Reusability and Its Limitations of the Modules of Existing BIM Data Exchange Requirements for New MVDs

13

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Abstract

Model View Definition (MVD) is developed as a subset of the IFC schema to define BIM data exchange requirements of the architecture, engineering, construction, and facility management industries. Several domains such as the Precast/Pre-stressed Concrete Industry, the American Concrete Industry (ACI), the American Industry of Steel Construction (AISC), and the U.S. Federal Highway Administration (Brim MVD) have defined or are currently defining model views for formally representing their BIM data exchange requirements and assisting their exchange processes using the neutral data format, IFC. However, even though several domain industries involve the same or similar sets of data exchange requirements for their MVDs, a lack of a proper approach for reusing existing MVDs results in that a data exchange process of new MVD including the same entities, attributes, and relationships of other MVDs contains inconsistent and heterogeneous sets of data exchange requirements. For accelerating the consistent MVD development reusing previous efforts and the interoperable BIM data exchange environment, this paper involves the investigation of existing MVDs and their module-based definition processes to identify the current problems in MVD development regarding reusability and contains the discussion of the promising method for utilizing predefined MVDs for new MVD development.

Keywords

Model view definition (MVD) • IFC schema • BIM data exchange • Interoperability

13.1 Introduction

Building information modeling (BIM) is not only an approach for digital representation of characteristics of a facility, but also a process of creating and managing such information as a tool for decision making throughout the lifecycle of the facility [1]. The key factor for success of BIM in industry is an efficient and flawless interoperability solution for its information flow between different disciplines [2].

Interoperability is imperative for sharing data between BIM software supporting different phases of building. There are various domains of AEC-FM industry that have already defined and been developing their exchange requirements of BIM data. The BIM data exchange should include a geometry of the model and an appropriate level of detail regarding building components [3].

Industry Foundation Classes (IFC) has been developed as a standard to support a full range of BIM data exchanges among different disciplines and heterogeneous BIM applications. Each domain adopts the part of the IFC schema to represent a BIM model with the pertinent domain knowledge. The subpart of the IFC schema is Model View Definitions

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(MVD) [5]. In addition, Information Delivery Manual (IDM) is developed for identifying exchange requirements (ER) of BIM data [4]. Since several BIM data exchanges of project phases consists of duplicated information, a concept that specifies information of an entity, an attribute, a relationship, or a property set, is repetitively utilized to avoid a redundant definition of BIM data exchange. Developing a well-defined MVD plays a pivotal role for successful building information exchange throughout a building project.

One primary idea in MVD development and data mapping processes is modularization. Modularization organizes a block of code with reference names and bindings so that it can be re-used. Modularization is an important means to classify and re-use information in most areas of software design and production. However, because of a lack of a feasible method or a robust standard for retrieving and utilizing the existing data exchange requirements and MVDs, the academia and the industries have been struggling to reuse predefined IDM and MVD for developing their MVD by reusing the definitions of the same requirements. As a result, several MVDs entail heterogeneous requirements and semantic compositions for the same BIM data exchange process with exiting MVDs. For the interoperable BIM data exchange environment in the AEC industries, this paper involves the investigation of existing MVDs and their development processes to identify the current status of industries' MVD development and develop an innovative framework for semantically and syntactically integrating BIM data exchange requirements of existing MVDs. In addition, this paper presents current development and potential uses of modularization to respond to the redundancies in the MVD development process and their benefits in making model views easier to define and implement.

13.2 Background

The development of MVDs mainly has four phases: (1) IDM development, (2) MVD concepts and mapping, (3) application implementation and certification, (4) BIM validation [6]. IDM is defined by industry professionals to create human-readable references for ER of specific exchange scenarios in use-cases [4]. ER is specified as Exchange Requirement Models (ERMs) and Functional Parts (FPs) mapped to a data model schema (IFC) to define model views. This step principally involves MVD developers and software vendors to carry out the specification process for the relevant use cases.

Then, these MVDs can be implemented in applications to develop translators in BIM authoring tools in order to execute IFC import and export routines for target exchange scenarios [7]. In the validation phase, an IFC instance model exchanged between different applications is examined to ensure that the model satisfies ER. Currently, according to this process, various groups have developed IDMs and MVDs for their target domain model exchanges. Developed MVDs and on-going projects are listed on the webpages of buildingSMART-tech.org [6].

For the sake of the MVD development, domain industries identify exchange models from the outset that illustrate who exchanges what BIM models and their information in what phase of the project. With the purpose of obtaining practical information of industries and professionals, the previous MVD development projects investigated the information from diverse user communities and software vendors.

13.3 Methodology

While most of developed MVDs focused on a particular domain, a large-scale project such as civil infrastructure construction generally involves diverse domains and requires iterative BIM data exchange processes among heterogeneous project participants. For providing a knowledge base and a development framework for defining an MVD standard, this study explores the in-depth analysis of existing MVDs in diverse industry domains and has a discussion of a promising approach for efficiently reusing BIM data exchanges and their requirements. To identify the heterogeneous sets of existing MVDs, the authors investigated the following MVDs: The Precast/Pre-stressed Concrete Industry (PCI), the American Concrete Institute (ACI), and American Industry of Steel Construction (AISC).

13.3.1 A Modularized Concept

Previous project of IDM and MVD development focusing on a general domain has shown that the concepts are highly redundant. Many repetitions exist of entity structures, features, relations and properties within different types of building elements. Redundancies may not be recognized without addressing multiple exchanges within a domain rather than

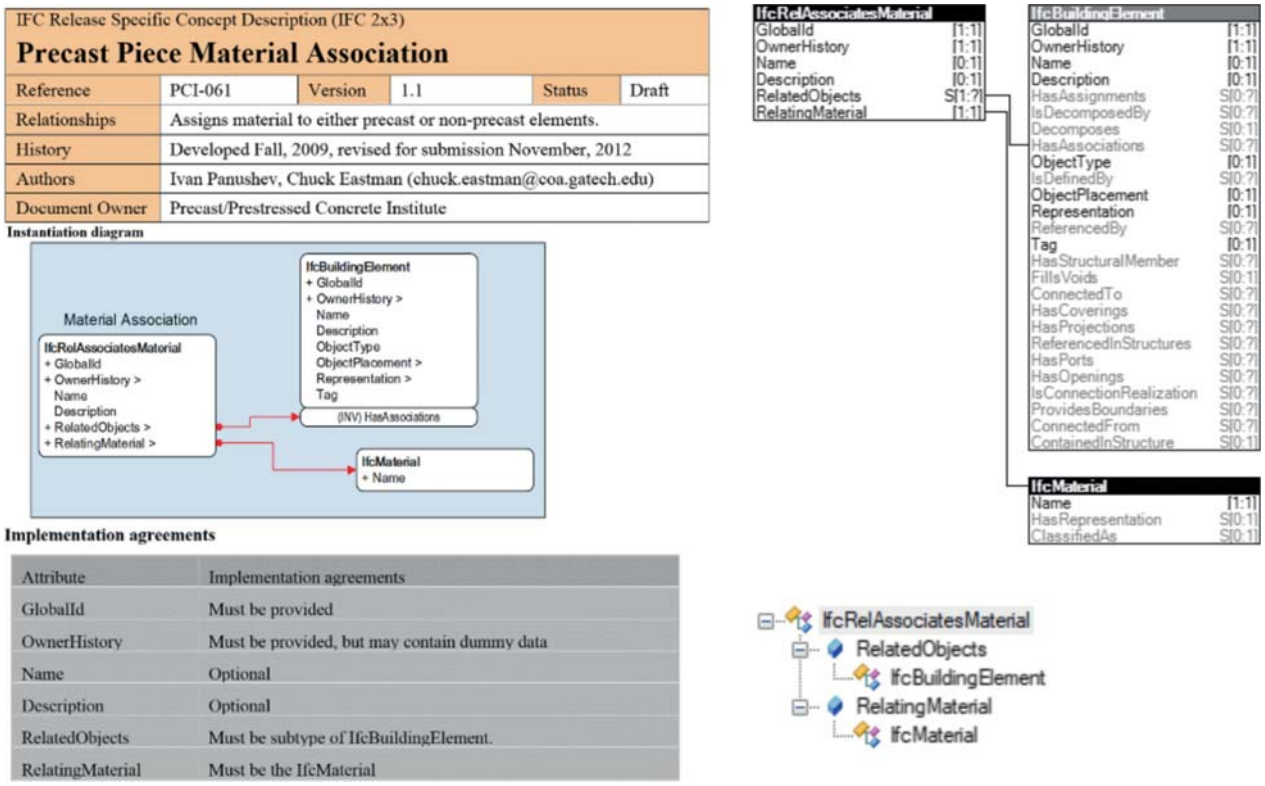

Fig. 13.1 A Blis concept defined for the precast piece material binding association and developed in the IfcDoc tool

singularly at the EM level. Software engineers extending their different BIM applications recognize redundancies when they write them and develop their own libraries of these data models, re-using them instead of coding them anew so as to reduce software maintenance efforts. Modules in IFC, were presented by Hietanen and See [5]. They adopted the word "Concept" as a way to organize code structure units and to name and access them. Concepts could include entity types, defined types, rules, functions and property sets and other IFC constructs. We refer to their definition as the Blis Concept definition. In practice Blis concepts were used as units of documentation, defined with a documentation template. Figure 13.1 shows a Blis Concept defined for the precast piece material binding association. The structure is diagrammed and its attribute rules are specified. IfcBuildingElement may be any sub-types of IfcBuilingElement.

13.3.2 A Concept in the IfcDoc Application

To efficiently assist MVD documentation and leverage definition reusability, IfcDoc has been developed by Constructivity, LLC and approved as a standard tool by buildingSMART international [8]. This application, which has been used for developing IFC 2 × 3 and IFC 2 × 4, facilitates the documentation of an MVD and to automatically graph the syntax specified. Parsing any MVD, say for diagramming it, requires that the MVD is syntactically correct. Thus, IfcDoc must parse the MVD against a standard version of IFC, which is usually taken until recently as the Coordination View (CV). IfcDoc has been made available as open source software, available in source and executable formats, with some documentation [9]. It adopted the way using a concept template so that the broad definition and requirements are used in several objects. Concept root was defined as a method to determine at what level in the Concept structure a particular concept should specialize. The concept template is a reusable definition skeleton that consists of the most frequently used entities, relationships, and attributes. Figure 13.2 shows a Blis Concept template of the precast piece material binding association developed in the IfcDoc tool. Concepts are focusing on specific objects, but some address a broad area, missing specific target object. This vague scope can make errors when a large sample having diverse types of entities is validated.

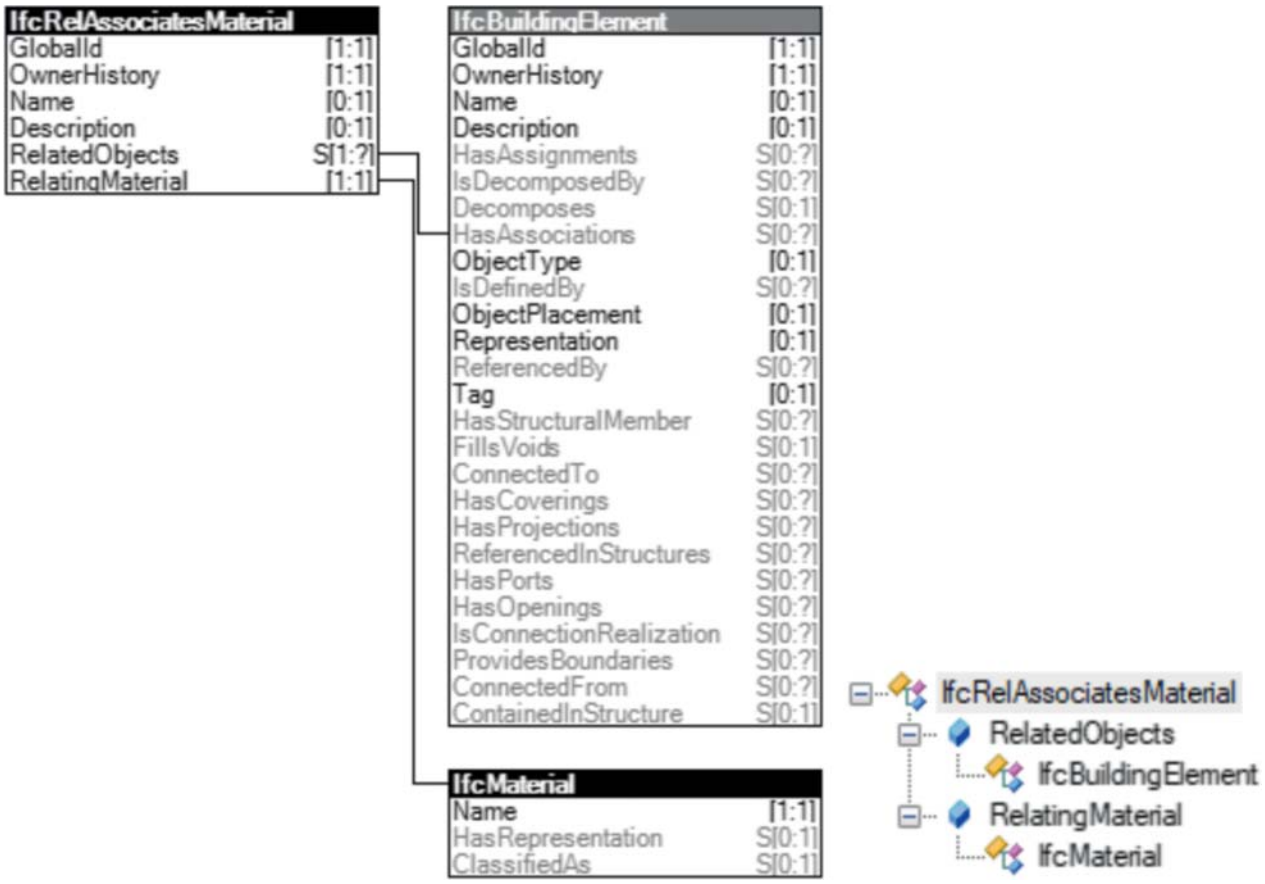

Fig. 13.2 A concept template of the precast piece material binding association developed in the IfcDoc tool

Based on this concept template, users can define concept blocks by adding more entities, relations, attributes, and properties in order to represent required exchange models. Thus, the concept templates are typically reused several times to define diverse exchange requirements that are developed as concept blocks. The composition of mandatory concept blocks is one EM. In addition, the collection of required EMs is one MVD. Figure 13.3 shows the concept block assigning the concept of the precast piece material binding association (PCI-061). The concept template can be reused by several entities, attributes, relationships, and property sets for efficiently representing BIM data exchange requirements with a limited set of definitions.

IfcDoc incorporates procedures to read and arrange IFC documentation in XML called mvdXML. It also has a checking capability to evaluate IFC instance files according to an imported EM in relation to the rules the MVD is part of. It automatically checks the MVD specification if the IFC structures make a well-defined IFC MVD sub-structure. The beginning MVD structure may be a full IFC schema, such as Release 4 or a restricted EM subschema, such as EM2 from the precast schemas. We use the schema checking capability of IfcDoc to check if a concept structure is well-defined in relation to its reference IFC schema or subschema. This paper examines the use of modularity in model view testing.

Because the modules that were identified each had their own unique scope and were independent from one another, they could also be written and debugged in different orders. In addition, some modules were quite specialized, thus they only were executed in one or a few EMs of an MVD, while other concepts were used widely, executed in most of the EMs. It is clear that the elimination of repetitious modules leads to much faster development. The implications are that modules speed up translator debugging and reduce code to translation.

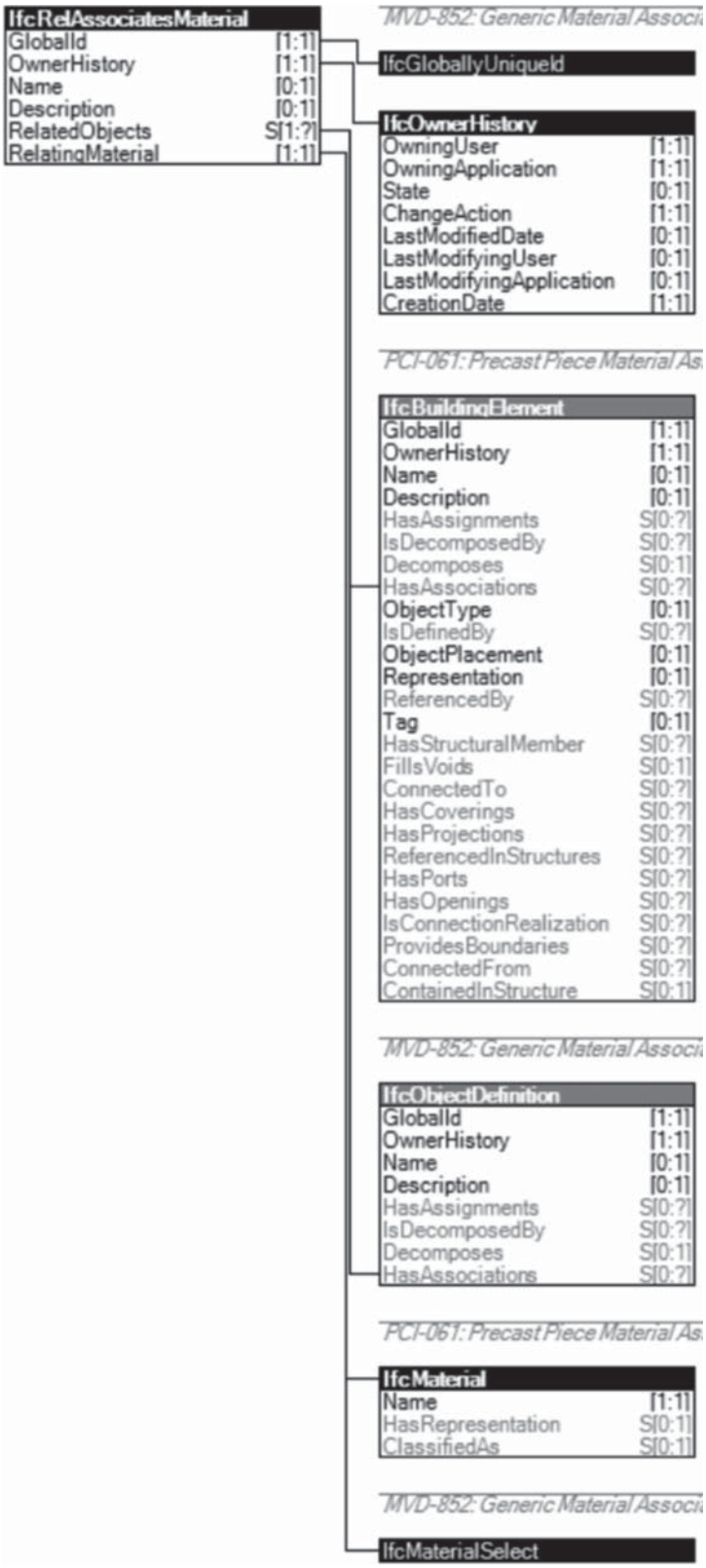

Fig. 13.3 A concept of the precast piece material binding association developed in the IfcDoc tool

13.3.3 Problems in Reusability of Concepts and MVDs for New MVD

The authors were involved in developing EMs in a variety of ways. This experience has allowed us to examine and test the benefits of modularity. However, there are the following several problems in fully reusing the concepts predefined in the previous MVD development projects:

- Heterogeneous definition processes and structure: Since each concept defines a specific entity, an attribute, a relationship, or a property set, a structure of the concept organization of new MVD should follow the one of previous one in order to use existing concepts. In other words, the structure and organization of concept templates in an existing MVD should be reused for the development of a new MVD. However, each MVD developer may have heterogeneous process of MVD development, thus, it would be challenging to utilize the same concept template again for a new MVD.
- Generalization of BIM exchange requirements: It is quite challenging to generalize and formalize a work flow and a data exchange process of a particular domain because they are subject to be varied according to diverse conditions such as a contract type, a project type, a team organization, or others.
- Reliability and representativeness of involved communities: Each MVD development project collects industry professionals and software vendors who can speak for the rest of an associated industry pertaining to BIM data exchange requirements. However, user-based requirement collection can result in varied workflow and its information according to knowledge and experience of attendees. Because of this problem, the collected EM can be inconsistent with regard to requirement definitions for the same EM of different MVDs.
- Project period and workforce: It is not only time-consuming, but also costly to organize a large number of meetings and put their opinions together for establishing EM and their requirements.

The following Figures represent different concept templates of existing MVDs: ACI, AISC, and Brim MVD. Figure 13.2 shows the concept template of the material binding association of the PCI MVD, Fig. 13.4 shows one of the ACI MVD, Fig. 13.5 shows one of the AISC MVD, and Fig. 13.6 shows one of the Brim MVD. Even though they all specifies the material binding association representing IfcObjectDefinition and IfcMaterials, they have their heterogeneous structures. The PCI MVD used IfcRelAssociatesMaterial, the ACI and AISC MVDs used IfcObjectDefinition, and the Brim MVD used IfcObject as a root entity that will be employed for being assigned by a concept template. In other words, in case of that a root entity is different, its concept block will be formed with a different organization. Even though the MVD development

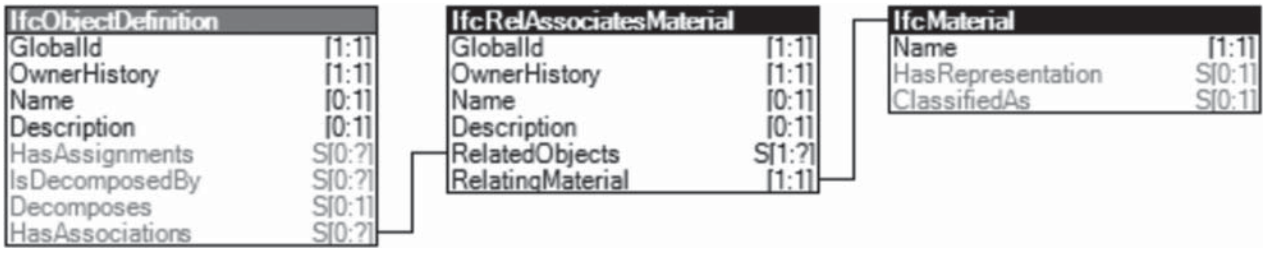

Fig. 13.4 A concept template of the material binding association (ACI)

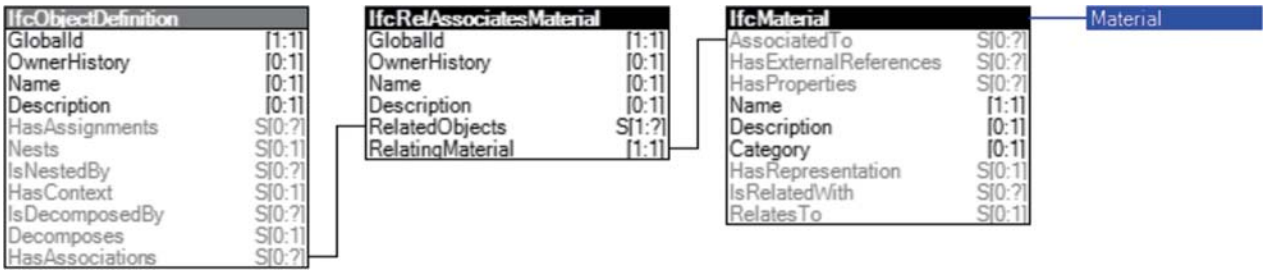

Fig. 13.5 A concept template of the material binding association (AISC)

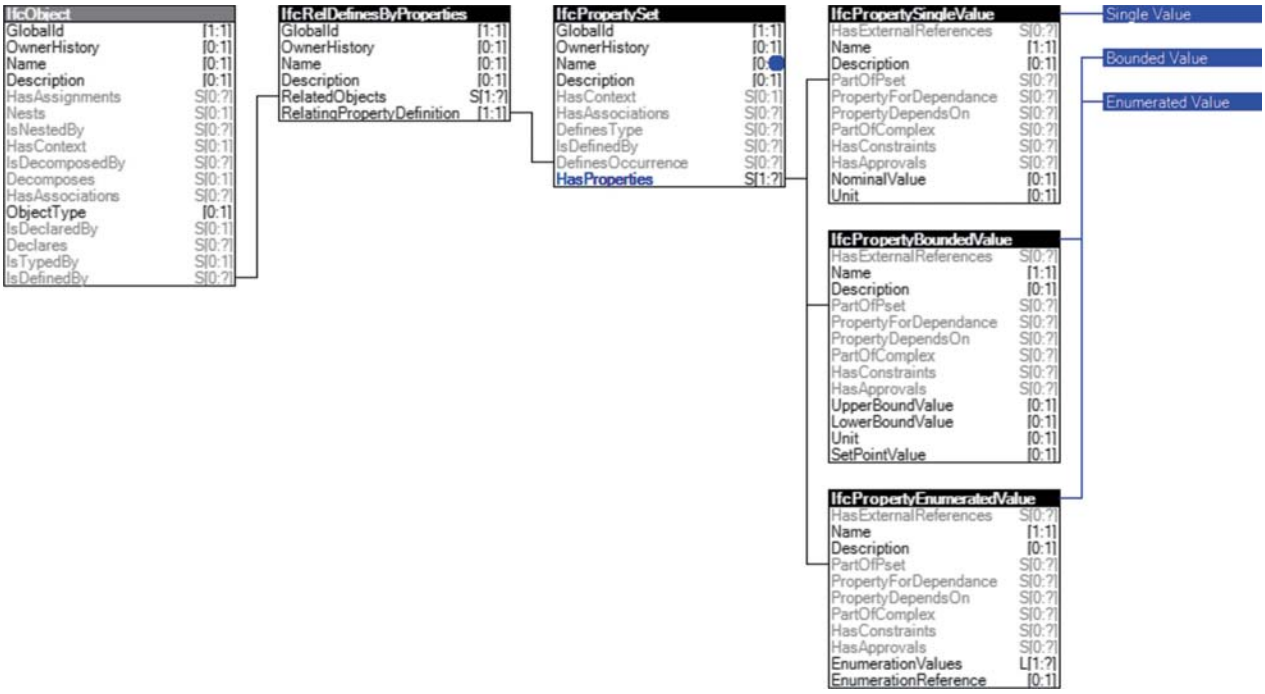

Fig. 13.6 A concept template of the material binding association (Brim MVD)

process is heterogeneous, the final contents of MVD will be the same. However, the imperative point is the reusability of concepts for expediating MVD development processes.

The structure of concept templates and blocks can also be one of obstacles for preventing modules of MVD. For the reusability of concept definitions, concept templates are provided in a IFC schema baseline in the IfcDoc format, but it might not be fit to new MVD development. Since domain knowledge entail diverse specifications, they may not need the existing concepts, but develop new concepts for their MVDs. As a result, the purpose of a concept, which is a modularized unit of knowledge for facilitating MVD development, might be useless. Thus, we recommend further investigation of concept organization and composition that provides a consistent MVD development.

13.4 Conclusion

Underneath the IFC schema, a standard for BIM data exchanges among different domains, applications, and phases, have been developed. However, MVD for developing the processes and interfaces of BIM data exchange has been overlooked, leaving academia and industry professionals to define it with their own methods. We need to deal with this increasing issue to retain our interoperability environment and facilitate BIM technology for the AEC industries. Thus, the results of this study are expected to explicitly represent the semantical and syntactical discrepancy of existing MVD sets and shows the current problems in reusing modularized concepts. MVD and its documentation tool, IfcDoc, are expected to allow all domain experts to consistently reuse pre-defined definitions and automatically developing MVD documentation. However, inconsistent structure of concept templates and block mapping have caused heterogeneous parts of MVDs that specifies even the same knowledge. Imperfection and inconsistency of concept and MVD development processes is one of critical limitations for establishing a standardized method for MVD development. Thus, formalization and generalization of concepts and their mapping processes should be discussed and investigated with diverse professionals for leveraging consistent MVD development processes and ultimately improving BIM interoperability.

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