Research paper

BIM to GIS: Multi-Criteria Queries for Material Tracking in Circular Built Environments

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Abstract
This study proposes a lightweight approach to BIM-GIS integration for circular economy applications, focusing on timber component repurposing in the Norwegian housing stock. Rather than emphasizing detailed geometric representations, we address key challenges in material stock assessment by prioritizing semantic data. Using the Level of Information Need (LOIN) framework, we identify critical parameters for timber reuse based on European standards EN 14080 and EN 14081. We implement a GeoJSON-based method that selectively extracts purpose-specific information from IFC models, achieving an 80.73% reduction in data volume while preserving all required semantic attributes. This enables multi-criteria queries linking 525 timber components to a cadaster dataset of 14,081 detached houses in Trondheim. Validation results confirm complete semantic data retention and sub-3-second query execution on standard GIS hardware. By focusing on essential material attributes rather than computationally intensive 3D models, the method supports scalable material stock assessments and efficient identification of reusable components. These findings demonstrate that selective information extraction enhances computational performance while maintaining decision-critical detail. Future work should explore ontology-driven approaches to improve multi-domain interoperability and enable more advanced semantic querying.

Keywords: Circular Cities · BIM-GIS Integration · Component Reuse · Material Stock

1. INTRODUCTION

The building sector significantly impacts the environment, contributing to waste production, raw material consumption, and greenhouse gas emissions (United Nations Environment Program, 2012; Intergovernmental Panel on Climate Change, 2022). Construction materials are responsible for nearly 23% of global carbon emissions, making sustainable resource management crucial (Huang et al., 2018). A circular economy (CE) approach can help narrow, slow, and close material loops, regenerating the natural environment (Konietzko et al., 2020).

A key challenge in achieving circularity within the built environment is obtaining detailed, up-to-date information on existing building stock at the component level. Most building stock information exists at an aggregated scale, making it challenging to assess material reuse or repurposing potential (Arbabi et al., 2022; Cartwright et al., 2021). Enhancing circular economy strategies in the built environment can benefit from structured, high-granularity material stock estimates that improve spatial resolution and component-level data. Achieving this requires scalable approaches that can be efficiently applied across multiple buildings, such as automated sensing and machine learning-based stock characterization. Additionally, integrating such methods with existing data infrastructures could improve information accessibility for circular economy stakeholders (Arbabi et al., 2022).

Building Information Modeling (BIM) provides detailed, structured information about building elements, components, and materials, enabling stakeholder collaboration and supporting informed decision-making throughout a building's lifecycle (Eastman et al., 2018). Meanwhile, Geographic Information Systems (GIS) support spatial analysis, visualization, and management of built assets at city and regional scales by integrating diverse

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datasets such as topography, infrastructure networks, and land use (Tsui et al., 2024). However, common GIS models often lack the detailed geometric and semantic information necessary for precise asset-level management. Due to fundamental differences in data structure and application domains, data integration and interoperability remain significant challenges in BIM-GIS integration. Another key limitation in material stock assessment is that many existing BIM models lack the necessary Level of Information Needs (LOIN) to provide accurate and reliable material quantifications. Instead of purpose-built models, many studies rely on generic, high-level archetypes that do not reflect site-specific variations in material use, construction methods, or regional conditions. Because these archetypes are not specifically designed to assess material stocks and their potential for reuse or repurposing, they introduce significant uncertainties in material quantity and quality assessments. When upscaling these generalized models to city or regional levels, errors propagate geometrically, leading to increasingly unreliable stock estimates. Addressing this issue requires LOIN-driven, site-specific BIM modeling to capture only the necessary material attributes. This approach improves data accuracy, transferability, and decision-making in circular economy applications.

However, implementing such an approach requires efficient data exchange between BIM and GIS systems. BIM information exchange primarily uses the IFC (Industry Foundation Classes) open standard, while GIS relies on GML alongside other OGC (Open Geospatial Consortium) standards such as CityGML, CityJSON, and GeoJSON. The integration process typically involves converting data between these different formats (Ohori et al., 2017; Sani et al., 2019; Zhu & Wu, 2022). Converting BIM data to CityGML results in a significant loss of both geometrical and semantic information (Wang et al., 2019; Zhu & Wu, 2022). Geometrically, transforming Constructive Solid Geometry (CSG) and Swept Solids used in IFC to Boundary Representations (BRep) and Triangle Meshes causes significant losses in volume and area calculations while increasing file size due to additional triangulation (A. H. Liu & Ellul, 2022). IFC can represent complex shapes as volumes, while CityGML allows only simpler surface geometries (X. Liu et al., 2017).

Semantic information, such as detailed material properties of building elements, is not fully supported in the CityGML format. As a result, critical material attributes are lost during conversion, and multi-layered materials are simplified into single entities. Building use classifications are also generalized, and spatial relationships (e.g., wall-to-wall connections, window-to-wall associations) are not retained (Stouffs et al., 2018). Despite efforts to reduce these losses through improved conversion methods and semantic mapping (Stouffs et al., 2018; Şenol & Gökgöz, 2024), the conversion from IFC to CityGML continues to introduce significant uncertainties when converted models are used for material stock assessment, as accurate material properties and quantities are essential for such calculation. These uncertainties are further amplified when high-level archetypes are used to estimate material stocks across multiple buildings. Since these archetypes do not capture site-specific variations in material composition, construction techniques, or reuse potential, their upscaling to city or regional levels leads to compounded errors in material quantification (Koutamanis et al., 2018).

Beyond these limitations, BIM models themselves require adaptation for specific applications. Figure 1 (BIM Forum, 2024) shows that estimating quantities and specific sizes of timber components in walls requires a Level of Development 350 (LOD) while calculating concrete wall volume might only need LOD300. Since buildings contain many elements and materials, multiple LODs may be necessary for different components to fulfill the same BIM use.

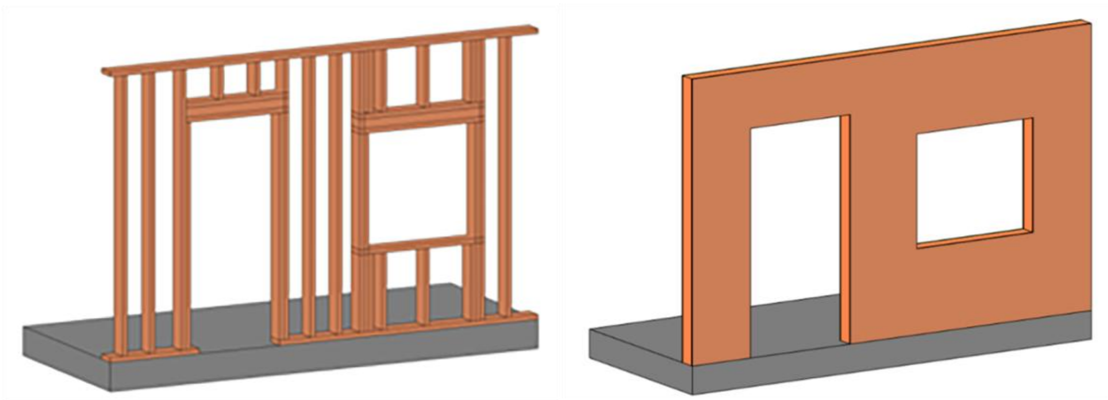

Figure 1. Different LOD Levels: LOD 350 on the left, LOD 300 on the right

While LOD specifications define the level of detail for different elements, they do not inherently consider whether the included information is necessary for a specific use case. In contrast, the Level of Information Needs (LOIN) framework (European Committee for Standardization, 2020) provides a targeted approach, specifying only the essential geometric and semantic data required for a given purpose. This improves accuracy while reducing unnecessary data redundancy. A recent study by (Parezanović et al., 2025) demonstrated the limitations of CityGML-based material stock assessments, revealing discrepancies of up to 60% in concrete and timber estimates compared to BIM and cadastral data. While these errors were attributed to differences in data sources and modeling approaches, further inaccuracies likely stemmed from the insufficient detail in their BIM models' LOD. Since the study relied on LOD 300, which represents building elements only in terms of overall shape and thickness (BIM Forum, 2024), this level of detail may be insufficient for accurately this level of detail may have been insufficient for accurately estimating timber quantities in walls and roofs.

Although CityGML is widely used for BIM-to-GIS integration, its geometric and semantic limitations raise concerns about its effectiveness in material stock estimation. As highlighted by (Çetin et al., 2023), material passports and circular economy strategies rely on detailed semantic attributes, such as material composition, classification, location, toxicity, and reuse potential. While CityGML provides a spatial framework, it lacks built-in support for these crucial material attributes, underscoring the need for enhanced semantic data integration in GIS. Current BIM-GIS integration approaches have advanced geometric transformations and spatial visualization but still face fundamental challenges when applied to material-focused circular economy applications. These methods often involve a trade-off between semantic detail and computational efficiency, limiting their effectiveness for material stock assessment. The study by (Parezanović et al., 2025) highlighted this issue, showing significant discrepancies in material quantification when using CityGML for circular economy applications. While CityGML is effective for spatial modeling, it was not originally designed to capture the detailed material attributes required for comprehensive resource management strategies.

This study proposes a targeted BIM modeling approach based on the LOIN framework to address these challenges. By defining only the information required for timber material repurposing, the BIM model captures precisely what is needed for this assessment—avoiding unnecessary complexity while enhancing accuracy. This ensures that material stock evaluations remain lightweight, scalable, and reliable at city and regional levels.

Furthermore, this study integrates purpose-specific semantic attributes into a GIS-compatible workflow using GeoJSON, supporting efficient material tracking and circularity strategies. By prioritizing semantic data over full 3D geometries, the method enables computationally efficient, large-scale material stock analysis, aligning with data-centric GIS approaches where semantic layers drive resource management strategies.

A major challenge in material stock assessments is that BIM models are often not explicitly tailored for material stock estimation and assessment. This can introduce quantitative and qualitative uncertainties, which may become more pronounced when scaled to city or regional levels, affecting the reliability of stock estimations. To address this, BIM models can be tailored based on specific objectives to ensure that only relevant information (geometric and semantic) is considered. This study examines how the LOIN framework can be applied to organize BIM data for effective reuse strategies, addressing the following research questions:

RQ1: How can the LOIN framework optimize BIM data structuring to ensure accurate and scalable timber repurposing assessment?

RQ2: How can BIM-to-GIS integration be optimized to enhance material stock analysis while ensuring computational efficiency and semantic completeness?

Section 2 provides information about the methods followed in this study. Section 3 demonstrates the BIM-to-GIS integration results and summarizes the LOIN framework application. Section 4 discusses the proposed approach's results, evaluation, and limitations while giving directions for future research. Section 5 concludes.

2. MATERIAL AND METHODS

2.1. System Boundary

This study focuses on the building envelope (exterior walls and roof) of Norway's detached timber houses, representing 81% of Norway's total residential building stock (Statistics Norway, 2024b). Timber detached houses and farmhouses account for approximately 90% of Norway's residential stock (Bache-Andreassen, 2009). Between 2013 and 2022, an average of 1,101 detached houses were demolished annually, accounting for 48% of all dwelling demolitions in Norway (Statistics Norway, 2024a). This highlights the significant turnover in the existing building stock and the potential for recovering high-quality structural timber from deconstruction. Additionally, 91% of timber waste from demolition during this period was used for energy recovery, with only 7% being recycled (Statistics Norway, 2024c).

The study focuses on tracking and repurposing timber from deconstructed buildings, ensuring accurate quantification and integration into circular material flows. This approach enhances reuse strategies and minimizes resource loss during demolition. The building envelope is one of the most frequently renovated components as cities transition toward energy-efficient buildings. As the existing building stock undergoes energy upgrades, accurately quantifying and assessing timber from deconstruction can enhance reuse strategies and support circular economy initiatives. Reclaimed timber can be repurposed into engineered wood products such as glued-laminated (glulam) and cross-laminated timber (CLT), extending its lifespan and reducing the demand for virgin raw materials. Understanding waste generation quantity, composition, and reuse potential is essential for planning sustainable material recovery, optimizing waste management, and minimizing the environmental impacts of urban redevelopment.

2.2. Information Requirements for Timber Repurposing

Timber is strength-graded wood with a square or rectangular cross-section. EN 14081 (European Committee for Standardization, 2019) parts 1-3 specify requirements for visual and machine grading, while strength classes (e.g., C18, C24, and C30) are defined in NS-EN338 (Standard Norge, 2016). However, these standards do not apply to reclaimed timber. To address this, national standards (Standard Norge, 2025a, 2025b, 2025c) have been developed to provide rules to grade reclaimed timber based on the rules for visual strength grading of timber accepted in the Nordic countries, which are defined in NS-INSTA 142 (Norsk Standard, 2009).

This study adapts existing regulations to reclaimed timber and assumes the same material characteristic requirements as EN 1401 and EN338. EN 14080 (European Committee for Standardization, 2013) states that assessing reclaimed timber for repurposing requires data on moisture content, strength grade, and cross-section, while EN 14081 includes wood species as an additional criterion. These factors determine whether reclaimed timber can be processed into new products such as finger-jointed, glued-laminated, or cross-laminated timber. Wood species can often be estimated based on a building's location and construction period (Espedal, 2017), providing an indication rather than a definitive identification. Moisture content assessment is outside this study's scope, as it requires physical measurements. Additional attributes such as profile size, length, and cross-sectional area provide further insights into individual timber elements' reusability. Combined with spatial data on position and function within the building, this information helps assess the timber's previous use and gives insights about its expected quality and potential for reuse in circular construction applications.

2.3. Method

The methodology consists of two main parts, as illustrated in Figure 2. The first part involves defining information requirements, modeling and model enrichment, and preparing and transforming the data from Revit to IFC model into GeoJSON using Python. The second part involves importing and linking the transformed BIM data with existing cadaster data in GIS, enabling multi-criteria queries within the GIS platform.

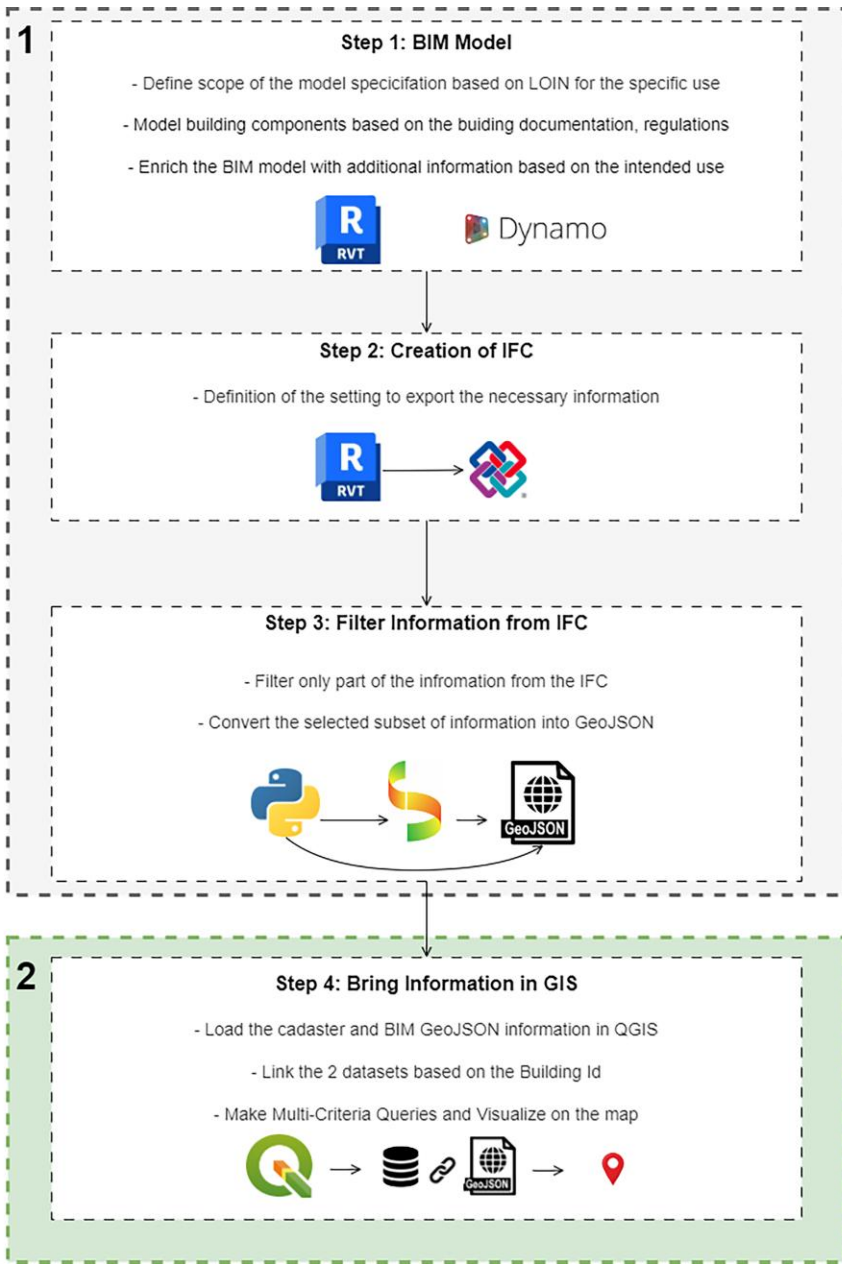

Figure 2. Workflow Overview

2.3.1 Step 1: BIM Modeling

We defined modeling specifications following the LOIN framework. The LOIN framework development followed a systematic four-step process:

- Requirements analysis: We reviewed timber repurposing specifications from EN 14080, EN 14081, and industry practices to identify essential parameters.
- Information categorization: Parameters were organized into three categories (geometric, alphanumeric, and documentation) according to the LOIN.
- Level of detail specification: We established the minimum required less geometrical and alphanumerical information for each parameter.
- Mapping: Each parameter was mapped to the corresponding shared parameter, component, and IFC property set to ensure consistent data exchange.
- This approach ensured that our BIM modeling captured all information necessary for repurposing assessment while avoiding redundant data collection that would impact scalability. After defining the LOIN schema, we modeled the BIM in Revit 2023.

Using Dynamo, the generated model was enriched with additional information and shared parameters in Revit 2023. We developed scripts to automate the computation of weight and cross-section area for each component—additional information, including strength class. Moreover, information about life expectancy, recycling factor, and waste category was added based on the Futurebuilt circularity index tool (FutureBuilt, 2024). We also added component classification numbers and descriptions according to (NBS, 2024; Standard Norge, 2022). At the building level, we added Building ID and coordinates to link BIM data with cadaster data in QGIS.

2.3.2 Step 2: Creation of IFC

After modeling in Revit, we exported the IFC model using IFC2x3, containing the necessary building and element information. Before exporting, we adjusted settings to include the newly created PropertySets containing our enriched model information.

2.3.3 Step 3: Filter information from IFC and conversion to GeoJSON

Since IFC models contain extensive geometric and semantic information, we extracted only the information described in Step 1 using Jupyter Notebook, Python, and the IfcOpenShell library. By filtering the IFC to include only necessary semantic information for GIS import, we prevented scalability issues that could arise from accumulating unnecessary data when upscaling to the city level. The filtered information was converted to GeoJSON using Python libraries: ifcopenshell, pandas, geojson, and json.

2.3.4 Step 4: Bring Information in GIS

We imported the GeoJSON file containing BIM information and the Shape (.shp) file containing Norwegian detached house cadaster data, shown in Figure 3. The files were linked using the Building Id common to both datasets. The cadaster data includes building year, footprint geometry, coordinates, and floor count, among other attributes. Finally, we created multi-criteria queries in QGIS and visualized the results.

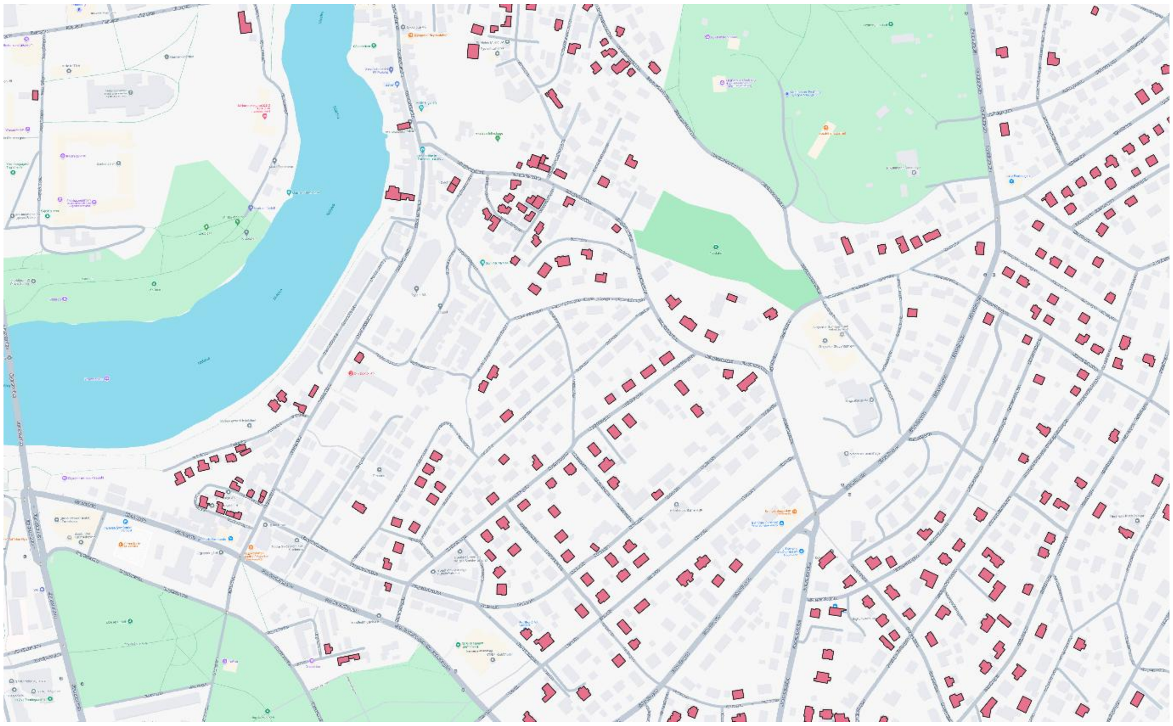

Figure 3. Visualisation in QGIS of all the Detached Houses in Trondheim as documented in the Cadaster Database

3. RESULTS

3.1 BIM for Assessing the Repurposing of Timber in Existing Buildings

This study employs a LOIN framework, as shown in Figure 4, that provides a structured approach for modeling information in BIM to support timber reuse and repurposing. The framework ensures that relevant geometrical and alphanumerical information is modeled in BIM to fulfill the information requirements for specific use.

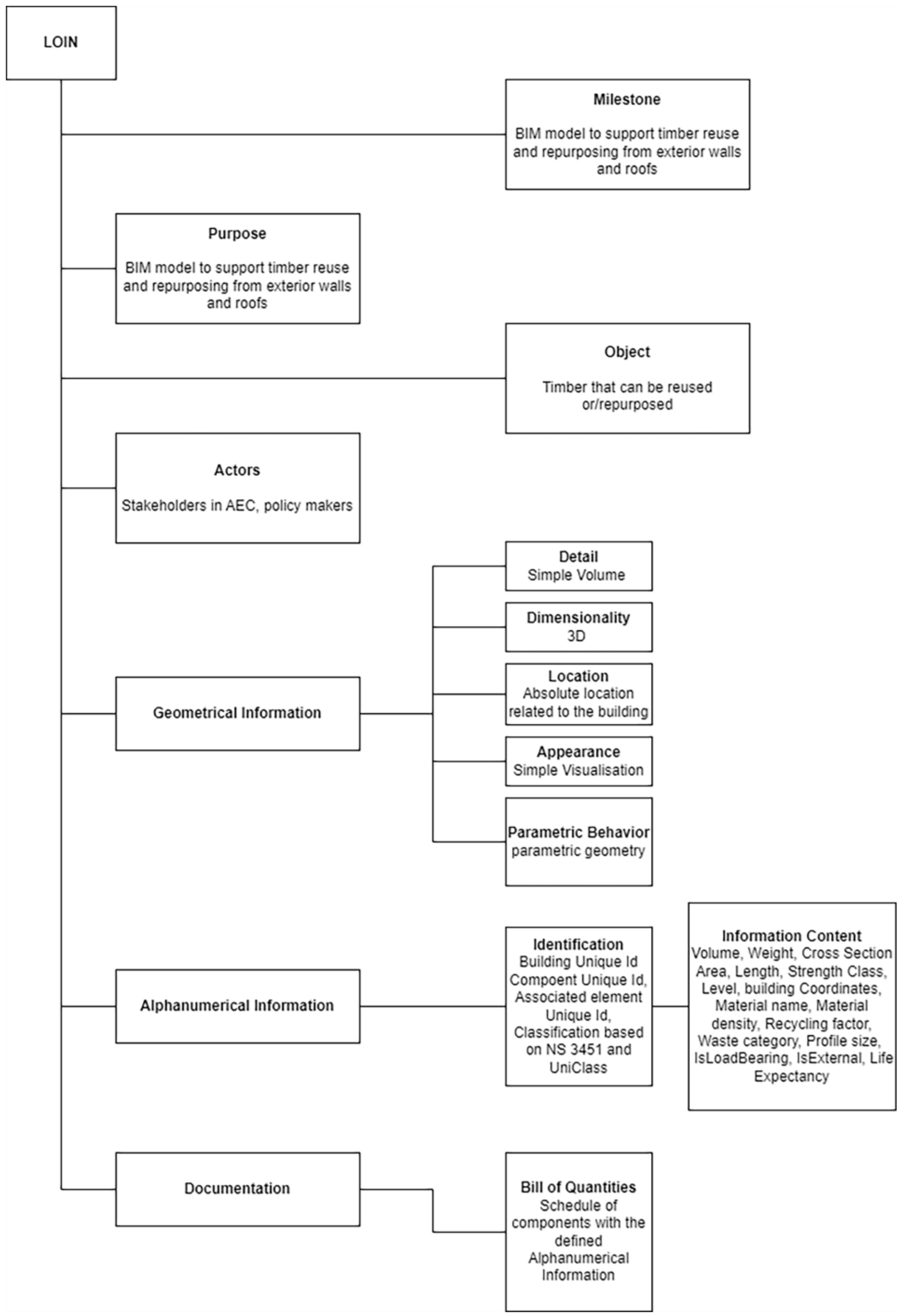

Figure 4. LOIN Framework Summary.(for full-size figures 4 through 8, see Appendix)

The framework comprises three main categories:

1. Geometrical Information – Timber elements are modeled as 3D objects with a simple volume-based level of detail. Each component's absolute location within the building and parametric behavior definition are recorded, allowing flexible integration within different BIM workflows. A simplified geometric LOD balances computational efficiency to generate the necessary information, such as volume and cross-section area.
2. Alphanumerical Information - Each timber component contains unique identification and classification based on established standards such as NS 3451 and UniClass. Moreover, it contains an attribute that

associates the component with the element it belongs to as an element ID. The components are characterized by their physical properties, including volume, weight, cross-section area, length, and profile size. Material properties are documented through strength class, material name, and density values. Performance attributes such as load-bearing capacity, external exposure, and life expectancy are also recorded. For circular economy applications, the recycling factor and waste category are included. Spatial information is maintained through level assignment. The model also contains building-level data, including building ID and coordinates. These comprehensive attributes ensure accurate documentation and traceability of all timber components.

3. Documentation – Bills of Quantities generated from the BIM allow structured reporting and inventory management of timber components.

3.2. Results from Queries and Mapping in QGIS

Table 1 shows a sample of information imported into QGIS under the building component layer. This dataset includes detailed information on timber profile sizes, cross-sectional areas, volumes, and positions within the building by including components that are classified using Norwegian Standard (NS) 3451 and Uniclass classification systems. Each component links to a unique building ID applicable to all Norwegian buildings by an IFC GUID for each component automatically generated in BIM. This structure creates a reciprocal link between BIM and GIS systems.

Table 1. Information at the Component Level Inside GIS and linked to the Cadaster Data

Building ID	Global Id (component)	Profile Size (mm)	Cross Section Area (cm^2)	Length (m)	Level	Volume (m^3)	NS 3451 Classification	Uniclass Classification Description	Uniclass Classification Number
27xxxxxxx	3HNV7duqn3e9K50s7$6g9Y	48x148	71	0.564	Level 1	0.04	231	Beams and joists	Pr_20_85_08
27xxxxxxx	3HNV7duqn3e9K50s7$6g4l	48x148	71	0.564	Level 1	0.04	231	Beams and joists	Pr_20_85_08

[a] The Building ID has been concealed to comply with GDPR regulations.

Figure 5 illustrates the integration between imported component data (red box) and cadaster data for the specific building (green box). The component dataset contains 525 timber elements, while the cadaster dataset includes 14,081 buildings classified as detached houses in Trondheim.

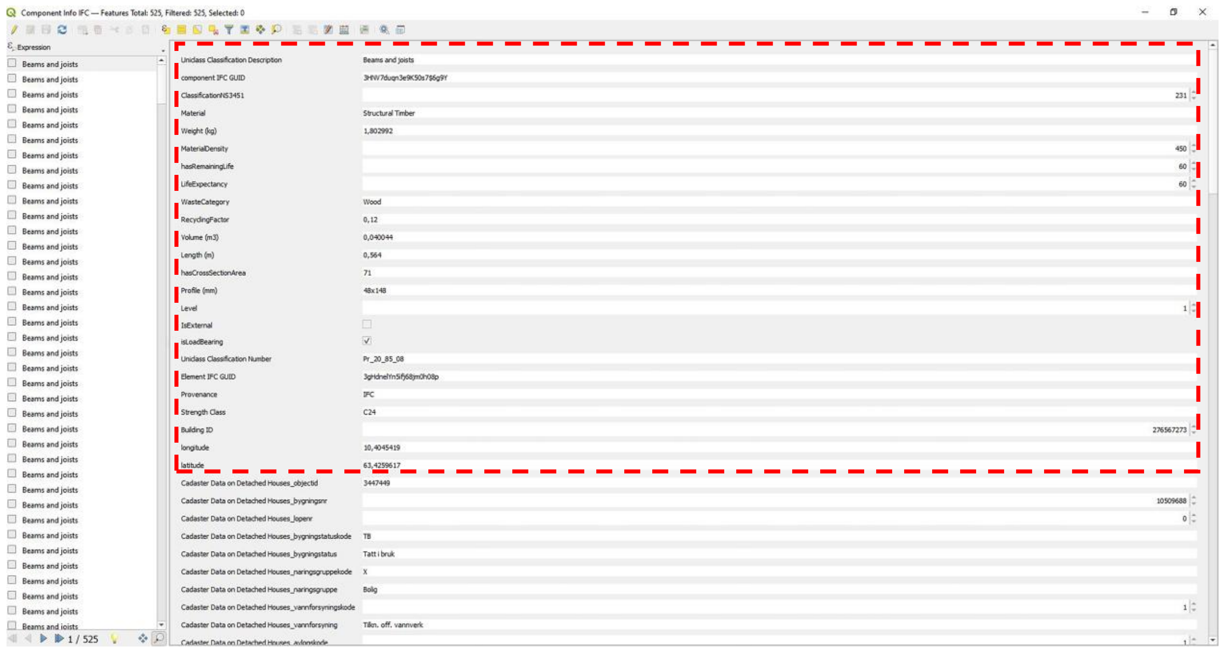

Figure 5. Component Data Linked to Cadaster Data based on the Building ID

Figure 6 demonstrates a multi-criteria query that filters information from component and cadaster datasets. This functionality allows filtering and sorting by combining different parameters and their values based on specific analysis requirements by combining fields and values from both datasets. The example query returns components with structural timber material, strength class C24, cross-section area smaller than 100 cm², and length less than 2.4 meters.

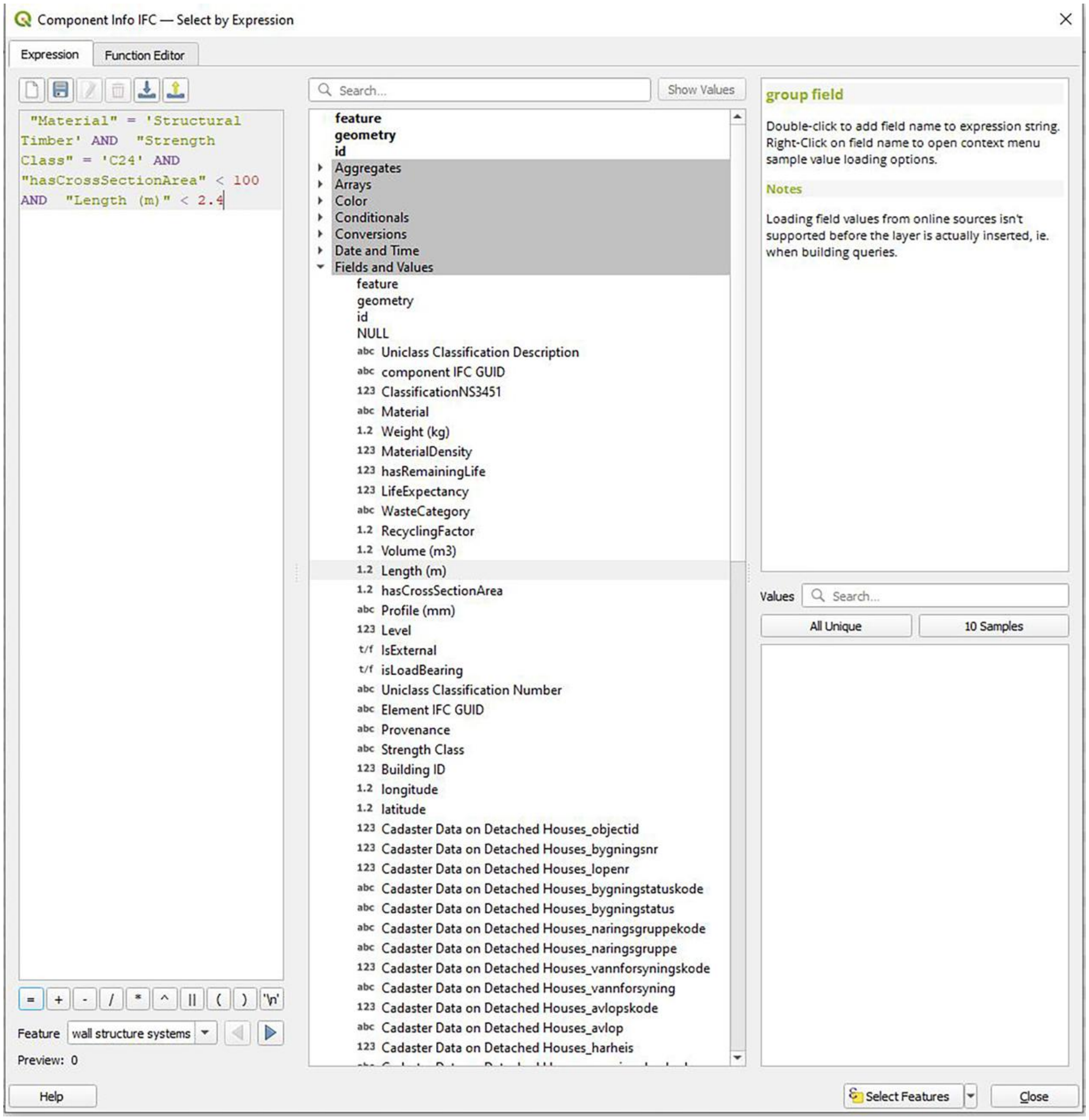

Figure 6 . Example of one Multi-Criteria Query

Figure 7 shows the 155 components that satisfy the query criteria. Users can visualize the buildings containing these elements on the map by selecting individual components.

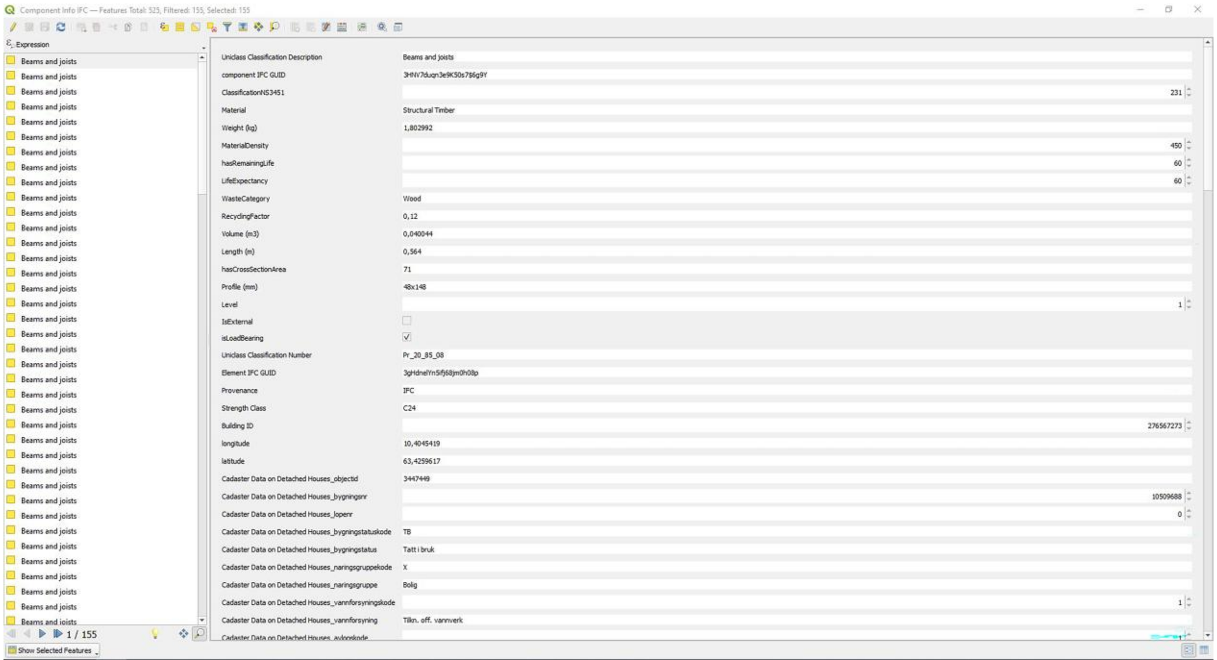

Figure 7. Results from the Query

Figure 8 presents additional statistical analysis using QGIS tools, providing an overview of the dataset. The component dataset's 525 timber elements have a total volume of 65.5m³ and a total mass of approximately 2880 kg.

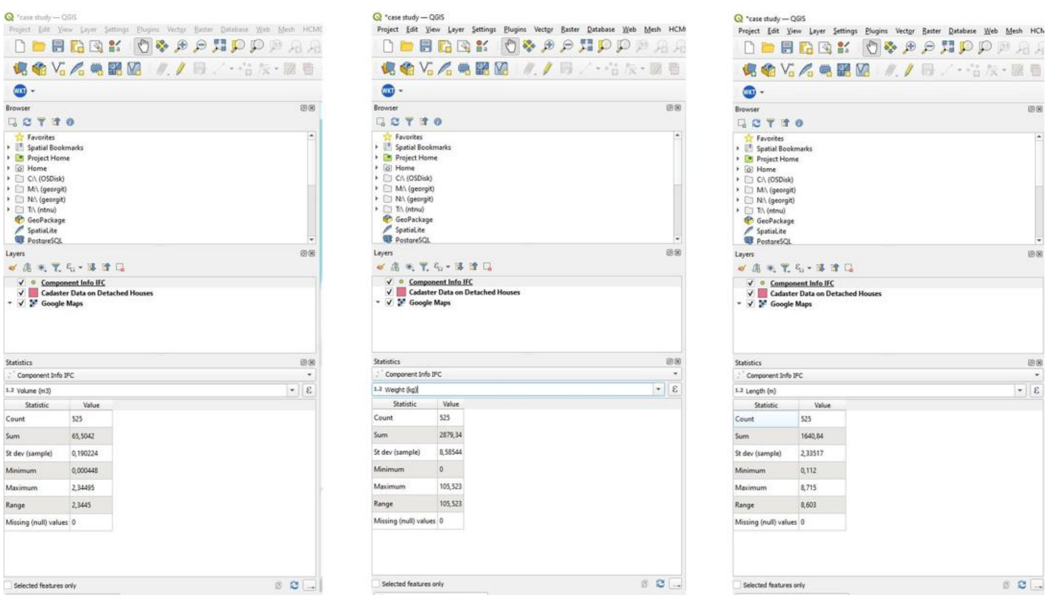

Figure 8. Summary of Values Contained in the GeoJSON

4. DISCUSSION

This section examines how our findings address the two research questions. For RQ1, which explores how the LOIN framework can guide BIM data structuring for accurate and scalable timber repurposing assessment, we discuss developing and applying site-specific, purpose-driven modeling approaches. For RQ2, which focuses on streamlining BIM-to-GIS integration to enhance material stock analysis while maintaining computational efficiency and semantic completeness, we evaluate the performance of our lightweight GeoJSON-based method through empirical validation.

4.1 Importance of Site-Specific BIM Archetypes

Our findings highlight that a significant barrier to accurate material stock assessment is the reliance on generalized BIM archetypes, which often apply a single level of detail (LOD) across all elements and fail to capture the nuanced material composition of buildings. While such archetypes support large-scale planning, they introduce substantial uncertainties in quantitative and qualitative material assessments, limiting their relevance for circular economy strategies. A LOIN-driven approach offers a pathway to address this challenge by enabling BIM models to be tailored to their intended use. Contextual, site-specific archetypes can support the modeling and extracting purpose-relevant material attributes, enhancing data transferability, scalability, and decision-making in urban circularity. Future research could investigate the automation of LOIN-based BIM workflows to support broader applications in large-scale material reuse assessments.

4.2 Application for Circular Economy

Our results demonstrate the feasibility of structuring component-specific data for circular economy applications within GIS. The resulting dataset enables multi-criteria queries that assess the timber stock at a higher granularity, supporting reuse and repurposing.

By upscaling to multiple buildings, this approach supports:

- Identifying buildings with high potential for reclaimed timber harvesting based on material volume and classification
- Filtering components by size, species, or location to align with reuse criteria
- Linking material stock data to demolition schedules or future construction needs to support recovery planning

This method enhances decision-making by providing detailed insights into individual building components and their spatial context, enabling planners to optimize resource allocation and plan deconstruction strategies more effectively. Multi-criteria queries and GIS visualization allow stakeholders such as planners, architects, and waste management companies to specify criteria for components' properties and identify relevant buildings that contain them.

For timber reuse specifically, access to detailed attributes—such as profile size, strength class, and prior building function—enables more accurate estimation of reclaimable quantities. These insights support more effective resource reuse strategies within the built environment.

4.3 Contribution to BIM-GIS Integration for Material Stock Assessment

This study contributes to BIM-GIS integration for circular economy applications by introducing a lightweight approach for embedding material-specific semantic data into GIS without relying on computationally intensive 3D transformations. The approach optimizes GIS file size by selectively extracting only purpose-specific information rather than using all the information in the IFC. In our example, the IFC file exported from Revit (2.18 MB) was reduced to a GeoJSON of 0.42 MB—an 80.73% reduction in data volume while retaining all relevant information. By comparison, the equivalent CityGML file was 7.05 MB, representing a 1578.57% increase in data volume relative to GeoJSON.

This approach showed:

1. Data volume reduction: Filtering non-essential elements yielded an 80.73% reduction in file size while preserving 100% of required semantic attributes.

2. Query performance: Multi-criteria queries across 525 building components and 14,081 detached building records executed in under 3 seconds on standard QGIS hardware (Intel Core i5, 4 cores, 16 GB RAM), indicating strong potential for scalability.
3. Information completeness: All alphanumeric parameters modeled in BIM were successfully transferred to GIS without data loss.
4. Integrity validation: All 525 components maintained correct links to their corresponding building records via cadaster IDs, with no broken references.

These findings provide empirical evidence that the proposed method balances semantic richness with computational efficiency, offering a scalable solution for material stock assessment across urban contexts.

4.4. Limitations and Future Research Directions

Increasing city model detailing and integrating multi-domain information introduces data management complexities and computational inefficiencies within traditional GIS platforms. As datasets expand and include millions of building components with detailed attributes and diverse information related to different lifecycle stages of buildings, GIS processing becomes increasingly resource-intensive. This proof-of-concept study has specific limitations that guide future research directions. The current approach relies on a single BIM model without multi-building validation, limiting its generalizability across diverse building typologies. While GeoJSON provides a straightforward data structure, it lacks formalized semantic relationships between elements, making it less suited for reasoning-based queries than ontology-driven approaches. Current queries are primarily attribute-based rather than relationship-based, constraining complex analysis capabilities. As datasets expand to city scale, traditional GIS platforms may face performance limitations when processing detailed component-level and multi-domain information.

Future research should address these challenges by leveraging semantic web technologies and ontologies. These provide structured frameworks for knowledge representation, facilitating the management and querying of complex datasets while improving the integration of diverse data sources. Ontologies enhance the scalability and efficiency of BIM-GIS workflows by managing data complexity and volume, making high-granularity BIM data integration more scalable for circular economy projects at urban and regional levels across multiple domains. Ontology-based solutions can formally structure component attributes, enabling automated reasoning for reuse and linking datasets across building, district, and city scales. This multi-scale approach is essential for comprehensive circular economy planning. Knowledge graphs and linked data principles improve the consistency and queryability of material stock datasets, allowing for more efficient analysis and decision-making in the geospatial realm for circular economy applications. These technologies offer promising pathways to overcome interoperability limitations between BIM and GIS systems. Additionally, future research should focus on developing low-technology solutions that can be easily implemented and globally accessible, supporting worldwide circular transition initiatives.

4. CONCLUSION

This study presents an alternative approach to BIM-to-GIS integration for material stock assessment, prioritizing semantic data integration to address key challenges in urban-scale circular economy planning. By addressing our research questions, we have demonstrated that specific information requirements for timber repurposing—such as profile size, cross-sectional area, length, and strength class—can be effectively modeled in BIM and transferred to GIS. This enables multi-criteria queries that support building stock assessment at the urban scale. Integrating building component-level data with cadastral information in GIS further facilitates circular economy planning by precisely identifying reusable materials. For timber specifically, our approach enables stakeholders to identify, quantify, and assess repurposing potential based on standardized criteria from EN 14080 and EN 14081.

Our method effectively optimized BIM-to-GIS integration through a lightweight GeoJSON-based approach that preserved essential material attributes while significantly reducing data volume. By excluding unnecessary geometry and metadata from IFC files, we reduced file sizes by over 80% compared to IFC and over 90% compared to CityGML, without losing any decision-critical information. This streamlined data structure enables scalable and computationally efficient material stock analysis at city and regional levels.

This study demonstrates that prioritizing purpose-specific semantic attributes over geometric complexity significantly improves material stock estimation. However, our findings also reveal that using generalized BIM archetypes introduces significant uncertainties in material quantification, particularly when scaling assessments to city or regional levels. To achieve more accurate, transferable material stock estimates, BIM models must be site-specific and contextualized, following a LOIN approach that ensures only the necessary material properties are included. Future work should explore strategies for automating LOIN-driven BIM modeling processes, enabling more precise and scalable material reuse assessments for circular economy applications.

APPENDIX

For a full-size versions of figures 4 through 8, click here or copy the following into your url bar: https://circulareconomyjournal.org/wp-content/uploads/2025/05/Triantafyllidis_Appendix.pdf

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AUTHOR CONTRIBUTIONS

Georgios Triantafyllidis: Conceptualization, Methodology, Software, Validation, Formal Analysis, Investigation, Resources, Data Curation, Writing – Original Draft, Writing – Review and Editing, Visualization, Project Administration.
Karl-Christian Mahnert: Resources, Writing – Review and Editing.
Lizhen Huang: Writing – Review and Editing, Supervision, Funding Acquisition.

DECLARATIONS

Competing interests: The authors declare no competing interests.

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