BIM Information reliability consequences for digital permit checking

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Keywords: Building Information Modelling, Automated Building Compliance Checking, Digital Building Permit Checking, Information Requirements, BIM Information Reliability.

Abstract

Building Information Modelling (BIM) is a driving force for automated building permit checking. There is a consensus among the industry that the use of open data standards is crucial to this process. The Industry Foundation Classes (IFC) open data standard provides a good base for automated permit checking worldwide. It has a large semantic definition of classes (objects/entities) that is supported by almost all software tools in the architecture, engineering, and construction (AEC) domain. The use of IFC has technically been proven to be useful and efficient for digital building permit checking. BIM modelling, according to data requirements in IFC, is a crucial factor in achieving trusted results. However, there are many examples where the delivered IFC datasets are inconsistent or have missing information, leading to unreliable results from automated code compliance checks. For example, providing values for properties inconsistent with the geometry representation can lead to a false positive result in a digital building permit check. The lack of sufficient information can result in checks not being executed or executed resulting in an incorrect result during the digital permit checking procedures. Therefore, this paper explores measures to improve the information reliability of BIM models for automated building permit checking processes. The paper provides industry examples and risks of inconsistent IFC requirements. Evaluation results of known solutions to check IFC datasets without assuming semantic reliability are presented. The paper concludes with recommendations for government organisations, architects, engineers, and technology providers.

1. Introduction

Automated building permit checking represents an opportunity for significant advancement in the management and verification of permits. This not only enhances operational efficiency but also significantly improves compliance with regulatory standards. The use of digital permit checking is particularly beneficial in the construction industry, where safety and legal compliance are paramount. Buildings are one of the projects. The effort that can be invested into the design and checking it against the building regulations is small compared to those of mass-produced products. Any automation in this process has a great upside, but only when the required input for automation doesn't bring more work.

The State of the art in automated building permit checking is based on the use of the Industry Foundation Classes (IFC) data standard. It is well known that IFC only defines the specification of objects, properties and structure of data but needs an additional definition of information requirements per use case. Experiments with adding surroundings and 3D planning information have been explored by Berlo et al., 2013 but are out of scope for this paper.

Current industry practice is to define more requirements for every use case. A typical simple project already accounts for multiple pages of Excel rows with information requirements on properties and objects. Most of these are often not standardised and need to be manually added to a BIM dataset.

It becomes overwhelmingly clear that the movement towards adding more and more information requirements is inefficient and error prone. This creates a false sense of completeness that is unrealistic and may lead to an unjustified feeling of security.

This paper explores alternative solutions to defining just more information requirements. It shows industry examples where fewer requirements have been leading to more reliable results in digital permit checking and tries to set realistic expectations for digital permit checking.

2. Current situation and Problem statement

A typical process of digital permit checking with BIM goes as follows:

1. In most cases, a BIM model in IFC format is required, and it must comply with a list of information requirements, usually defined in a guide provided by the administrative body (a municipality or other checking authority).

2. A permit applicant needs to adapt the modelling of the design so that the result meets the data requirements requested by the authority. In practice, this means manual work to define classes in a certain way and to add properties and values just to create an IFC that can be used for automated checking. The permit applicant generates a new IFC file specific to the permit check.

3. The permit applicant uploads the IFC file to the digital/automated permit-checking system.

4. The digital/automated permit checking system relies on the semantics inside the IFC dataset to run rules to perform the check.

5. A result report is generated.
6. A human often does the final check, and some other procedures might take place before the permit is granted.

This setup relies on three aspects: (1) A clearly defined set of information requirements. (2) A valid IFC file. And (3) A software tool/system that executes the rules for the checks. These three aspects depend on each other. It is necessary to have the BIM model in IFC so that the software can execute the check. In addition, the information needed to perform the check also has to be provided in the IFC model. To achieve automation of checking, the system should include all the necessary rules according to each regulation. More rules require more information in the IFC file, and therefore, the information requirements document has been extended. This results in more manual work that designers/permit applicants need to perform to enable automated checking. At some point, the manual work of adding information to an IFC file can outweigh the gains of the automated permit check. Asking for more information in the IFC to feed the checking system also increases the dependency on reliable information in the IFC file. When the information needs to be manually added to the IFC, the reliability shifts from an automated checking rule to a user manually inputting data.
For example, when an automated system checks the slope of a ramp based on a custom property value, the check relies on the manual input of a user to provide that property value. When the IFC is not structured correctly, the ramp might not even be provided in the IFC file as a proper IfcRamp, but as a different class.
These situations lead to a false sense of reliability in the automated checking system. Observing a trend where more specifications are being made that ask for more data in the IFC file, the sense of security is falsely increasing, while the efficiency is decreasing due to manual labour and the risks for 'false positive' results are growing.
False positives, where the system incorrectly identifies a building permit as valid when it is not, and false negatives, where the system incorrectly identifies a building permit as invalid, must be prevented in automated building permit checking. The risks associated with false positives and negatives in digital permit checking are multifaceted and significant.

3. Research methodology

This study takes an exploratory approach to formulate a hypothesis on improving the information reliability of BIM models for automated building permit checking. This exploratory research suits the investigation of a situation when there are no earlier studies to refer to, and the goal is to gain familiarity for the preliminary stage of investigation Patton, 2002. The study follows three research steps: 1) identify known solutions to check IFC datasets without assuming semantic reliability, 2) ideate how to use them for better IFC check reliability, 3) formulate a hypothesis for future research. Steps 2 and 3 are described in the following section 4, while the hypothesis is presented in section 5.

4. Potential Solutions for improving reliability of checks

BIM-based solutions for building checking can provide better opportunities for the reliability of checks compared to traditional methods, such as those based on 2D CAD files or drawings. However, if these solutions are not implemented correctly, they can have the opposite effect. Within this BIM-based solutions context, one strategy that can help achieve greater reliability is using microservices, resulting in more flexible, smarter, and tailored checking solutions. Each microservice can be specialized to handle specific aspects of BIM models, such as geometry processing, data validation, etc. This enables a

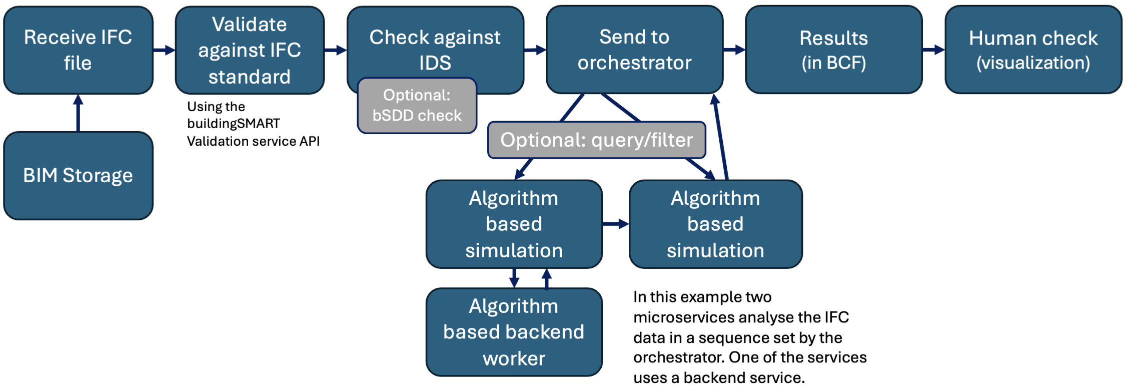

Figure 1: An example of different independent quality checking services combined using a service orchestrator to create one automated check process.

more focused and high-quality development of each microservice, including scalability and performance issues.

However, to obtain reliable results, a quality check process for BIM models is required. When opting for the IFC standard, requirements can involve validations at different levels. For example, IFC models must be consistent with the IFC data schema, including the version for which they are intended to be created. In addition, they must also comply with the data requirements required for each type of checking. Figure 1 shows an example of different independent quality checking services combined using a service orchestrator to create one automated check process. Nowadays, many services can be integrated through APIs.

By using smart online microservices that perform specific analyses, complex calculations could be performed without entering additional (manual) information. Information can be derived instead of depending on manual, labour-intensive and error-prone inputs. Voxelization and connectivity graphs are examples of techniques that can be implemented in microservices for automated checking purposes. These are described below.

Voxelisation of geometry / agents

A voxel represents a single sample, or data point, on a regularly spaced, three-dimensional grid 2. Using voxels as geometry instead of the default triangulated geometry opens the opportunity for different kinds of analysis. Transforming the IFC data to voxels that are independent of the semantic meaning of objects or connected properties creates a Minecraft-style visualisation. By sending an agent (algorithm) through the voxels, certain human behaviour can be simulated. This method has been applied to a minimally viable product in Estonia. The technology was used for fall detection checks and the detection of free head space. This way, non-semantic objects and wrongly classified objects are also taken into consideration. The method is quite processor intensive. The server load would be high, and therefore, the technology is not expected to be cheap or available for free. The Technology Readiness Level (TRL) of this experiment could be considered around 5 or 6. It requires quite some technical expertise to use this functionality in any environment.

Connectivity Graph

Another way to derive information from the IFC data without having to rely on semantic definitions is the use of a so-called *connectivity graph*. Certain types of objects with

Figure 2: An example where the use of voxilisation showed that people can fall from the stair flight due to a lack of protection (railing, etc). Source: ACCORD demo country Estonia

certain properties are *connected*. Instead of manually modelling these connections they can be derived from the geometry. For example, all public spaces are connected (through doors). Calculating the fastest or shortest exit route can then be derived through analysis. An ACCORD microservice from Future Insight and BIM.works is tested to define the *fire-safety route*. The analysis showed more reliable results compared to manually defined routes in the IFC data. An example is shown in Figure 3 . This example is a mix of using semantic meaning of IFC objects (IfcDoor and IfcSpace) and calculating other parts. This mix is chosen since IfcDoor and IfcSpace are things that are typically already available in an IFC dataset, but escape routes are not. This way modellers don't have to manually add information that then can be 'automatically checked'. This lowers the threshold for the applicant, and lowers the reliance on manually input data. There is a broader perspective of derived values. Many attributes and properties in IFC could be derived. Examples like thickness, height, length, etc can all be automatically and independently measured by a receiving software tool. By deriving these characteristics instead of the manually entered values many human errors, or errors on export of the IFC, can be eliminated.

This technology is considered TRL level 7 but also requires quite some (expensive) computing power. buildingSMART International is currently experimenting with *information consistency checks* in the buildingSMART IFC Validation service. The *information consistency checks* will derive height, volume, area, and other characteristics from the geometry and compare the calculated values to the values in the attributes, properties and quantity sets. When the values are consistent (within a small margin of error) the IFC is marked as *valid* by the buildingSMART IFC Validation service. Otherwise, an error or warning is reported. The buildingSMART IFC Validation service is being integrated into the ACCORD framework through a newly developed API in work package 4. The TRL of this information consistency check in the validation service is currently at 4.

Visual (Human) checks

Although the above-mentioned technologies will bring additional reliability to automated checks, there will always be caveats or exceptions. Therefore, for the time being, it is wise to have people continue to perform visual checks. Even the technologies

Figure 3: Visualisation of the calculated (derived) fire escape route.

mentioned depend on data input. Objects may still be incorrectly modelled which will cause unexpected results. A typical example of an IfcDoor that is mistakenly exported as IfcWindow will break the calculation of the fire exit route. In this situation, however, it is most likely that the check will result in a negative output. In other words: no permit will be given, and the author is stimulated to model better. In classic rule-based checking, an incorrect dataset (IFC file) can result in a false-positive result (a permit is given that should not have been given), which still makes the algorithmic approach the better option for the case of permit checking.
By displaying various objects with common errors in a visually distinctive manner and in the correct combination, errors and inconsistencies can quickly become visible to the (trained) human eye. By setting up a number of these types of displays for different visual checks, a final quality control step can be built into the workflow.

5. Recommendations to improve information reliability of BIM models

As others have already proven by Krijnen and Tamke, 2015, the algorithmic approach to IFC analysis has potential. Based on the above listed potential solutions, this paper suggests the following pathway for improving the reliability of BIM models and compliance checks 4. First, IFC validation is performed as illustrated in 1. The next step involves algorithm-based checking, which could include e.g., Voxelization and Connectivity Graphs. Finally, visual checks are conducted by humans to ensure accuracy and completeness.
The three steps presented comes with the following recommendations, which should be tested and verified in real-life BIM-based building projects:

- Keep the information requirements as simple and clear as possible to make it fea-

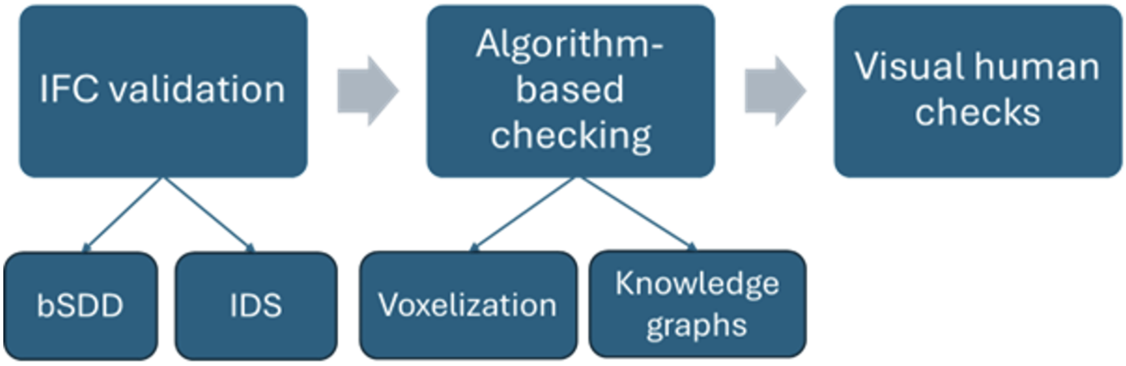

Figure 4: Steps (with suggested services and technologies) to improve the reliability of IFC files and compliance checks.

sible. The more complex these requirements are, the more possibilities arise to interpret them. ACCORD follows the recommendation from Tomczak et al., 2022 to use the buildingSMART International, 2024c Information Delivery Specification (IDS).

- When configuring the checks and the accompanying information requirements, make sure to do this with a small multi-disciplinary team of a least a permit issuer, a legal expert and a technical expert. Only this way a proper translation of a regulation to an automated check and minimal and realistic requirements will occur.

- Make sure the requirements are automatically processable. As long as requirements are only available in an excel or PDF file it is impossible to automatically check the quality of an available IFC file. By making sure the few requirements which are defined are available in IDS they can at least be checked automatically.

- Avoid dependency on manually entered values. People make mistakes, especially when entering complex values. Use libraries with the correct and certified values and when possible have them automatically linked to objects. This can be done using the buildingSMART International, 2024d solution for Data Dictionaries (bSDD).

- Make the quality check as easy as possible available to the people creating the IFC dataset. This allows BIM authors to check their own work. The lower the threshold and better access to the actual testing tool, the higher the chance for a good quality model. Communication about potential model improvements can be done using buildingSMART International, 2024a BIM Collaboration Format (BCF).

- Use the official buildingSMART International, 2024b IFC Validation service to check the quality of the IFC data.

6. Conclusion

Digital tools can create a sense of false security. This paper raised the issue of possible risks with rule-based digital permit checking with IFC. Rule-based checks can give unreliable results when the input data from the BIM is not properly modelled. As a result, this paper suggests an approach where IFC validation is first performed utilising microservices. Then, algorithm-based checking, including e.g., Voxelization or Connectivity Graphs, is performed. And finally, visual checks are conducted by humans to

ensure accuracy and completeness.
The paper explored solutions to improve the information reliability of BIM models for the use case of digital and automated permit checking. While the solutions discussed show promise, they are still in the early stages of maturity and require significant computing power. The solutions will never cover full reliability on their own either, thus, human checks and sensibility remain a necessary component to ensure the accuracy and completeness of compliance checks.
The paper provides recommendations for government organisations and technology providers to mitigate the risks associated with poor information reliability of BIM models. The combination of strict information requirements, precise modelling, advanced technology, and trained human oversight is essential for a reliable workflow in automated digital permit checking. Focusing on just one of these aspects could lead to unreliable results.

Acknowledgements

Part of the work reported in this article is based on research conducted within the project "Automated Compliance Checks for Construction, Renovation or Demolition Works" (ACCORD), which has received funding from the European Union's Horizon Europe research and innovation programme, HORIZON-CL4-2021-TWIN-TRANSITION-01-10: Digital permits and compliance checks for buildings and infrastructure under grant agreement no 101056973, and UK Research and Innovation programme (UKRI) under grant agreement no 10040207.

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