DEVELOPMENT OF AN IFC-BASED CONVERTER FOR BIM INTEGRATION INTO AUGMENTED REALITY APPLICATIONS FOR BUILDING CONSTRUCTION TRADES

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Abstract

To address the shortage of skilled labor in the construction industry, the application of augmented reality on construction sites offers substantial potential to enhance coordination and communication among different trades, thereby reducing labor-intensive processes. This requires the reliable transfer of geometric and semantic information from Building Information Models, including all data relevant to construction execution, through suitable data exchange formats. This paper defines information requirements for the IFC schema for the BIM-to-field use case in the construction trades, discusses appropriate exchange formats for geometric and semantic data, and presents the development of an IFC-to-Unity converter.

Introduction

A key challenge currently facing the construction industry is the shortage of skilled labor. Numerous studies (Klaus *et al.*, 2025; PwC, 2025; Emanuel *et al.*, 2023) indicate that this shortage is particularly pronounced in construction and craft-related occupations.

The implementation of digital technologies can enhance process efficiency in the construction sector (PwC, 2025), thereby contributing to the alleviation of skilled labor shortages.

At the same time, the gap between digitalization potential and actual digital capabilities in the construction industry continues to widen (PwC, 2025).

According to Klaus *et al.* (Klaus *et al.*, 2025) the gap between digitalization potential and actual capabilities is especially pronounced in the areas of simulation and visualization, cloud technologies and platforms, and Internet of Things solutions.

When the potential of digital solutions is examined across different user groups in the construction sector, it becomes evident that construction trades, particularly construction workers, play a central role.

According to the Bitkom study *Digitalization in Skilled Trades* (Geffert, 2026), only 18% of the surveyed construction and finishing trades currently use BIM. At the same time, 76% of all surveyed skilled trade companies report that their employees require stronger digital skills (Geffert, 2026). These findings point to limited BIM adoption and a continued need for workforce-oriented digital support.

In this context, the BIM-to-field concept offers a promising approach. Its objective is to make BIM-based information accessible and usable on construction sites by delivering execution-related information in a user-centered and role-specific manner. Augmented reality (AR) represents a particularly suitable interface for transferring such information from the BIM model to the site in a form tailored to the specific requirements of different user groups and supportive of their on-site activities.

Against this background, the BIM-to-field concept offers considerable potential to improve on-site coordination, support craft workers during execution, and help mitigate the shortage of skilled labor.

Correspondingly, previous studies have shown that the use of AR on construction sites can accelerate on-site decision-making (Marinho *et al.*, 2026), improve collaboration, and enhance overall project performance (Alizadehsalehi *et al.*, 2020).

The BIM-to-field concept enables the positioning of building information models from the planning phase directly on the construction site using AR, allowing relevant information to be visualized via a device such as a smartphone, tablet or AR headset. The workflow from the building information model to the construction site is illustrated in Figure 1. In particular, the underlying data and its preparation represent a major challenge.

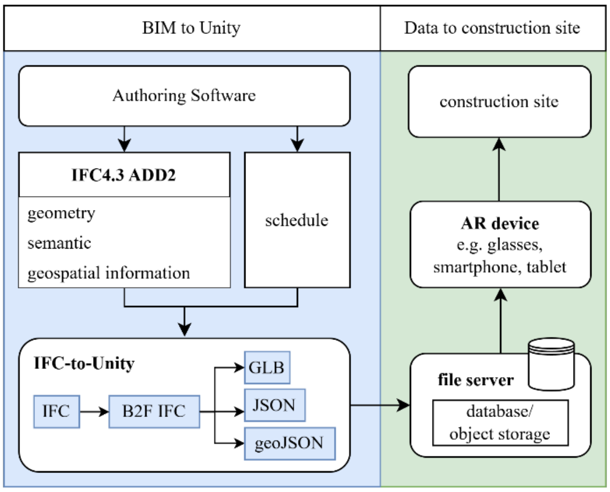

Figure 1: BIM-to-field concept within this research

Research Gap

Several AR applications already exist for both research and professional practice. These applications describe the BIM-to-field process in detail or provide functional solutions for a specific use case. However, most existing AR applications are based on the principle that information from the Building Information Model is used primarily for inspection and verification purposes. Consequently, these systems are not yet suitable for providing complex, role-specific action instructions for the various trades involved in construction execution. To sum up, most current AR applications are designed to support supervisory and managerial roles on construction sites, rather than operative roles within the construction trades.

At the same time, it is necessary to address how the different BIM standards adopted by various companies can be handled consistently. In this context, the varying information requirements and divergent coordinate reference systems (CRS) used during the planning phase must be considered. In OpenBIM, Industry Foundation Classes (IFC) is used as an open standard for exchanging model information. For this reason, the focus of this research is placed on the IFC-to-Unity process illustrated in Figure 1.

This paper describes how planning information for on-site execution can be systematically extended within an IFC model and defines the basic information requirements necessary to enable actionable, role-specific guidance for construction trades in an AR environment. Rather than extracting model data in isolation, the approach focuses on IFC-standard-compliant enrichment of existing model information, ensuring semantic consistency and interoperability.

In addition, the paper demonstrates how schedule-related information can be integrated into the IFC data structure in order to explicitly address individual trades as well as distinct role profiles within each trade. This enables the derivation of task-oriented, temporally structured instructions suitable for execution-level workflows on construction sites.

Furthermore, approaches are presented to address challenges arising from heterogeneously georeferenced IFC files and from common modelling inconsistencies and errors. Together, these measures ensure a robust, reliable and standards-based BIM-to-Unity data integration pipeline that supports construction workers beyond purely supervisory use cases.

Methodology

This study presents a structured approach to defining information requirements, analyzing the IFC schema and developing a converter for the BIM-to-field use case. The aim is to integrate BIM-to-field-specific information into the IFC schema to enable context-sensitive, AR-based work instructions for craft workers on construction sites.

The process begins with defining the problem and delimiting the research scope, driven by the absence of interoperable, IFC-compliant representations of the information required for field-oriented BIM applications.

To identify relevant concepts, existing approaches, and technical implementation strategies, an exploratory, non-systematic literature search was conducted using backward and forward snowballing, following Wohlin (Wohlin, 2014).

The literature search started from an initial set of key publications on construction scheduling, construction-specific information requirements, approaches for integrating such information into the IFC schema, georeferencing in IFC, digital data exchange and AR-supported construction workflows. It was iteratively expanded by reviewing the reference lists of relevant papers and identifying citing publications, thereby capturing relevant concepts, existing approaches and technical implementation strategies that informed the subsequent methodological steps.

On this basis, the study addresses four interrelated objectives:

- to define core information requirements for representing the BIM-to-field use case in IFC
- to examine how use-case-specific information, including schedule-related information, can be integrated into the IFC schema
- to implement these requirements in a technically robust and IFC-compliant manner
- to optimize the IFC-to-Unity information flow for downstream visualization and AR-based task guidance

These objectives are addressed through a detailed analysis of the IFC schema based on the IFC4X3_ADD2 documentation (buildingSMART International, 2026). The analysis focuses on the entities, attributes, and semantic relationships required to represent, link, and transfer the relevant information.

The resulting requirements are then translated into the development of a Python-based converter, including the selection of suitable Python packages for IFC processing, data handling, and workflow implementation.

Information Requirements

In current practice, information on building elements is commonly embedded directly within the IFC model, whereas scheduling information is usually generated in a separate planning environment and only subsequently linked to the building information model. Nevertheless, IFC provides several mechanisms for incorporating such information and representing schedule structures.

In addition to model information and schedules, supplementary information is sometimes also required. For example, tradespeople need access to assembly instructions for different products.

Therefore, an AR application for use in different construction trades must be able to interpret information from both the building model and the schedule. It must also be able to supplement information that is not part of the building information model, if necessary.

To support this objective, the following section presents a concept that defines the minimum structural requirements of an IFC model for consolidating the essential information in a single IFC file.

In line with the taxonomy proposed by Liu (Liu, 2021), which distinguishes the main categories of *product*, *organization*, *process* and *external factors* for construction workers, the discussion focuses primarily on what is being built and who is responsible for carrying out the work at a given time and place.

IFC Structure requirements

This section defines the minimum IFC data structure requirements for building construction that are necessary to support the coordination of complex trade structures and interdisciplinary interfaces through an AR-based application. The information requirements and relationship definitions developed in this work are based on the IFC4X3_ADD2 standard (DIN Deutsches Institut für Normung e. V., 2024). Additionally, this section illustrates the foundational concepts of the IFC schema that facilitates the integration of 4D information and responsibility assignments into the IFC data structure.

To ensure interoperability across different BIM software environments, the proposed extensions are realized through an entity-based modelling approach that is fully aligned with the IFC schema. Rather than introducing proprietary data structures, this approach uses existing IFC entities and standardized relationships. This preserves schema conformity and enables consistent interpretation across different BIM authoring and analysis tools.

Consequently, no new attributes are introduced in the form of *IfcPropertySingleValue* unless they are explicitly required as an extension. In this paper, existing IFC entities are systematically reused. These entities are interconnected via *IfcRelationship* instances. These relationships are defined according to the mapping shown in Figure 3.

This establishes a semantically consistent link between structures and responsible actors within the AR application. In this context, *IfcCrewResource* is used to represent a specific construction trade, to which different IfcLaborResources are assigned. These *IfcLaborResources* are specified by an *IfcActor* which is defined by *IfcOrganization* (organization name) and *IfcPerson* (first name, last name).

Huymajer et al. (Huymajer *et al.*, 2024) present a similar approach. However, their work focuses on construction scheduling in tunnel engineering. Applications in building construction, as well as interfaces to augmented reality systems, are not addressed. Nevertheless, *IfcTask*, *IfcLaborResource* and *IfcPerson* are also used to represent IFC-based construction processes.

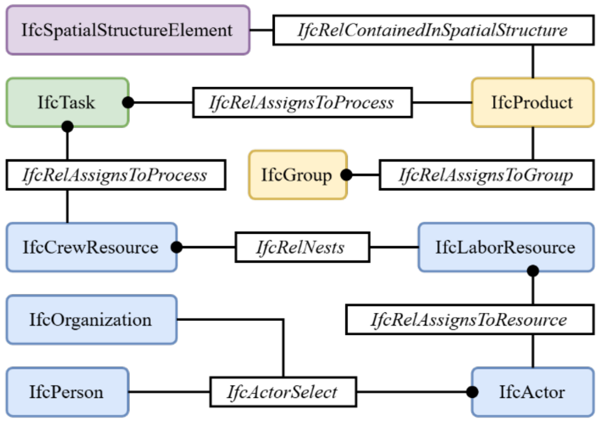

Figure 3: Entities and Relationships used in IFC

The construction trade (*IfcCrewResource*) can be associated with *IfcTask* entities, which represent construction activities. These tasks are, in turn, linked to *IfcBuiltElement* instances, which constitute a subtype of *IfcProduct* and describe the physical building elements involved in the execution of the tasks. *IfcMaterial* is used to describe the material characteristics, while *IfcPhysicalSimpleQuantity* entities are used to specify geometric properties, such as volume.

An *IfcBuiltElement* can be spatially located through its assignment to an *IfcSpatialStructureElement*. For instance, *IfcBuildingStorey* defines the corresponding floor level, whereas *IfcSpace* specifies the room or functional area in which the element is situated.

The defined entities are illustrated in Figure 2. In the figure, the information associated with the masonry trade and a sand-lime brick wall is highlighted in green for illustrative purposes.

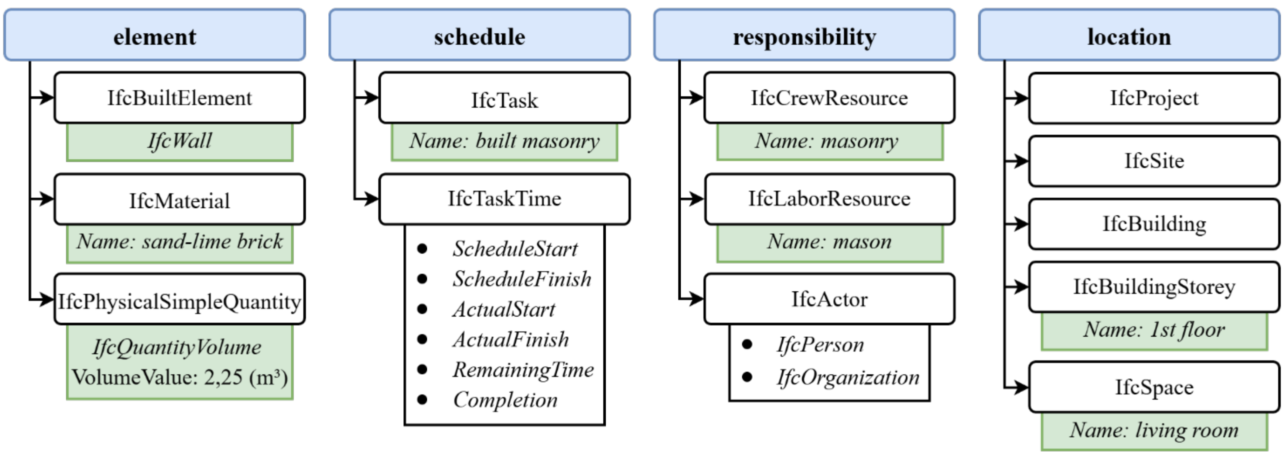

Figure 2: IFC entities for coordinating construction trades in building construction - exemplified by the trade masonry

In addition to *IfcTask*, scheduling information is enriched using selected *IfcTaskTime* attributes (Figure 2), which capture planned durations derived from the BIM model, as well as on-site execution states. Schedule deviations are documented using the *ActualStart* and *ActualFinish* attributes, the *RemainingTime* attribute shows the remaining time, and the Completion attribute indicates task completion, encoded as an *IfcPositiveRatioMeasure* (0.0-1.0).

Geometric and spatial reference Information

In addition to the semantic requirements imposed on an IFC file, particular attention must also be paid to the geometric modelling with respect to the heterogeneous BIM standards applied by industry practitioners. For the concept presented in the previous section to function as intended, building components must be modelled as instances of *IfcElement*.

With regard to georeferencing, it must be considered that different coordinate reference systems are commonly used in practice. This heterogeneity poses challenges for data integration in Unity, as models must be correctly aligned in a common coordinate reference system while simultaneously ensuring that their spatial extent remains sufficiently close to the origin. The latter is essential due to performance constraints and spatial jitter caused by floating-point precision limitations due to the large distance of the objects from the world origin (Thome, 2005).

The problem can be mitigated by positioning the model coordinates close to the origin. If necessary, they can be converted to a global CRS using the transformation parameters defined in *IfcMapConversion*.

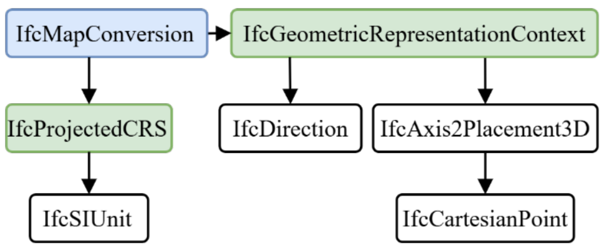

Figure 4: IFC entities linked to IfcMapConversion

IfcMapConversion stores the transformation parameters of the 2D Helmert transformation (buildingSMART International, 2020) and references *IfcProjectedCRS*, which defines the target CRS, as well as the applied length unit (*IfcSIUnit*). All entities associated with *IfcMapConversion* are illustrated in Figure 4.

To improve the interoperability of geospatial data and allow it to be integrated into Geographic Information Systems (GIS), the origin of the Cartesian model is converted into geodetic coordinates using the 2D Helmert transformation.

To preserve the associated geospatial information, these data are stored separately in a GeoJSON file. As GeoJSON relies on the World Geodetic System 1984 (WGS84) datum as its underlying CRS (Butler et al., 2016), the developed converter evaluates the EPSG code specified within *IfcProjectedCRS* to identify the coordinate reference system in which the IFC model is defined and to ensure a consistent transformation into the global reference frame. The coordinate transformation workflow is illustrated in Figure 5.

Development of an IFC-to-Unity Converter

During the development of the converter, the focus is placed on transmitting the previously defined semantic, 4D and geospatial information requirements for the BIM-to-field use case to the construction site.

Additionally, as the AR application runs natively on AR-capable end devices and is Unity-based, the building information model must be converted into Unity-compatible formats.

To validate the converter's functionality during development, two different IFC files are used as input datasets. Table 1 summarizes the key characteristics of these files.

Table 1: IFC Test Files used for Development

Test IFC	1	2
Size	80217 KB	286 KB
Nr. of Objects	1591	15
Source	Revit 2025	(buildingSMART, 2026)
Length Unit	m	mm
EPSG-Code	EPSG:25832	EPSG:32760
File Schema	IFC4X3_ADD2	

An AI assistant was used to support parts of the programming work (code suggestions and refactoring). All methodological decisions, result validation and final implementation approval were performed manually.

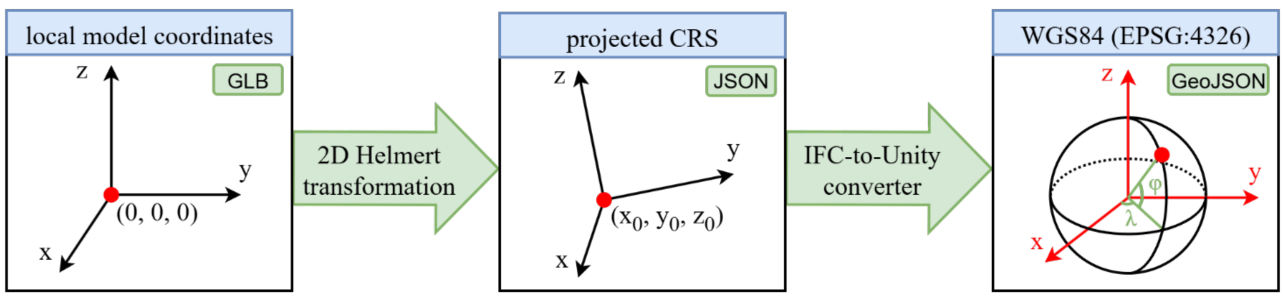

Figure 5: workflow for coordinate transformation to increase interoperability

Transmission of Geometric Information

As Unity cannot read the IFC schema, an appropriate 3D file format is selected to minimize data volume and loading times. Lee et al. (Lee *et al.*, 2019) compare the performance characteristics of commonly used 3D file formats, such as OBJ, STL, FBX, glTF and GLB. The analysis shows that glTF and GLB exhibit the highest rendering efficiency based on measured loading times within a web application.

A glTF asset is represented by a JSON-formatted (.gltf) file that contains a complete scene description, accompanied by separate binary files that store geometry data and image files that contain textures. If all this information is encapsulated within a single container file, the format is referred to as GLB. (Khronos Group, 2021)

To minimize loading times in the AR application while reducing the number of files to be managed, GLB is selected as the export format.

To transform the data from IFC to GLB, Python is used in combination with the *ifcopenshell* package (*IfcOpenShell*, 2024). The *ifcopenshell.geom* extension is used to control the geometric properties.

Since length units may be defined differently in different IFC files (see Table 1), the converter verifies whether the coordinates are defined in the length unit metre. If this is not the case, the coordinates are converted to metres before the transformation is applied.

Test IFC 1 (see Table 1) contains building openings that are modeled using void elements (*IfcOpeningElement*). To prevent these void elements from being exported as visible 3D objects into the GLB file, an auxiliary function is implemented within the codebase that collects the IDs of all objects of the type *IfcOpeningElement* and enforces the creation of openings in the GLB file by explicitly enabling opening subtractions. For this purpose, the software package *ifcopenshell* (*IfcOpenShell*, 2024) is utilized. During the export process, the filtered void elements are excluded.

Transmission of Semantic and 4D Information

The GLB format is geometry- and material-centric and does not provide a standardized way to natively represent IFC semantic information such as entity types, property sets or relational structures.

Various file formats are used in the literature to store semantic data for AR applications. Common options include CSV (Arvikar *et al.*, 2025), XML (Rehman *et al.*, 2025) and JSON (Lieblich & Weise, 2013). As XML (Extensible Markup Language) and JSON (JavaScript Object Notation) are both object-based, they can represent hierarchies and relationships derived from the IFC structure. This makes them particularly well-suited to the BIM-to-field use case.

As buildingSMART provides a dedicated ifcXML standard (Lieblich & Weise, 2013), XML is the preferred choice for representing the pure IFC structure. However, the performance of the AR application on the construction site poses a significant challenge within the BIM-to-field context. In this regard, the JSON format offers a significant advantage as it can be parsed more efficiently (Afsari *et al.*, 2017), resulting in improved runtime performance. Consequently, JSON is used as exchange format.

Before the properties are written to the JSON file, the converter first enriches a duplicated IFC model (B2F IFC) with the required entities.

At this stage, supplementary information – specifically scheduling and responsibility data (see Figure 2) – is extracted from a construction schedule. For validation purposes, a simplified schedule in JSON format is used, incorporating information on *IfcTask*, *ScheduleStart*, *ScheduleFinish*, *IfcCrewResource*, *IfcLaborResources*, *IfcActor*, *IfcPerson and IfcOrganization.*

Once the properties have been added to the B2F IFC, the BIM-to-field–relevant information is stored in an object-based manner in JSON format using Python. The exported properties are mapped to the corresponding 3D object using the GUID as the linking key.

Transmission of Geospatial Information

Geospatial information is stored in accordance with the workflow illustrated in Figure 5. Local model coordinates are stored in the GLB file to improve rendering performance and avoid visual artefacts. The projected coordinate reference system used during the planning phase is stored as an object in a JSON file. This enables spatially consistent, project-specific alignment and assembly of multiple models.

To further enhance interoperability, particularly with GIS applications, the coordinates of the projected coordinate reference system are also transformed into the WGS84 reference system and stored in GeoJSON format.

The converter uses the Python package *pyproj* (*pyproj*, 2026) to transform the coordinates into the target system (WGS84; EPSG:4326). As illustrated in Figure 5, the local model coordinates are transformed into global coordinates, and the EPSG code defined in IfcProjectedCRS is used to determine the source CRS for transforming the model origin into WGS84.

The geospatial coordinates stored within the IFC model itself remain unchanged.

Graphical User Interface

Figure 6 illustrates the graphical user interface (GUI) of the developed IFC-to-Unity Converter. To provide planning data for use in a BIM-to-field application in the most accessible and flexible way possible, the GUI has been designed so that the core functionalities can be controlled via the GUI. Accordingly, the converter functions described in the preceding sections can be selectively enabled via the GUI. The default configuration is shown in Figure 6.

Geometry-related functions are not selected by default in the GUI as these operations are only required when the underlying IFC file does not conform to the modelling standard. In such cases, in addition to the geometry functions already described, the GUI provides further options to rotate the model around the Z-axis and redefine the Z-axis (force Z-axis), should the coordinate system be misinterpreted.

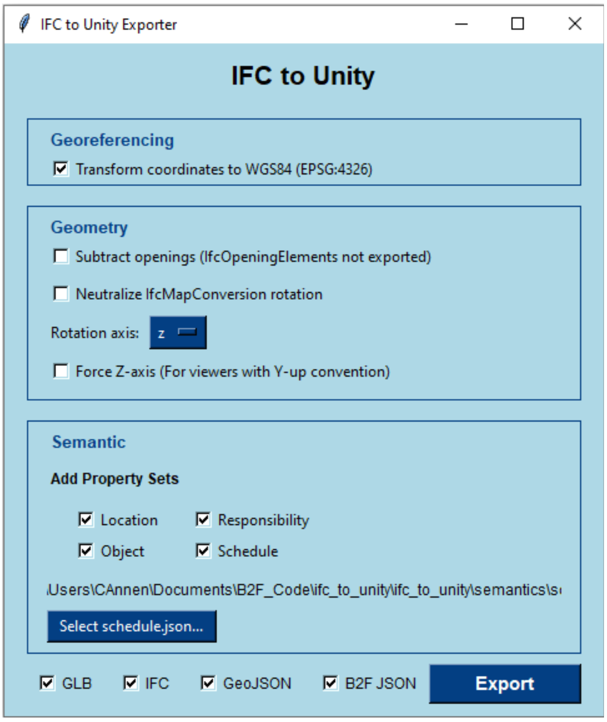

Figure 6: Graphical User Interface of the Converter

Validation

The validation of the IFC-to-Unity converter was carried out in two phases:

(1) preparation of the input data and
(2) execution of the validation.

Twelve IFC models were used as input data. Additional model information is summarized in Table 2. As no construction schedules were available for these models, model-specific schedule files were generated automatically from the IFC data. For this purpose, a Python-based schedule generator was developed to identify *IfcProduct* entities with geometric representations, group them by building storey and element category, and assign them to the trade groups structural works, finishing works, building services and other works. Based on this, deterministic synthetic actors and sequential task schedules were created.

The implementation was carried out in Python using *IfcOpenShell* for IFC parsing and geometry-related model queries. Standard Python libraries were employed for grouping, identifier generation, schedule logic and serialization. The objective was not to create technically realistic construction schedules, but to provide formally complete schedule data in JSON format, containing all input parameters required by the converter and thereby covering the previously defined minimum information requirements.

After a suitable schedule had been generated for each IFC file listed in Table 2, the resulting IFC-schedule pairs were processed by the IFC-to-Unity converter and transformed into the target formats GLB, IFC, GeoJSON, and B2FJSON. All input files were successfully transformed and thus formed the basis for the subsequent validation phase.

Table 2: IFC Files used for Validation

File	Model	Nr. of Objects	Size
1.1	structural	693	73058 KB
1.2	architectural	380	912 KB
2.1	structural	1138	49974 KB
2.2	architectural	469	922 KB
3.1	structural	435	79480 KB
3.2	architectural	322	1044 KB
4.1	structural	1016	80595 KB
4.2	architectural	639	1840 KB
5.1	structural	778	77369 KB
5.2	architectural	698	1897 KB
6.1	structural	890	17205 KB
6.2	architectural	383	972 KB

During validation, particular attention must be paid to the quality of the input data. The converter fully populates the entities assigned to the categories *Schedule* and *Responsibility* shown in Fig. 2, whereas those assigned to *Element* and *Location* depend on the completeness of the information contained in the input data. For example, if no material is assigned to an element, the exporter cannot infer the missing information automatically.

Accordingly, the validation is performed as follows. The properties assigned to the categories *Element* and *Location* are checked by means of scripts such that missing properties are reported only as warnings during export. By contrast, the properties assigned to *Schedule* and *Responsibility* must be transferred completely and correctly. Any deviation detected in these categories is therefore reported as an error during export. The whole validation process is shown in Figure 7.

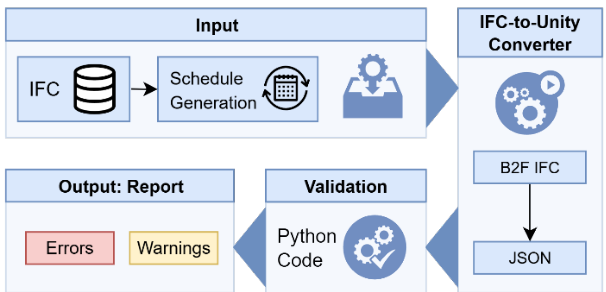

Figure 7: Validation Workflow

The validation is considered successful if the reports for the IFC files listed in Table 2 contain no errors and if all warnings can be logically explained.

The validation is performed on the exported JSON file, as this file is generated at the final stage of the IFC-to-Unity workflow. If a given piece of information is present in the JSON file, it can be assumed that it has also been successfully transferred to the B2F IFC.

The results of the validation are shown in Table 3.

Table 3: Validation Results

File	Attributes Checked	Errors	Warnings	Warning Ratio
1.1	8494	0	638	7.5%
1.2	15882	0	1526	9.6%
2.1	10601	0	654	6.2%
2.2	26916	0	2484	9.2%
3.1	7094	0	627	8.8%
3.2	9507	0	935	9.8%
4.1	14584	0	1132	7.8%
4.2	23968	0	2302	9.6%
5.1	15758	0	1374	8.7%
5.2	17377	0	1667	9.6%
6.1	8650	0	632	7.3%
6.2	21086	0	2072	9.8%
Total	**179917**	**0**	**16043**	**8.7%**

The warnings can be attributed to the following issues:

(1) the IFC source data do not provide values for either *Name* or *LongName* of *IfcBuilding* and
(2) some objects within the spatial IFC structure are not assigned to an *IfcBuildingStorey*.

As both warning types result from inconsistent input data, they are considered acceptable within the scope of the pipeline validation. Since the cross-model verification reveals no errors, the validation of the IFC-to-Unity converter is therefore considered successful.

Conclusions

Within the scope of this paper, various approaches are investigated to transform information from a building information model into a format readable by a game engine (Unity). It is demonstrated how both geometric data and semantic information can be transferred in a structured and interoperable manner. In accordance with the principles of OpenBIM, IFC version 4.3 ADD2 is employed as the source format for data transformation.

This paper formulates semantic requirements for building information models and the underlying IFC schema in order to enable the BIM-to-field use case for trades and construction workers in the construction industry. A set of relevant entities is defined based on IFC4X3_ADD2 to support targeted coordination among different trades. This includes information on building element properties, responsibilities, construction schedules and spatial location on the construction site. By relying on standardized IFC entities, interoperability between heterogeneous BIM authoring tools is ensured, while simultaneously establishing a foundation for enriching IFC models with additional information acquired during construction in future developments.

For geometric representation, GLB is identified as a suitable target format, while JSON is proposed for the transmission of semantic information. With regard to the export of 3D data, particular attention is given to the handling of IFC models that have already been georeferenced during the planning phase using *IfcMapConversion*.
While Unity operates using local model coordinates, BIM-based building planning typically relies on cartesian CRS. In contrast, data integration into GIS environments requires the use of global coordinate reference systems. To enhance interoperability in the context of data exchange, a workflow for handling these differing geospatial requirements is presented.

Furthermore, strategies are presented to prevent the export of non-essential 3D objects (e.g., *IfcOpeningElement*) by selectively filtering them out of the resulting GLB file.

Based on these findings, an IFC-to-Unity converter was developed and successfully validated.

In the context of further research, the defined information requirements will be refined and extended with trade-specific attributes. In addition, an interface for integrating construction scheduling data will be developed. This includes the specification of a linkage to scheduling tools commonly used during the planning phase, enabling the consideration of complex temporal dependencies within a BIM-to-field application. Moreover, future work will investigate methods for integrating newly acquired on-site information into the planning model. Within the field-to-BIM approach, particular emphasis will be placed on integrating schedule updates and construction progress data into the BIM environment.

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