information delivery process and in the form of information requirements, shown in Figure 2. The processual change consists of using information requirements not only for checking as is currently the case, but also for modelling, thus generating EIR-compliant project deliverables by default. This change could significantly reduce iterations within the information delivery process, in which the project deliverables, e.g., BIM models, are sent back and forth for rework until they pass the formal conformity check. With the information requirements included in the deliverables since creation of all elements within the modelling environment – or even by adding them during modelling – efforts of both information receivers and providers can be drastically reduced.

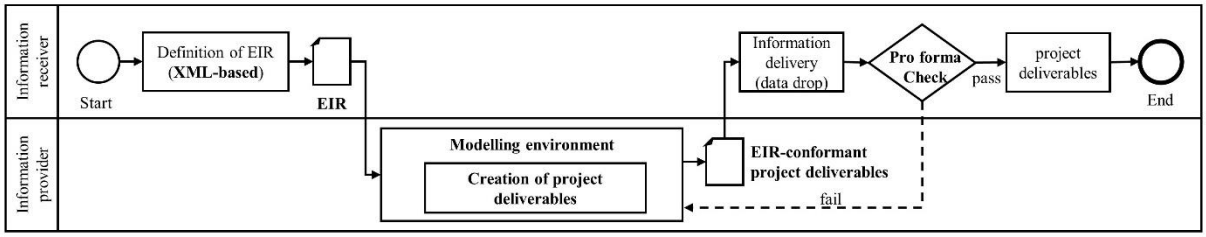

Figure 2: Proposed workflow change for the information delivery process.

Regarding the form of information requirements, the proposed Add On implementation aims to provide a machine interpretable EIR that supports established standards for information requirements by including standardized XSD, such as the LOIN schema.

3.2 Previous Implementation and Add On Input

The scope of the input file for the Add On was based on previous research on EIR documents. Given the closeness of EIR and the LOIN scopes, the input file is XML-based to accommodate the LOIN schema proposed in ISO 7817-3. This design decision allows the implementation of the alphanumerical information according to the current version of the LOIN schema from ISO 7817-3 (GitHub 2024a), including the data template mechanism proposed in ISO 23387 (ISO 2020). In addition, the XML input was extended to address information requirements included in EIR documents, but not necessarily in the LOIN scope, such as geolocation settings (EPSG codes, coordinate systems, coordinates), project info (contact details of information provider and deliverer), provided data (reference documents and their location), file naming requirements as well as formats and versions (used for automated export), required trades, among others, as explained in Mellenthin Filardo et al. (2023). The Archicad Add On (named iReq) was implemented in C++ using the Archicad Software Development Kit (GRAPHISOFT 2024). It has three primary functions: (1) Load XML, (2) Data Drop and (3) Provided Data, which trigger a set of other functionalities each. (1) allows the user to load an XML file, e.g., project specific EIR information. (2) triggers a one-click automated export of the project deliverables (IFC as well as PDF files) according to the naming convention, file format, versioning, and in the case of IFC, even the MVD, to a specific path (e.g., desktop or CDE)

defined in the previously loaded XML file. (3) merely enhances comfort by allowing users to visualize and access reference documents (e.g., drawings, documents, survey data) from the modelling environment, thus avoiding oversight as well as long searches in complex, project specific file and folder structures.

3.3 Peer Group Evaluation Loop

The peer group evaluation with BIM professionals addresses two main issues of the proposed research. (1) it acts as a fail-safe to assure that the content of defined requirements, based on previous research, continues to be in agreement with industry needs and not just conforming with possibly far-fetched standardization and research work. (2) it supports both the technical feasibility and content validation of the proposed workflow change described in Section 3.1.

The first round of peer group evaluation was performed between January 31 and February 29, 2024, with 23 BIM professionals working in building planning and construction in Germany. The evaluation started with a demonstration of the Add On (named iReq). First, the input information (XML file) was shortly shown for context. Subsequently, all functions of the iReq Add On were demonstrated, including their effects in- and outside the modelling environment. Finally, an anonymous survey with 10 questions was distributed.

Of these 23 BIM professionals, 91 % stated that they are required to deliver BIM models and 83 % claimed to receive EIR information. Of these, 78 % indicated that they receive text-based documents (PDF or comparable). All BIM professionals use a modelling environment.

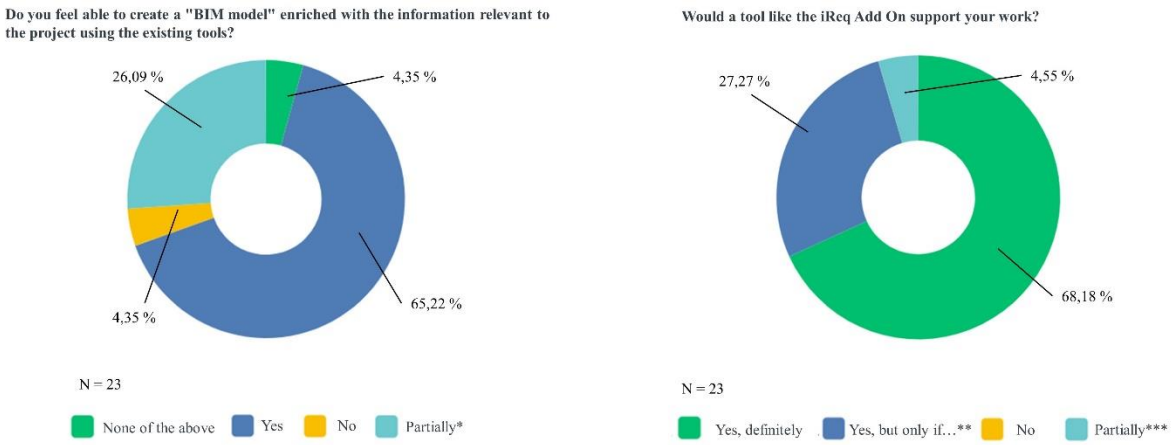

Figure 3: Excerpt from the survey with BIM professionals. The left diagram shows how many are required to create BIM models (blue and cyan, 91 % in total) and the right one shows how many would use such an Add On as well as the required XML-based EIR (blue and green, 95 % in sum). Asterisks denote answers, where user could explain their reservations in their own words.

Furthermore, when asked if they see benefits in using such a tool as the proposed Add On themselves, 87 % agreed, with another 13 % agreeing with reservations regarding the ability of clients to provide such input files. When asked about further necessary features of the iReq Add On, user feedback ranged from extending the input information to support IDS over an enhanced user experience within Archicad to user management capabilities, such as managing updates of the XML input file and having an overview of the classification elements and the assigned properties and sets of properties. The peer group evaluation is still ongoing.

3.4 Feedback Implementation Loop

The user feedback was assessed and classified in three categories, as shown in Figure 4: (1) user experience/Archicad usability, (2) extension of the Add On input and (3) user governance.

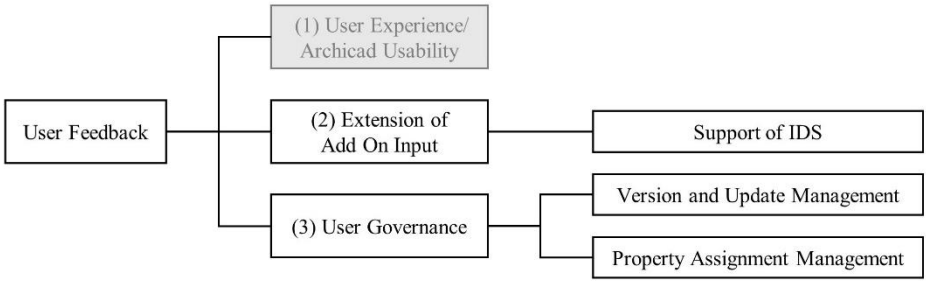

Figure 4: Classified user feedback from surveyed BIM professionals.

(1) was disregarded, given that it is a vendor issue and not part of academic research. For broad application and acceptance of the proposed methods, intuitive design and usability are important. Under (2) the authors identified that multiple users would prefer to use IDS as an input for the iReq Add On. Under (3) the authors formulated two main subcategories: Versioning and update management (of the XML input) and management of the automated property assignment. These three improvement and extension goals were implemented using the Archicad SDK, also used for previous implementations.

For the support of the IDS input, a testcase from the IDS GitHub repository (GitHub 2024b) was used as a reference, from which the XML input file was extended with an IDS part, which assigns a property with an integer value to an IfcWall. The IDS data type was modelled through a restriction (xs:integer) on the possible values. While IDS supports multiple facets for defining applicability and requirements, not all are suitable for inclusion in the design environment from the beginning on, as they rely on existing structures and designs. The suitable subset of facets however could be implemented and supported well.

To simplify the management of the automated property assignment, the updated implementation now integrates deeper into the logic of Archicad by integrating the requirements on the classification level, and not on the level of individual parts, as was the case before. Here, the improved integration into the Property Manager functionality comes at the cost of a very specialized implementation, that cannot easily be transferred to other environments. After the update, the assigned properties and their constraints can be managed in the interface that experienced users of Archicad already know and use, so the integration into existing workflows becomes more seamless.

An important aspect identified in the survey was the management of updates and changes to the imported requirements. As currently the EIR and its implementation are not considered fixed, but should develop during the design process, changes become inevitable and must thus be regarded. Upon importing a new XML file into the iReq Add On, the new requirements are merged into the application. Upon a conflict, for example when the datatype or the name of a property changed between versions, the user is prompted for a decision. This is inspired by the merging in the Git version control system and prevents accidental removal or change to the requirements. This merging strategy works for requirements from LOIN and IDS, so the integration of those two approaches becomes feasible and useful.

4. Results

The input file used for evaluation, containing alphanumerical information after the LOIN schema (life cycle costing (LCC) codes after ISO 15686-5, as well as German cost classification properties (DIN 276) assigned to either Wall or Column or both) as well as project information (project status, phase, required trades (for drawings, lists and specific output files), contact and client details, IFC output (design transfer view MVD, IFC version 4), project location (EPSG codes for the project zero, including coordinates, coordinate system, geodetic datum and vertical datum), provided data (file names, Uniform Resource Identifiers (URIs), and paths), and the previously described IDS testcase information was loaded by the iReq Add On. After loading the XML file, all requirements, including both the LOIN alphanumerical information and the IDS information are stored into the Archicad project. The LOIN and IDS information is stored more precisely to the Archicad Property Manager, where all the properties and property sets are summarized including their assigned classes in the Archicad classification system and can be managed easily. This accommodates the user governance evaluation feedback, given that users can see clearly which properties exist within the project and to which elements or classes they are assigned to.

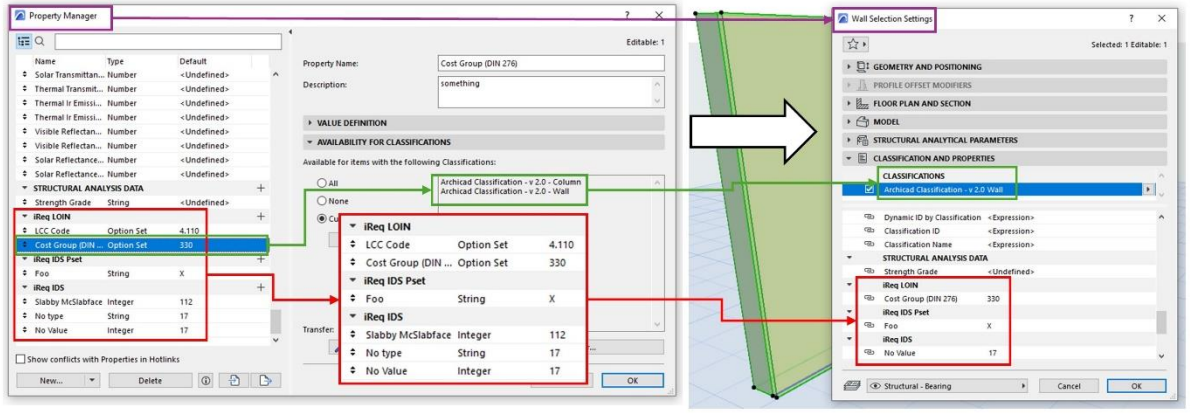

Figure 5: Implementation of user feedback results of the categories (2) extension of the Add On input (red and green) and (3) user governance (violet), where both the LOIN and IDS conformant properties and their values are mapped to specific elements by default within the property manager tool.

The Property Manager also allows editing. An excerpt of the Property Manager can be seen in Figure 5 (left), where the loaded LOIN and IDS properties are shown with their respective assigned classes. To confirm that the assigned properties have indeed been assigned to the intended elements, the settings for a Wall element are shown (right), where the defined and loaded requirements, both LOIN and IDS, can be found (properties and default values, where defined).

Furthermore, the management of XML input version changes and updates was implemented. As shown in Figure 6, when loading an XML file, the iReq Add On will check if the loaded content already exists and ask the user for a decision, either keep the existing data or overwrite with the new one. The Add On does this for all the loaded content upon every import if a collision is detected.

The presence of information requirements imported by the iReq Add On in the output IFC file has already been addressed in previous research (Mellenthin Filardo et al. 2023).

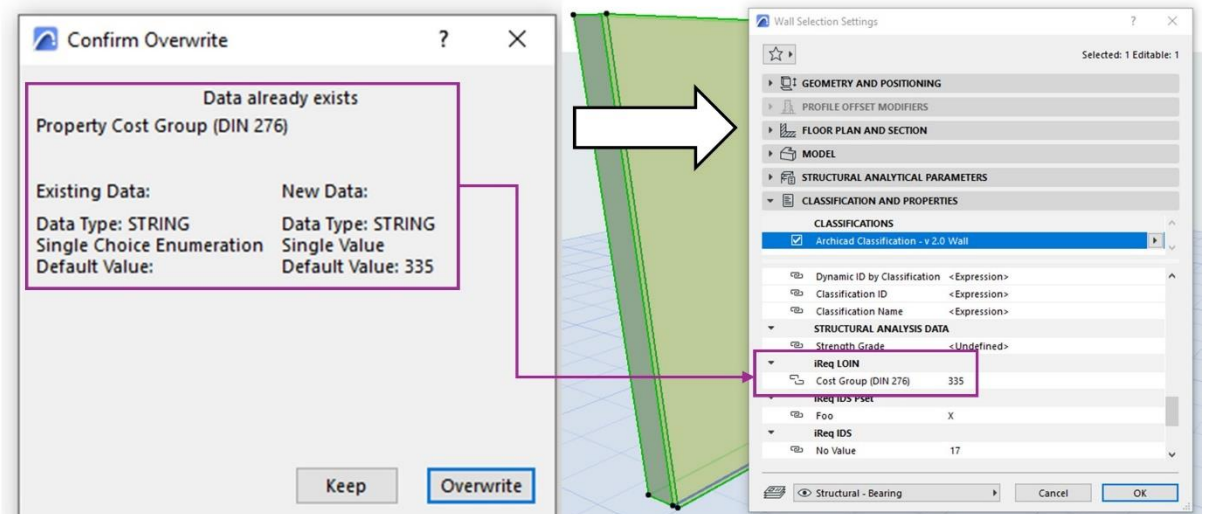

Figure 6: Implementation of user feedback results in the category User Governance (violet), depicting version management and overwriting options of loaded XML-based information requirements.

5. Conclusions

This paper presented the evaluation with BIM professionals and subsequent extension of the iReq Add On for Archicad 26, which consists of a series of functions to import, assign, manage, and export information requirements based on established standards. This study shows that both the LOIN and IDS approaches are compatible with the proposed change in the information delivery process: Preponing the usage of information requirements to cover not only the checking process, but also the generation of conformant project deliverables. It further shows a possible solution for versioning and updating information requirements as well as enhanced management of assigned LOIN and IDS requirements, aiming at a broad adoption.

Regarding the IDS extension specifically, the authors observed that the dependence of IDS on IFC sometimes makes it difficult to abstract the used concepts into more general form and be agnostic of the underlying classification system. Regarding the LOIN schema, the authors could confirm that the inclusion of the data template structure is a well-suited mechanism to describe the alphanumerical information. It also showed that requirements for the project output, such as naming, file format, version, MVD (in the case of IFC), were not covered by the documentation element of the LOIN schema. Further, the LOIN schema addresses information provider and information receiver in the prerequisites, but it does not allow the definition of details, such as contact information, which is usually needed in such projects and could easily be implemented. These findings should be regarded in future development of the schema.

These results show that many of the existing concepts and approaches developed for model checking can already be used during the design phase, when integrated directly into the modelling environment. The two standards used in this work for the formulation of requirements, LOIN and IDS, already cover a large portion of current use cases, which further motivates this development. Furthermore, this work demonstrates that already existing standards are well suited for addressing the identified research gap, highlighting the potential of processual changes in the information delivery process, especially during design and model

checking, instead of a change in standards or the development of new schemas. It also illustrates how a reduction in management overhead between stakeholders could look like by allowing an automated information requirement management within the software.

Future research should extend the LOIN Add On implementation to also cover geometrical information. Given the ongoing development of the schema, this research focused on the more advanced part of the schema (alphanumerical information). The results should also be validated in different modelling environments, as the specifics of the Archicad modelling environment its limitations may have influenced some implementation design choices. Nonetheless, it shows the viability of the information requirement coverage in modelling environments based on a standard, similar to the IFC support by software vendors.

Data Availability

The Add On developed in this paper and the input data are provided at: *https://github.com/mafilardo/iReq*.

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