BIM Model Asseveration: Definition and Supporting Tools

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Abstract

In this paper, we introduce the concept of "BIM Model Asseveration", explain the rationale behind it and propose some alternatives for implementing ICT and normative tools for supporting this newly named action. The paradigm shift introduced in the evolution from traditional design practices, in which every information is intentionally inserted (i.e. drawn) on deliverables, to BIM-based methods (object-based design authoring, incremental model construction, team collaboration and model information consumption) is discussed. During the development of a BIM model, a lot of unrequired/unchecked information is introduced into it when objects are instantiated. This is particularly true in the early design phases, when there is still a lot of uncertainty about the final specifications of components and if manufacturer-supplied objects (i.e., non-generic) are used for modelling. This is because those objects usually have all or most of its properties filled with specific product data and high visual fidelity. This problem is implicit in BIMForum's LOD definitions: "Level of Detail can be thought of as input to the element, while Level of Development is reliable output."; a lot of data enters the model, but only a fraction of it can be safely consumed. How can users of a BIM model know if some piece of information found in the model is valid, checked and available to be consumed by other professionals during the design phase? How can the author of a BIM model protect oneself from unauthorized/early use of information inadvertently inserted in the model or still not thoroughly checked? The usual recommend practices in this regard are either tacitly consider all information in the model as valid or to use Model Element Author (MEA)/Model Element Tables (MET), part of an agreed BIM Execution Plan, as guides for what information is to be provided and may be consumed at specific milestones. Then we present both the procedure for asserting the validity of needed model information (properties and geometry) - to be performed before delivery of (federated) models to coordination or for sharing among other professionals - and the proposed terminology to represent it (BIM Model Asseveration). Support from BIM authoring software or CDE platforms for asseveration certainly would be useful but is still largely lacking. We propose some possible approaches for developing tools that could help in model asseveration. We hope naming this procedure and proposing implementation approaches may foster the offering of professional tools for asseveration in the AEC market.

Keywords: BIM, Asseveration, MET, LOD, MEA

1. Introduction

BIM (Building Information Modelling) is increasingly becoming the new standard way for building design development, although adoption levels still greatly varies among countries (Kassem & Succar, 2017). Unfortunately, many people still see BIM as an evolution of CAD (Computer-Aided Design/Drafting), i.e., as a tool, instead of the process or methodology that BIM really is (Migilinskas, Popov, Juocevicius, & Ustinovichi, 2013; ArchiStar, 2019). Based on this wrong assumption, their approach to BIM implementation is simply to replace their CAD tool by a BIM authoring tool, without changing their design and collaboration processes.

In the traditional or CAD-based design workflow, 2D drawing sheets documenting the design are produced. All elements on those sheets (lines, arcs, symbols, annotation text, etc.) are manually inputted in a CAD authoring tool, by the designer oneself or by an auxiliary draftsperson. As design progress through its standard phases (schematic design, design development, construction documents) more detail is added to this graphical documentation, strictly under the designer intent.

On the other hand, design using BIM authoring tools is not based on drawing individual graphic elements. Instead, 3D objects are instantiated into the BIM model from object libraries. These objects may feature not only very detailed geometry but also a complex set of properties properly filled with specification values from their manufacturers.

In later design phases, a designer may intently insert an object in the model representing a specific product chosen for the project, when object dimensions are final and all parameters will hold specified values. However, this same object may be used in earlier phases, when it is used only as a design intent placeholder, containing much more information than the designer has already decided about (Sacks, Gurevich, & Shrestha, 2016).

Different from 2D representations, a BIM model usually "appears precise and certain" (Abualdenien & Borrmann, 2019, p. 136), which leads to false assumptions on information validity.

Therefore, a BIM model may contain unverified data in its objects, differently from a CAD drawing where all information is derived from explicit designer input. A proper way to proceed for avoiding erroneous or unintended assumptions from this unverified information in the model is to consult the project Model Element Table (MET) which registers the intended Level of Development (LOD), at a given milestone, for each type of component in project BIM models (Bedrick & Reinhardt, 2019). The Model Element Table is also referred to as 'Object Element Matrix', 'BIM Element Matrix', 'Responsibility Matrix – Information Deliverables' among other denominations. Most BIM Protocols and Guides recommend to include a MET in the project BIM Execution Plan – BEP (Sacks, Gurevich, & Shrestha, 2016) to inform model authors what Level of Development (geometry and properties) is required at each milestone or design phase as well as to guide BIM model information consumers (e.g., other designers, consultants, etc.) on what information from the issued model they can rely upon at a given time.

An informal survey conducted by the authors among local designers and BIM managers in Brazil revealed that the majority of practitioners do not even know what a MET is, because it is not specified in the BEP of most projects. Even some BIM implementation consultants are not aware of this practice. It is suspected that the same behavior can be found in other markets. Among those professionals that do not use a MET, three alternative strategies were identified:

> 1. *Cleaning/zeroing the unused/undefined parameters in BIM objects they use and that come pre-filled with manufacturer or generic values*. This strategy avoids liability arising from the use of unverified information from the model but incurs in additional designer work for erasing values and may lead to miss original information from the object specification that may be need by the designer in later stages.
>
> 2. *Using generic objects and replacing them with specific or more detailed ones as the design progresses*. This strategy also implies continuous work from the model author for replacing components and also requires the availability or creation of several versions of a component (placeholder, generic, augmented generic, specific…). An additional drawback of this strategy is that the GUID (Global Unique IDentifier) associated with a component will be changed as the object representing it is replaced, leading to possible automated checking failures and tracking issues.

3. Keeping the unverified data on the objects and possibly facing liability for their misuse. Data validity is assumed or is inferred by consumers based on design phase or through explicit inquires to model authors. This strategy is seldomly practiced.

We infer these behaviors are due to the legacy of the formerly mentioned CAD-based design workflow on which all information in the graphic documentation is supposed to be valid as it is always explicitly entered by the designer. As BIM models replaces CAD drawings, the same assumption is kept (i.e., all data in a BIM model is to be trusted at all times); therefore, by this thinking, no unverified data should remain in the model.

The use of a Model Element Table from a project BEP to guide model authors and consumers has to be disseminated among practitioners as it is thought to be the most straightforward procedure for the authors and the safest behavior for model information consumers and, therefore, the recommend practice found on good BIM guides and protocols (Sacks, Gurevich, & Shrestha, 2016).

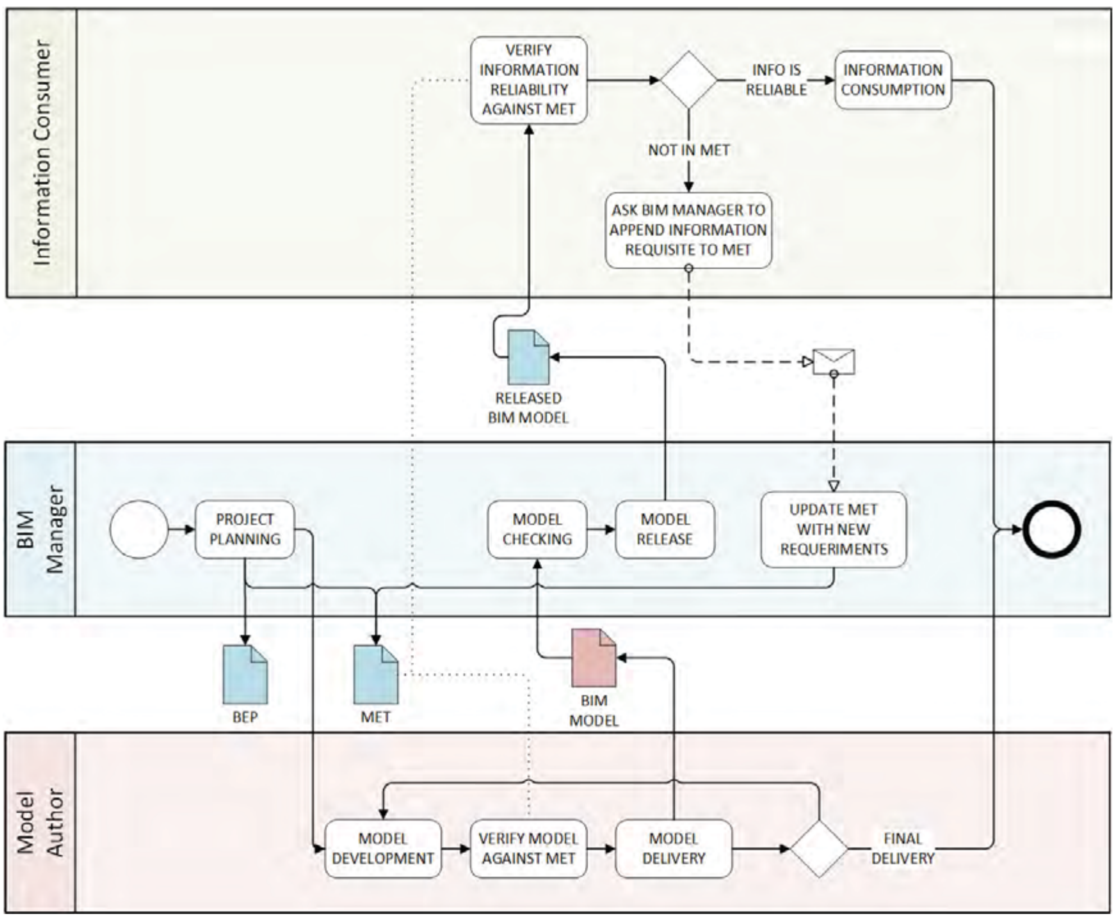

Figure 1: Simplified flow-chart of BIM project planning and model development / information consumption processes

Figure 1 shows a simplified flow-chart representing the processes of BIM project planning and design model development along with the resulting documents. The action of model delivery at a given milestone implies that the requirements for it are fulfilled and the information needed at that time can be consumed. Likewise, in the information-consumer side, having just the model is not enough for using its information, since the model can contain unverified information. Therefore, reliability verification against the MET is necessary, before model information use.

2. BIM Model Asseveration

Model Element Authors (MEA), responsible for creating/updating the information on a certain type of component in a BIM model, at a given project milestone/phase, as stated in a BEP, **should ensure** that the corresponding objects' size, shape, location, orientation and quantity are set according to the MET-specified LOD as well as all the required properties for the component, at that milestone, **are provided and verified**. Model information consumers are supposed to check the MET for assessing the reliability of a needed piece of information found in a model, at a given milestone, trusting that, if the required information is present in the model, **it was verified by the author**. This reliability on the validity of all the required information provided in a BIM model is the foundation of the MET-based system.

We propose that this still unnamed act of *asserting the validity of all required model information (including both geometry and properties)* to be called **'asseveration'** (Oliveira & Santos, 2019) .

BIM Model Asseveration is an action tacitly supposed to be performed before the delivery of federated models for coordination or sharing among other professionals. Giving a name to this procedure enhances awareness about it and stimulates research, certification, support, adoption and practice.

For a model to be considered asseverated, asseveration have to be performed in all model information from all components required by the MET for a specific milestone, according to the specified LOD/LOI (Level of Information).

It is important to differentiate *provisional information* from *unverified information* in a model. For example, a model object required to be at LOD 200 (i.e., "with approximate quantities, size, shape, location, and orientation" (Bedrick & Reinhardt, 2019)), at a given milestone, **still has provisional information after asseveration**, but now **it is not unverified** as before, and can be used for the specified LOD 200 purposes.

Also, it is worth mentioning that **asseverated models may contain invalid or non-checked information**, as long as that information is not among the ones required on the project MET for the corresponding project milestone model delivery date. That is why model information consumers are supposed to check the MET **before** using any data from the model. If the MET was properly constructed (i.e., registers all the information needed for all intended model uses at each milestone), this will not be a burden since consumers will have no interest in the non-required (and possibly invalid) information. If they do need some missing/unchecked information, then the MET has to be amended, specifying the new requirement at a future milestone (see Figure 1).

Asseveration is especially relevant for non-geometric properties. Even in a CAD-based workflow, practitioners are used to the fact that graphic elements representing the geometry of building components in a drawing are provisional at early design phases (e.g. the length of a wall or position of a door or column) and are cautious when using this information to advance their own work. However, they usually trust any textual information added to the drawing at any stage, and tend to do the same with attribute data found in model objects.

The concept of BIM model asseveration is tied to the model authoring workflow. In some workflows, in which all information in the model is intently inserted (e.g., all objects were created by the author) or represents the output of an automated and reliable process (e.g., structural components dimensioned by a stress analysis software), this information is considered asseverated. The same is valid when all required attribute values are checked when an instantiated object is inserted in the model.

Even in these workflows, in which the information input during model authoring is highly intentional (being very similar to the traditional methods of design, such as with 2D CAD), when it comes to collaborative BIM process with multiple delivery phases and BIM uses, there is still the challenge of managing and controlling what information must be in the model (and, also important, which can be consumed) after each design milestone.

Working according to the best practice, under the governance of a Model Element Table, may be cumbersome or unpractical, both for model authors and model information consumers. Depending on the amount of component types under the responsibility of a MEA and the quantity of properties on them which are required at a model delivery date by the MET, a lot of verification work is imposed on the designer. Even if there is not much variety on component types, but the quantity of instances in the model are large, the designer probably will benefit from some form of automation or support for the asseveration procedure. In the following section, some computer-based approaches to asseveration tools are proposed.

3. Proposed approaches for BIM model asseveration

According to a Design Science Research methodological approach (Dresch, Lacerda, & Antunes, 2014), after detecting a relevant problem ("lack of asseveration tools") and its characteristics, the authors investigated and proposed several artifacts (in this case, computer tools) which may solve the identified problem.

The proposed approaches for supporting asseveration described in this section address one or more of the following identified challenges to the task of asseverating a BIM model:

- Tagging asseverated information at attribute-level on each model object instance;
- Efficient look-up of requirements on a MET for a certain MEA, component type and milestone;

Reinhardt and Bedrick (2019, p.249) suggest using two properties (*Current LOD* and *Target LOD*) on all elements in a model as a way to identify those elements that have not yet reached the intended level (i.e., not been asseverated when *Current LOD* < *Target LOD)*. Having the *Target LOD* on each model instance also allows for a finer specification degree (instance level) than the component-type level in the lines of a MET. The problem with this approach is that LOD standard levels (100 to 500 in AIA/BIMForum system or 1 to 7 in the British PAS 1192-2:2013 (BSI, 2013), etc.) are mostly related to geometry and cannot inform about component attribute development status, i.e., is not at attribute level as needed.

3.1 Asseveration marker on properties of object instances

For the model author, the repetitive and error prone task of verifying each element's properties is critical for limiting author's liability risk. The amount of element properties to be verified can be enormous depending on the project size and complexity and intended BIM uses.

A checkmark style marker on each property of each object instance in the model to be ticked after asseverating the attribute (would help identifying verified items, avoiding rework on verifying it again. Figure 2 shows properties 'X' and 'Z' of Door 1 object have already been verified (i.e., asseverated) while property 'Y' was not yet. This scheme would make it possible to implement a filter for non-verified properties that are required for the next model delivery and ensure their verification or removal before release.

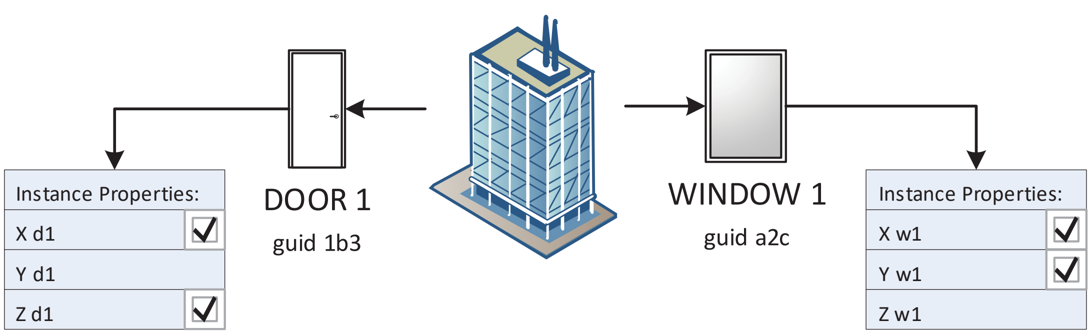

Figure 2: Tagging system for instance properties asseveration check

Unfortunately, popular current BIM authoring tools do not natively support such feature and achieving this behaviour would require development of an add-on. For software tools that offer an Application Programming Interface (API) this would be possible. This solution could rely on an internal data structure or on an external file for keeping these data or even on saving them along with standard content in the application's native file, depending on the available programming features. Revit's API (Autodesk Inc, n.d.), for example, allows storing multiple schemed data into model's components. This enables a plugin to manage each component instance linking them to a local database for recording the status of all its properties.

Another approach is to maintain a side database, relating each component's GUIDs, its properties and current status. As shown in Figure 3, an external database would keep a list of properties of each object instance in the BIM model, along with their status (asseverated or not).

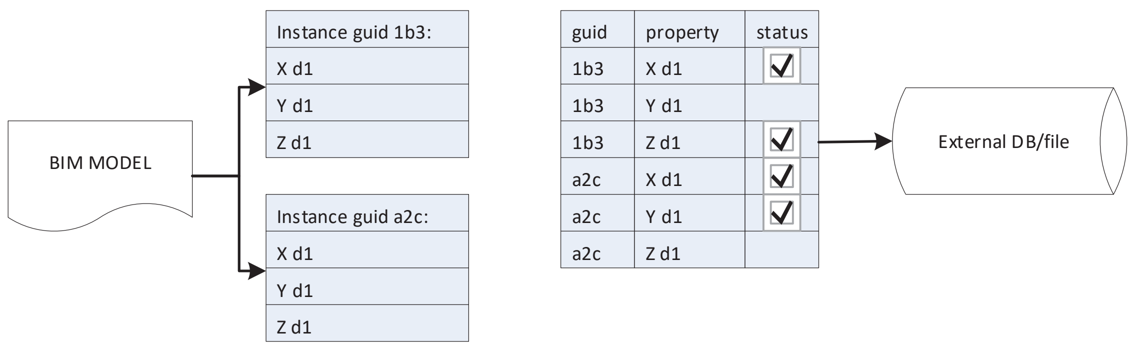

Figure 3: Component attribute status mapping to an external database

Creating such plugin would be challenging or even impossible due to the lack of a development interface (public API for developers) in some authoring tools. In such situations, an external software (fully independent from the authoring application) could perform a similar task based on an interoperable format (e.g. IFC, Industry Foundation Classes) exported from the modelling software.

The advantage of building such tool is that it could work with any IFC-compliant soft vendor acting as a post-processor for the model helping author to find unverified or missing requirements. Since components' GUID don't change for each exportation, items already verified can be easily identified, avoiding re-work, making necessary only the verification of new requirements since the prior milestone.

3.2 Digitized MET requirements

The previous proposal relies on a mixed use of technologies (plugins) for supporting the asseveration procedure and is still based on human-focused documentation (MET on BEP), which leads to time-consuming and error prone procedures.

Enabling machine interaction with such documentation is desirable and could be achieved in many ways. Application Programming Interfaces (APIs) for reading spreadsheet files (e.g. .xlsx files) are widely supported and accessible for developers. Having those documents formatted in such way that computer programs can read them makes it possible for authoring tools to access project planning and requirements.

More sophisticated solutions are already being offered to allow BIM managers and other project stakeholders collaborate on creating the projects requirements. That's the case of LOD Planner (Planner, 2019), an online web-based tool that helps the construction of the project scope and BEP with a user-friendly interface. If projects like this evolve to enable internet access to its information (through a REST API, for example), developers could build solutions that enable, for example, authoring applications to access project requirements for next delivery milestone and compare them with the current status of models being developed.

That feature can both help model developers on the task of assuring the delivery is in accordance with the MET requirements and also support information consumers on identifying valid information in the model.

Although these tools help in both ends (model creation and information consuming), it is noteworthy to remember that the reliability of information is still implicit. The consumer assumes the model delivered to one milestone had all information verified through the asseveration procedure, but there is no explicit tagging on each model's component to guarantee it.

3.3 CDE-Integrated solution

One way of filling all the gaps and solving possible doubts and uncertainties along the process would be to store all project information (BEP, MET, model content, etc.) in a single data repository. That is the reason for implementing and integrating the procedure of model asseveration onto a CDE (Common Data Environment). Instead of an external database for each model (as described for the first approach), a single database for all models of the project would hold the verification register for each piece of modelled data.

Enabling the access to this data via internet (REST API), by authenticated and authorized users, could enable a much more flexible project planning and development.

Using the CDE as a model server and MET keeper would allow features like filtering unchecked information so that it does not appear for information consumers (both on online model viewers and in model file downloading, in which case the interoperability file could have unverified data removed during exportation), as represented on Fig. 4. That way, all the information accessed by consumers through the CDE is considered explicitly asseverated and reliable for consumption.

This approach enables many other related features for supporting the asseveration procedure that will be explored in future works.

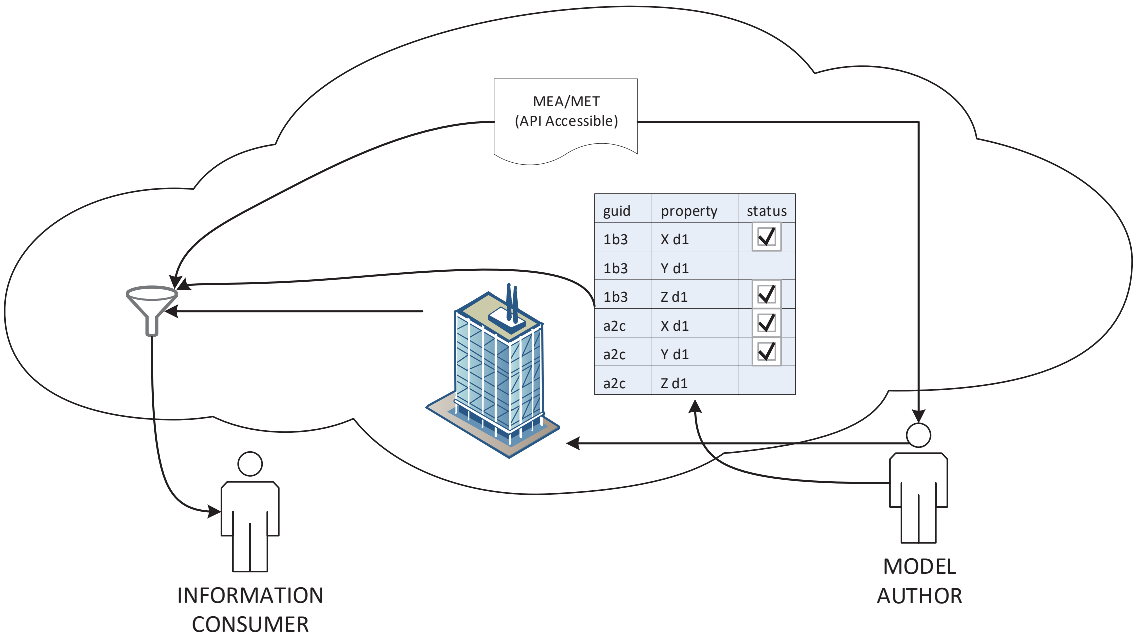

Figure 4: CDE-enabled asseveration procedure schema

3.4 Normative approach

Faria & Santos (2018) developed a prototype tool for automating the creation of a MET from a table-formatted input consisting on intended BIM uses vs. project milestones. This tool is based on a database that relates information requirements to BIM uses at standard project phases. This same database could be used to support asseveration without the need to access online MET information, as long as the information on this database is standardized. The use of such a standard would dismiss the need for a MET, which could be replaced by a much simpler MUxPM (Model Uses x Project Milestones) Table.

These standardized attribute lists for each BIM use could be pre-loaded on authoring software, a CDE or complementary programs to aid the designer on producing and asseverating a BIM model. Those systems would be able to asseverate the model contents against intended BIM uses.

The Brazilian Association of Technical Standards (ABNT – *Associação Brasileira de Normas Técnicas*), is developing a related standard on their ABNT/CEE-134 BIM Objects WG ("Requirements for Building Information Modelling (BIM) Objects" standard under development). This standard establishes the requirements on BIM object content (geometry level of detail, properties, connectors, 2D representations) based on intended Model Uses (e.g., Energy Analysis, 4D Planning, Quantity take-off, Electrical Building System Design, etc.).

One possible downside of such strategy is the low flexibility of such rigid documentation as standards, that usually takes years to be revised/updated – what would lead to slow response time for improvements and new BIM uses. But this work could be the foundation for a customizable solution, with flexible capabilities.

An extra parameter would be inserted on each object instance informing the BIM uses that component is ready for (this is required in the mentioned Brazilian standard). As long as new information is inserted, other uses would be enabled and this attribute updated– this could be automated on an authoring tool using a plugin.

4. Conclusions

Anecdotal evidence shows most BIM professionals do not use the recommended practice of verifying the validity of required data in their authored models against a project-defined Model Element

Table at each delivery milestone nor they check the same table for confirming the validity of other's model data before consumption. These two rarely performed procedures do not have a defined name, as evidenced on performed literature review. In this work, we proposed to name the act of "*asserting the validity of all required model information (including both geometry and properties)"* as "asseveration". We hope that having a name for it will help to foster awareness about it and stimulate the development of supporting tools, increasing its adoption and practice.

Current BIM authoring tools and CDE platforms do not offer support for asseveration. In this work we proposed several approaches that can be used on computer tools for aiding asseveration of models. Two proposed approaches are client-side: i. storing asseveration flags inside the model, on the authoring tool, and; ii. storing asseveration status on an external database, created from the model data through a plugin. Another proposed solution is implemented on both client and server sides: storing MET information on the server to allow client queries on what information needs to be asseverated (author side) and filtering out information that cannot be consumed (consumer side). A fourth solution is to implement a server-side only approach, where both MET data and models are kept on a Common Data Environment. Both properties asseveration and filtering would be performed at this specialized server. An alternative approach, useful on all proposed solutions, replaces the MET table with a Model Uses x Project Milestones Table and a Model Uses x Properties database, although this database is pending development yet.

The tools proposed in this paper can both help the designer asseverate models before delivery and also the model information consumers, by assuring that only validated data is exchanged reliably.

The next step in our research is to implement the most promising approaches and validate them on a real scenario project (study case), measuring its performance, benefits and the perception of the users.

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