2026 European Conference on Computing in Construction
Corfu, Greece
July 12-15, 2026

IFC5 FOR COLLABORATIVE AND TRACEABLE CIRCULARITY IN CONSTRUCTION

Tong Wang[1] and Thomas Krijnen[2]
[1]Delft University of Technology, Delft, The Netherlands
[2]AECgeeks, Eindhoven, The Netherlands

Abstract

Contemporary practices like evidence-based circularity and material tracking and tracing, are characterized by collaborative processes to layer, recombine, and update information non-destructively. This paper explores how the emerging IFC5, with USD-inspired, layer-based composition, enables such needs. The data model consists of layers, representing geometry, material characteristics, and lifecycle evidence. We explain how the principles help in a social housing circular window reuse scenario using a python-based web application on top of a Postgres database. By structuring information as composable layers, the introduced data model supports evidence-based circularity tracking, allows material and component matchmaking and information management.

Introduction

The transition to circularity in the built environment increasingly depends on the sector's ability to treat existing buildings as future supply systems, i.e. the repositories of products and components that can be recovered, verified, and redeployed. This shifts the feasibility of reuse and remanufacturing away from questions like "can we dismantle this?" toward information questions: what elements exist, where are they, what are their specifications and conditions, and can this evidence travel across project boundaries? This illustrates a critical premise for circular transition: without structured, component-level knowledge of the current stock, reused components remain difficult to specify, price, insure and certify.

The current information management practices in construction are typically fragmented across project phases, proprietary tools, and organizational boundaries, which makes multi-actor updating and validation difficult and leads to "static" records that quickly diverge from reality. This fragmentation is a well-recognized barrier in the circular construction literature, a persistent "information gap" between the data needed to scale reuse and what is available in practice, spanning identification, condition assessment and traceability (Byers et al., 2024).

To overcome circular transition challenges, in practice the use of digital technologies for tracking element reuse is increasing as exemplified in cases such as Durmiseciv (2018) and Hemubo (2026).

However, to scale up this way of managing information for circular transitions, system level stakeholder participation needs to be enabled. This increases the importance of governance, versioning, and responsibility for updates, which are features that are rarely robust in conventional document-based handovers (Çetin et al., 2023). Consequently, advancing circularity requires modular data models and lifecycle information infrastructures that enable multiple stakeholders to contribute, update, and reuse information consistently with traceable information records. This paper aims to answer:

RQ1 What are limitations in contemporary IFC technology in encoding buildings as future supply systems for circular construction?

RQ2 How can IFC5 and its JSON-based serialization format (IFCx) alleviate some of these pain points?

Methods

To answer the research questions, this study follows the following steps.

First, the current IFC technology limitations have been studied in literature as well as the IFC5 core principles to overcome such limitations.

Second, literature review has been conducted to understand the circular transition context in more detail, including the emerging regulations and supporting standards which make circular transition not wishful thinking, but a must take with mandatory data requirements, as illustrated in the emerging regulations and standards section below.

In parallel, we build upon ongoing research projects that support the understanding of challenges in the lifecycle information management of built assets for modular, participatory and traceable circular practice. This enables a solid foundation to showcase the potential that the new development in IFC5 could bring.

To make evaluation more concrete, we design a simple scenario of circular window reuse with the same asset owner.

The last part presents the data model, and the demonstration of the IFC5 at various milestones along the scenario process.

Results

Findings from the literature review as well as prototypical development to assess the applicability of IFC5 in the context of circularity are shown in this section.

Limitations of current IFC

Buildings as future supply systems require a data-oriented information modelling approach and to that extent Building Information Modelling (BIM) and the predominant open standard Industry Foundation Classes (IFC) to encode such information has seen more consistent adoption in the construction industry over time. The latest official edition of IFC is IFC4.3, encoded in the EXPRESS schema language, hereafter referred to as IFC4. There are limitations in IFC4 when it comes to facilitating circular construction. Tomczak et al. (2024) concludes that availability of specific information such as component connections that are vital for understanding demountability, remains a challenge in IFC and BIM-based workflows. This relates to (i) downstream information flows with limited ability for information to travel upwards; detailed manufacturing information might only be present at the time of a construction, but due to export-centric workflows where information flows downstream, authoring tools have little ability to consume this information to maintain a comprehensive record of information; (ii) construction knowledge is distributed across multiple project partners. While there are ample research and initiatives to define and compare information requirements, these only stipulate information contents between given point to point exchanges of information. Within the industry there is little incentive outside of these exchanges to combine knowledge.

Limitations of the current IFC and EXPRESS/SPF (Step Physical File; the predominant text-based serialization format used for IFC) it is based on can be summarized as: (i)Limited support for developer tooling and mindshare of the EXPRESS language and related serialization technologies due to idiosyncrasies and datedness, which does not connect to modern web-based APIs that are quick to deliver value and test assumptions. (ii) Technical serialization-level limitations such as the inability to combine data sets, inability to establish links across information carriers and lack of modularity in the IFC schema. (iii) Lack of uniformity in data due to the extensive set of modelling mechanisms, valuing backwards compatibility over consistency. (iv) High degree of complexity that impedes mapping to other storage technologies such as relational databases. (v)Monolithic exchange structures that do not enable granular composition with other datasets or incremental updates over time (van Berlo et al. 2021). These limitations impede the use of IFC for lifecycle updates of asset data, with multistakeholder collaboration. Building richer retrieval mechanisms on top of IFC serialization and data models has been attempted in Krijnen and Beetz (2018) and Wolf et al. (2025) using SPARQL on top of an efficient binary serialization mechanism or a GraphQL mapping respectively. While that aids discovery of information, it is not a step into the direction of freely recombining information. The semantic web has also been used in disseminating construction information and allows for collaborative authoring due to the nature of linked data, however geometrical information is not always efficiently stored (Pauwel et al. 2017) and there is not a rich ecosystem for working with geometry in the semantic web. The semantic web is most powerful when fully embraced natively in applications to depend on things like inference, which is not the case to date.

These aspects are recognized in buildingSMART. And over time, starting with designing and defining future principles (BuildingSmart,2020), the technical roadmap (BuildingSmart, 2020) and first explorations into a IFC5 resulted in the publication of a standard called IFC5 alpha (BuildingSmart, 2026). It is heavily inspired by Universal Scene Description (USD) (USD, 2026) a standard used in the film industry, a sector with similar needs in collaborative authoring. From USD, IFC5 derives its layer-based composition, data inheritance mechanisms, central placement tree and focus on explicit data for robustness with additional layers of meta-data for semantic richness. With such principles, IFC5 is particularly well aligned with the need for modular, multi-stakeholder lifecycle information management because its development direction explicitly shifts IFC towards modular schemas and extensibility. Information that is important for circular construction, e.g., condition assessment, deconstruction attributes can be added and iteratively refined without forcing every stakeholder to implement the entire schema or exchange the full model.

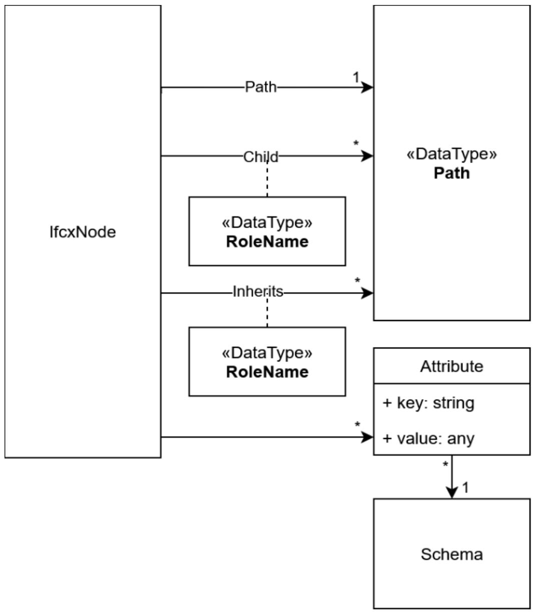

Figure 1: Schematic representation of the data model of nodes in IFCx. Children (for element decomposition and containment) and inheritance (for data reuse) are established as references to paths. The serialization remains flat without nesting. Multiple Paths do not uniquely identify a node. This realizes the collaborative distributed nature by allowing different sources to augment the shared understanding of an element

IFC5 alpha follows an exchange format in JSON with a minimal schema. The exchange structure is called IFCx and consists of a header with provenance information, imports, schemas and a data array of primitives. Primitives are objects that have a path in the tree, inheritance relationships to other primitives, children relationships to other primitives and attributes as key-value pairs. The schemas in the header govern the validity of these key-value pairs. Imports from the header are essentially prepended to the dataset and can contain schemas and other primitives. Inheritance relationships broadcast all information, attributes and children, along the inheritance edge and are essential to realize re-use of information (see Figure 1).

Emerging regulations & supporting standards

The EU policy context for traceable, reusable construction components is increasingly shaped by a shift toward digitized, interoperable information flows. The Construction Products Regulation (CPR), Regulation (EU) 2024/3110, explicitly motivates the need for "well-functioning information flows" using electronic means and machine-readable formats, so that coherent product performance information is available along the supply chain and supports the digitalization of the construction sector (Eota, 2024). A central mechanism introduced by the CPR for product-level traceability is the Digital Product Passport (DPP). Article 76 requires that a DPP includes core compliance information (notably the declaration of performance and conformity), corresponds to the product type and its unique identification code, and allow designated actors to introduce or update information in the passport. Importantly for reuse workflows, Article 76(3) states that DPP requirements should improve traceability of products along the value chain. CPR also links unique identifiers, data carriers, and the DPP registry mechanisms to the horizontal DPP framework established under the Ecodesign for Sustainable Products Regulation Regulation (EU) 2024/1781, unless CPR delegated acts specify otherwise. For renovation, the Energy Performance of Buildings Directive (EPBD) introduces building-level information pathways via renovation passports and (where they exist) digital building logbooks (DBLs). In Article 12(7)(8) it requires renovation passport information to be uploadable to national energy performance databases, and that the "easiest approach" is to use a machine-readable, standard format that supports seamless integration and querying (European Commission, 2024). Open data schemas such as Industry Foundation Classes (IFC) are explicitly intended to provide vendor-neutral, machine-interpretable representations that enable information exchange across tools and use-cases, forming a backbone onto which circularity modules (e.g., material passports, audit results, condition states, reuse certifications) can be attached (BuildingSmart, 2026).

Lifecycle information management for circularity

Lifecycle information management has long been positioned as an enabler of collaboration in BIM-based delivery and operations, but circularity raises the bar by even requiring data continuity beyond a single project and into end-of-life recovery and second-life deployment. Standards-based guidance associated with ISO 19650 frames the core problem as ensuring the right information is created, shared, and maintained over the whole asset lifecycle through controlled processes and a common data environment (UK BIM Framework, 2021). In circular settings, this lifecycle requirement becomes sharper: component information must remain usable when the original design/construction team is gone and when new actors (deconstruction contractors, remanufacturers, reuse marketplaces, regulators, new designers) need to interpret and trust the data. Policy and practice guidance on pre-demolition or "waste" audits implicitly treat information as the first circular intervention: the European Commission's audit guidance emphasizes qualitative and quantitative assessment of what will arise from demolition/renovation in order to maximize recovery and reuse (European Commission, 2018). Yet, even where audits exist, their outputs are commonly delivered as isolated reports or spreadsheets that are difficult to integrate with design models, asset registers, maintenance systems, and marketplaces. This means that the information is generated but not maintained as an updatable asset. This is the specific information-management failure that circular pilots attempt to mitigate through traceability schemes (e.g., coded material databases in Kerkrade; component-level QR/NFC "DNA") because such mechanisms create a minimum viable link between physical components and persistent records that can be consulted by later stakeholders (Durmisevic, 2018). The same "information-first" premise appears in Amsterdam's circular window-frame practice: embedding an identifier on frames that links to a web page containing provenance, processing, finishing, and expected lifetime data which effectively treats the component as an information object that can be managed and verified across actors and over time (Hemubo, 2026). Together, these applied cases indicate that even though circularity is constrained by recovery logistics (Lu et al., 2023), emerging technologies are making assets into a next use traceable.

However, one key implication is that circularity is not well served by monolithic, one-size-fits-all datasets; instead, it requires modular data models that can (i) represent construction objects consistently, (ii) attach new lifecycle modules (condition monitoring, disassembly history, compliance evidence, ownership transfers), and (iii) support interoperability across heterogeneous systems. Research on digital product passports and material passports has increasingly converged on modular modelling as a response to the complexity and volume of lifecycle data. For example, a modular ontology modelling approach for digital product passports has been proposed specifically to address the challenge of representing, managing, and exchanging circularity-relevant information at scale, arguing that modularity improves extensibility and reuse of data structures as requirements evolve (Kebede et al., 2024). This direction is reinforced by the circular construction ecosystem (e.g., Buildings-as-Material-Banks initiatives), which frames material passports as structured datasets that describe the characteristics giving materials value for recovery and reuse and positions them as “one-stop” information resources. This is an ambition that is only attainable if information can be structured, updated, and exchanged across actors (BAMB, 2020). The housing-sector evidence base further underlines why modularity matters: social-housing organisations need passport data that covers maintenance, renovation, and demolition use-cases simultaneously, implying that the underlying model must support different stakeholder views and responsibilities without losing semantic consistency (Çetin et al., 2023).

Implementation

To answer the second research question a protypical implementation is conceived to simulate a simplified scenario in a circular construction context. The scenario is developed and validated in the on-going research projects with multiple stakeholders in façade products to rethink future circular constructions (NGF, 2025); the phases and steps described have been discussed and validated as realistic potential to-be scenarios. This scenario is used to link various stakeholders with the modular design principle of IFC5. In this research the focus is not on a demonstration and validation of the entire workflow, but on the technical requirements involved. The scenario is explained as follows: a social housing organization (the client) demolishes a single residential building (Building A) and seeks to reuse selected windows in a new replacement building (Building B). The operational challenge is threefold: first, the demolisher must capture reliable “as-removed” window information during selective strip-out; second, the architect designing the new building must be able to perform matchmaking using data that is integrated into the building information model rather than dispersed across unstructured reports. And lastly the asset owners should be able to provide demolishers with demountable window sets and keep track of the reused windows in the new building.

Demolition phase: demonstrated in updating

Before demolition begins, windows in Building A are represented as identifiable component instances in the client’s digital building model. During selective removal, the demolisher updates the model by appending statements to their layer of information, per window instance, the data required for downstream reuse decision-making. In addition, the demolisher records a condition snapshot and handling-related notes relevant to transport and onward processing, reflecting the practical reality that removal method, contamination, and damage significantly affect reuse feasibility. The demolisher’s contribution is framed as a specialized dataset: it describes the state of each window at the point of removal and the conditions under which it can plausibly be reused, without requiring the demolisher to author design information for the new building. This separation of responsibilities is essential for scalability as demolishers can provide factual “as-removed” information, while architects can interpret that information within the constraints of the new project.

Design phase: demonstrated in matchmaking

The architect uses the updated window information (stored in a federated set of multiple layers) as a stock list for reuse. Matchmaking is performed by comparing recovered-window descriptors to the dimensional and performance requirements of the new building design. This produces a mapping between the new building’s window openings and specific recovered window instances, which supports both procurement planning (reducing the number of new windows that must be purchased) and design development (ensuring that the design accommodates the constraints of the recovered stock, where reuse is intended).

Installation and maintenance phase: demonstrated partially in querying

Once installed in the new building, each reused window is recorded as an “as-installed” component instance, including its installed location, installation date, and any relevant references to associated product information. This paper only demonstrates the querying for windows without linking to the other digital repositories. Where a Digital Product Passport exists for a given window product (for example, if the window has been remanufactured and supplied under a product regime that provides a DPP), the installed component record includes a pointer to that passport. This creates product-level continuity: the same product information can be accessed later for maintenance, renovation, or audit, and updates can be managed by the responsible actors in the passport system rather than being embedded as static attachments. The building-level traceability layer is also established through a building repository approach consistent with the logbook pathway. The owner maintains a record of installed reused windows as part of the building’s digital record, enabling future renovation planning. This links product-level traceability and building-level traceability so that reused windows remain discoverable across the building lifecycle, rather than becoming “lost”.

Prototype development

Here we illustrate how IFC5 data models and serialization technologies relate to the circular construction context described above. Note that the demonstration is meant to show and validate features on a conceptual level. Due to the limited number of constructs, uniformity of structure and usage of JSON, for which most modern database management systems have native support, this structure is easily serialized to a relational database. For this experiment the following table layout (Figure 2) was chosen. Important to note are the indirections between Project – Layer – Primitive, so that a Project has multiple layers (this is the multi-disciplinary aspect). A primitive has a single attribute blob as a JSON field and inherits children edge pointing to UUIDs. Also note that Primitive UUIDs are not unique (in the IFCx structure they are called “path”), so that multiple definitions pointing to the same path can be retained. This also enables the multi-disciplinary nature so that objects are open to be extended with additional data.

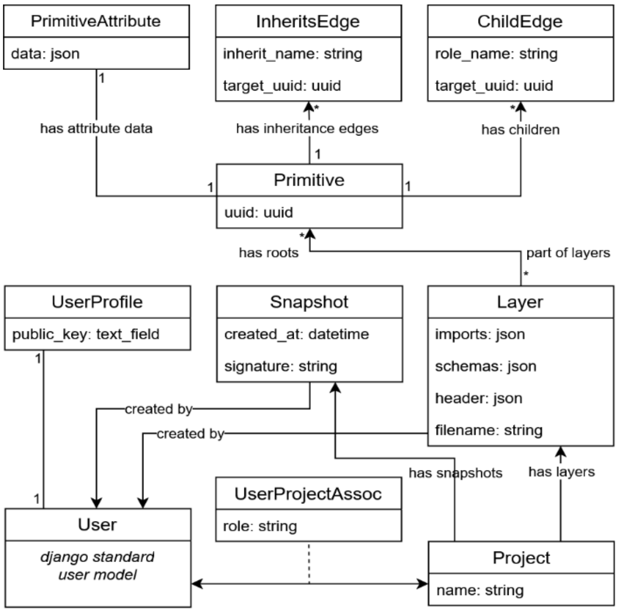

Figure 2: Data model used in the implementation.

Data ingestion follows an append-only nature, meaning that all data is immutable in the database, newer opinions (attributes at the same path) can override pre-existing ones and will come in with a higher strength, but it is possible to go back to a previous state because everything is time-stamped. Snapshot allows stakeholders to take a state of the project and create a digital signature. The database model is generated from python code and implemented in the Django web framework. The queries shown later are actual logged queries from the implemented prototype.

To investigate the implications of circularity tracing and reuse, we have experimented with only storing the layer_id in case of a root primitive (a primitive with no incoming child or inheritance edges). The root primitive is typically the IfcProject entity. Therefore, subsequent children can freely be associated with multiple layers (and therefore physical projects) to see how data can flow between projects in accordance with the physical products when one building is decommissioned and windows are moved to the next building. Listings below illustrate the different purposes enabled by this data model, i.e. querying, updating, and matchmaking.

Querying

As mentioned above, there have been initiatives of query languages on top of reserializations or conversions of IFC models but widely implemented IFC query languages to date are not in use. This section illustrates that by means of the simpler layout of IFC5 data, reliance on industry standard data representation techniques such as JSON and mappings to standard database management solutions, querying techniques are available on top of IFC5 content.

Listing 1 describes Postgres-specific query using JSON-object-subset search. As such we can locate all

PrimitiveAttribute instances of class IfcWindow. Note how the association of a class (or building element type) is like any other data attribute field an arbitrary (but schema-enforced) key-value pair. This is something already observed in van Berlo et al. (2021) where it was called “late bound” type definitions, since distinct building element classes do not relate to specific behavior in software, and mappings from native models to IFC classes need to be fully configurable by the end-user.

```
SELECT *
FROM primitive_attribute INNER JOIN primitive
ON (primitive_attribute.primitive_id = primitive.id)
WHERE primitive_attribute.data @> '{"bsi::ifc::class":
{"code": "IfcWindow"}}';
```

Listing 1. SQL query on top of the data model to demonstrate indexed JSON-object-subset search in contemporary database.

In addition, we want to find (recursively) all elements inheriting from the Primitive with this attribute (but not elements having it as a child) because the class association might be assigned at a re-used archetype (or a Family as sometimes called in BIM authoring tools). Everything that inherits from these primitives is also an IfcWindow (unless the attribute is locally overwritten there). The inheritance aspect can be solved transitively by applying a recursive Common Table Expression (CTE) in Postgres with the results from the previous query, following inwards edges (Listing 2).

```
WITH RECURSIVE edge AS (
  SELECT primitive_id, target_uuid FROM inherits_edge
),
walk AS (
  SELECT
    p.id, p.uuid,
    ARRAY[p.id]::bigint[] AS visited_ids,
    0::int AS depth
  FROM primitive p
  WHERE p.uuid = ANY(ARRAY['2c2d549f-f9fe-4e22-8590-
    562fda81a690'::uuid,'592504dc-469a-44d6-
    9ae8-c801b591679b'::uuid,'25503984-6605-
    43a1-8597-
    eae657ff5bea'::uuid]::uuid[])
  UNION ALL
  SELECT
    p2.id, p2.uuid,
    w.visited_ids || p2.id,
    w.depth + 1
  FROM walk w
  JOIN edge e ON e.target_uuid = w.uuid
  JOIN primitive p2 ON p2.id = e.primitive_id
  WHERE NOT (p2.id = ANY(w.visited_ids))
),
uniq AS (
  SELECT DISTINCT id FROM walk

)
SELECT p.*
FROM primitive p
JOIN uniq u ON u.id = p.id ORDER BY p.created_at, p.id;
```

Listing 2. SQL query using a recursive CTE to find inheriting primitives. This is a verbatim copy of the query. The array of uuids present in the query comes from the Object-Relational Mapping;program code to interact with the database schemas)

This also highlights how modern database solutions can be used to efficiently apply the inheritance and children relationships to the dataset. In the IFC5 project team it has been discussed whether data inheritance is necessary as it has negative implications on data locally and complexity. The experiment here shows that the complexity and performance concerns are not insurmountable.

The query above is for finding primitives that inherit from other primitives. Similarly, a query can be used to do a forward traversal over inheritance and children edges. This query is used when returning the data to the user to return a full model subset. This query is equivalent, just the edges are formed as the union of inherits_edge and children_edge, and the direction is reversed (concerns the ON clauses in edge and primitive).

This full model subset is valid IFCx again that can be visualized in one of the supported tools (Figure 3).

Figure 3: Query demonstration. Note that the result presented is not a visual selection of relevant models: with the IFCx serialization structure, a query result is a complete and valid model subset that can be used and recombined, for the full set see (IFC5 Development, 2026).

This highlights an important distinction between IFC5 alpha and earlier editions of the spec, which had much more dense graphs requiring a lot of other contexts, such as IfcGeometricRepresentationContext and IfcProject with IfcUnitAssignment. These combinations made extracting and concatenating content much more complicated. In IFC5 because of the flat pre-composition data structure, the literal serialization of the primitives selected provides us with all the relevant contexts.

Updating

When the demolisher receives the window query model, they can go on-site to add inspection information. Using a modular ontology, they create a new layer with only this information. The usage of paths in IFCx, makes sure that information lines up with the pre-existing content. This is to illustrate the applicability of updating information by a specific stakeholder in the process (Listing 3).

```
{
  "path": "23ea7c34-6e5a-47ee-b292-ebedfd585438",
  "attributes": {
    "decommissioningStatus":"removed",
    "currentState": "stored",
    "conditionGrade": "B",
    "damage": "minor_scratch",
    "contamination": "none_detected",
    "disassemblyType": "reversible",
    "reusePotential": "direct_reuse",
    "recommendedAction":
      "clean_and_reinstall"
  }
}
```

Listing 3. IFC5 primitive that is ingested by the demolisher showing the modularity of IFC5 schemas and the collaborative data authoring by composition of data on paths

Matchmaking

At this stage, a new project is created. The architect uses this data model with the dimensions of the windows enriched with the inspection information to select suitable windows to be reused. We illustrate this with just a simple wall with the same void. To this experiment, a wall is created in the open-source BIM authoring tool Bonsai with an opening that matches the to-be-reused window, saved as IFC4 and converted to IFC5. The transfer of the window element from the old model to the new model is manifested by means of creating a new primitive in the old model that inherits from the window to be reused. In this case, a placement transformation is necessary because the demo model used does not have proper relative positioning (Listing 4).

```
{
  "path": "33ea7c34-6e5a-47ee-b292-ebedfd585438",
  "inherits": {
    "circularReuse":  "23ea7c34-6e5a-47ee-b292-
    ebedfd585438"
  },
  "attributes": { "usd::xformop": {
      "transform": [[0.0, -1.0, 0.0, 0.0],
            [1.0, 0.0, 0.0, 0.0],
            [0.0, 0.0, 1.0, 0.0],
            [4.98, 12.97, -0.71, 1.0]]
}}},
```

Listing 4. Primitive that is created in the new model that inherits from and repositions the reused window instance (The term "circularReuse" is a human-readable label to reference the inheritance edge; it has no computer-interpretable semantics.)

Now we place this removed window from another building on the newly created wall (Listing 5, Figure 4).

```
{
  "path": "46b17e20-783e-4bf5-ac74-714b859be0b3",
  "children": {
    "Body": "a03ebe4d-2e40-524e-9144-c03ebec7100e",
    "Window": "33ea7c34-6e5a-47ee-b292-ebedfd585438"
  },
  "inherits": {
    "material":  "8a187a90-3dcf-58cc-b3a6-51a9a407c55a"
  }
}
```

Listing 5: Newly created wall primitive with additional child inserted

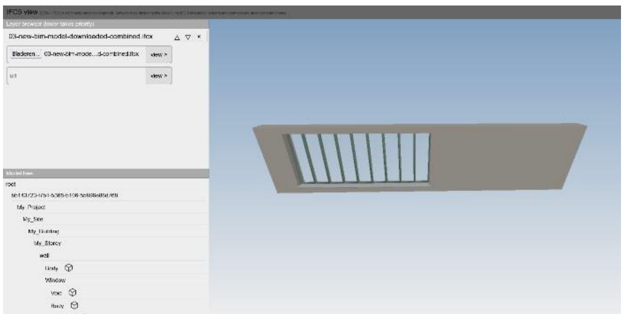

Figure 4: Result of reused window model when recursive query

traverses also into the reused window by means of path references

Discussion

The study can be further improved by testing other user requirements for circular construction, such as updating logistics constraints by transporting parties and warehouse facilities for storing the products and integrating other information sources like IoT for smart homes and linking with digital building logbooks or renovation passports.

It is worth noting that this research does not aim for a complete circular workflow but the technical possibilities of using IFC5 to enable modular, participatory and traceable data exchange. This is used to support circular use cases like querying by the clients for their assets, updating information from the perspective of the demolishers and the matchmaking by the architects using reclaimed windows for a new project. These are based on a simplified circular scenario. Future research should study from the user perspective to what extent this could be adopted and implemented in the inter and intra organizational settings, which will impose a greater need on transport and APIs as this research focused predominantly on the data-model.

In addition to that, the emphasis here has been mostly on the serialization-level aspects of the IFCx data encoding used by IFC5 and how industry-standard solutions such as the Postgres database management system with its support for JSON fields in tables, indexed JSON object subset search and recursive expressions enables a good amount of the core set of functionalities that are needed to deliver a platform to host such functionality. It is expected that other tooling around JSON is equally valid and useful, such as DuckDB or command line tools such as jq. In this implementation there is nothing special about Postgres and that is exactly the advantage of the IFCx JSON-based serialization mechanism.

In IFCx, provenance is tracked by means of the containing layer, but there is still ongoing debate on the balance between primary file-based workflows and more transient datasets created as query results and how this impacts the need for per-component identity or provenance records. The focus on data model in this research left aside most of the queries of transport: how do the various layers get into one (federated) data environment? In this research, the requirements for that have been simplified by simulating a case where the owner of the windows did not change. These are worthwhile, but also mostly orthogonal, questions for future research.

Conclusions

Emerging regulations for circular construction have raised requirements to exchange information among multiple actors in a modular and traceable approach. This paper has described pertinent IFC4 limitations in encoding information for the purpose of circularity and how IFC5 can help different actors in the value chain to deal with the emerging regulations for circular strategies like reuse of built assets using a simple context. The used dataset can be found in the following link: https://zenodo.org/records/18505849.

Currently, re-allocating the data representation of an IFC element to a new project in a fully immutable append-only and traceable data model would have been impossible to accomplish on IFC4 datasets due to the contextual references required to context and objectified relationships and the lack of data-level composition mechanisms.

With the new capability and data model of IFC5, the circular transition can be operationalized and upscaled by the supply chain partners participating in data querying, updating and matchmaking for reusing of assets.

Acknowledgments

Part of this work is funded by Het Nationaal Groeifonds Toekomstbestendige leefomgeving.

References

BAMB. (2020). Materials passports. https://www.bamb2020.eu/topics/materials-passports/

BuildingSMART International. (2026). Industry Foundation Classes (IFC). https://www.buildingsmart.org/standards/bsi-standards/industry-foundation-classes

BuildingSMART International. (2020) Ten principles of a future IFC. https://github.com/buildingSMART/NextGen-IFC/wiki/Ten-principles-for-a-future-IFC

BuildingSMART International. (2020) Technical roadmap.https://www.buildingsmart.org/about/technical-roadmap/

BuildingSmart International (2026) IFC5 development. https://github.com/buildingSMART/IFC5-development/

Byers, B. S., Raghu, D., Olumo, A., De Wolf, C., & Haas,

C. (2024). From research to practice: A review on technologies for addressing the information gap for building material reuse in circular construction. Sustainable Production and Consumption, 45, 177–191. https://doi.org/10.1016/j.spc.2023.12.017

Çetin, S., Raghu, D., Honic, M., Straub, A., & Gruis, V. (2023). Data requirements and availabilities for material passports: A digitally enabled framework for improving the circularity of existing buildings. Sustainable Production and Consumption, 40, 422–437. https://doi.org/10.1016/j.spc.2023.07.011

Çetin, S., Raghu, D., Honic, M., Straub, A., & Gruis, V. (2023). Material passports for social housing stock: A tool. In S. Çetin (Ed.), Towards a circular building industry through digitalisation (pp. 151–186). TU Delft OPEN Publishing. https://pure.tudelft.nl/ws/portalfiles/portal/237912925/Material_passports_for_social_housing_stock.pdf

Ding, L., Wang, T., & Chan, P. W. (2023). Forward and reverse logistics for circular economy in construction: A systematic literature review. Journal of Cleaner Production, 388, 135981. https://doi.org/10.1016/j.jclepro.2023.135981

Durmisevic, E. (2018, November). The Super Circular Estate project: Journal No. 1. Urban Innovative Actions.https://uia.urban-initiative.eu/sites/default/files/2019-02/Kerkrade_Journal.pdf

European Commission. (2025). Renovation passports (Article 12, Annex VIII): Annex 4 to the Commission notice providing guidance on new or substantially modified provisions of the recast Energy Performance of Buildings Directive (EU) 2024/1275 (C(2025) 4132 final).https://energy.ec.europa.eu/document/download/0a4a6 d59-58c0-4e80-a58a a6ee944573ab_en?filename=Renovation+passport+%28Article+12%2C+Annex+VIII%29+-+annex+4.pdf

European Parliament and Council of the European Union. (2024, November 27). Regulation (EU) 2024/3110 laying down harmonised rules for the marketing of construction products and repealing Regulation (EU) No 305/2011 (Text with EEA relevance). Official Journal of the EuropeanUnion.https://www.eota.eu/sites/default/files/files/OJ_L_202 403110_EN_TXT.pdf

European Commission. (2018, September 14). Guidelines for the waste audits before demolition and renovation works of buildings. DocsRoom. https://ec.europa.eu/docsroom/documents/31521/

Hemubo. (2022, December). De Bosleeuw: Circulaire kozijnen.https://www.hemubo.nl/wp-content/uploads/2022/12/ARTIKEL_Bosleeuw-circulaire-kozijnen-DEF.pdf

International Organization for Standardization. (2025). ISO 23387:2025 Building information modelling (BIM)—Data templates for objects used in the life cycle of assets (2nd ed.) https://www.iso.org/standard/85391.html

Kebede, R., Moscati, A., Tan, H., & Johansson, P. (2024). A modular ontology modeling approach to developing digital product passports to promote circular economy in the built environment. Sustainable Production and Consumption, 48, 248–268. https://doi.org/10.1016/j.spc.2024.05.007

Krijnen, T., & Beetz, J. (2018). A SPARQL query engine for binary-formatted IFC building models. Automation in Construction, 95, 46-63.

Ding, L., Wang, T., & Chan, P. W. (2023). Forward and reverse logistics for circular economy in construction: A systematic literature review. Journal of Cleaner Production, 388, Article 135981. https://doi.org/10.1016/j.jclepro.2023.135981

IFC5-Development (2026). BuildingSmart Internationa. https://github.com/buildingSMART/IFC5-development/tree/main/examples/ACCA%20Building

NGF (2025). National Growth Funds for the future proof living environment. https://www.nationaalgroeifonds.nl/overzicht-lopende-projecten/thema-energie-en-duurzame-ontwikkeling/toekomstbestendige-leefomgeving

Pauwels, P., Krijnen, T., Terkaj, W., & Beetz, J. (2017). Enhancing the ifcOWL ontology with an alternative representation for geometric data. Automation in Construction, 80, 77-94.

Tomczak, A., Benghi, C., van Berlo, L., & Hjelseth, E. (2024). Requiring circularity data in BIM with Information Delivery Specification.

Tomczak, A., v Berlo, L., Krijnen, T., Borrmann, A., & Bolpagni, M. (2022, November). A review of methods to specify information requirements in digital construction projects. In IOP Conference Series: Earth and Environmental Science (Vol. 1101, No. 9, p. 092024). IOP Publishing.

USD (2026) Universal Scene Description. https://openusd.org/release/index.html

UK BIM Framework. (2021). Guidance Part 3:Operational phase of the asset life-cycle (Edition 2).https://www.ukbimframework.org/wp-content/uploads/2021/02/Guidance-Part-3_Operational-phase-of-the-asset-life-cycle_Edition-2.pdf

van Berlo, L., Krijnen, T., Tauscher, H., Liebich, T., Van Kranenburg, A., & Paasiala, P. (2021, October). Future of the industry foundation classes: towards IFC 5. In Proc. of the 38th International Conference of CIB (Vol. 78, pp. 11-15).

Wolf, N., Esser, S., & Borrmann, A. (2025). IFC2GRAPHQL: Schema Mapping and Automated Api Construction From IFC to Graphql.