From Information Silos to Integrated Ecosystems: A GIS–BIM Data-Driven Framework for the Pietrafitta Innovation Hub

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Abstract

The increasing complexity of territorial and productive systems requires digital environments capable of connecting information across different spatial scales and operational stages. This paper proposes an integrated GIS–BIM framework for supporting the management and traceability of forest resources, from their place of origin to their storage and handling within a logistics facility. The approach was tested through the Pietrafitta Innovation Hub case study, where territorial data, building information and supply-chain processes were brought together within a shared digital ecosystem. The framework establishes a continuous relationship between georeferenced trees, forest management units, timber batches and warehouse spaces, enabling information to follow the resource throughout its transformation and movement. Interactive tools and dashboards support the consultation of tree histories, the monitoring of material flows and the assessment of storage conditions. The results show that GeoBIM integration can move beyond the simple visualisation of territorial and architectural models, becoming an operational instrument for coordinating data, processes and decision-making. The proposed approach is modular and adaptable to different contexts, providing a conceptual basis for the development of process-oriented digital twins and more transparent, efficient and sustainable resource management systems.

1. Introduction

In a context characterised by the increasing production and circulation of spatial information, digital transformation is redefining the tools used to observe the territory and the conditions under which it can be understood. The reality is shifting from predominantly static configurations to a complex information system consisting of constantly evolving data, relationships and processes. Information from geomatics surveys, satellite systems, Internet of Things (IoT) sensors, three-dimensional models, administrative databases and collaborative platforms is facilitating the transition towards dynamic environments in which heterogeneous data can be updated, correlated and queried to support planning, monitoring and management activities (Goodchild, 2007; Batty, 2018). From this perspective, information's value lies not only in its availability, but above all in the ability to integrate it with content relating to different spatial and temporal scales and to different disciplinary fields. This generates new modes of knowledge and new ways of interpreting and governing the territory.

The gradual convergence of Geographic Information Systems (GIS), Building Information Modelling (BIM) and data-driven platforms has given rise to digital ecosystems in which the traditional boundaries between spatial representation, modelling of the built environment and process management are becoming increasingly blurred (Xia et al., 2022; Zhu & Wu, 2022). While GIS has historically focused on representing and analysing territory through georeferenced data and spatial relationships, BIM was developed to describe a building's entire life cycle using parametric models rich in geometric, performance, and management information (Sacks et al., 2018). Although these two paradigms were developed for different purposes, the growing complexity of territorial transformation processes makes the need for their integration within shared digital environments increasingly evident. Interoperability between GIS and BIM is now a key research topic in the field of territorial digitalisation and many studies have highlighted how the main challenges go beyond the conversion of data formats, relating in particular to the alignment of different semantic models, reference systems, levels of detail (LOD) and data structures (Biljecki et al., 2016; Deng et al., 2016).

The proliferation of data-driven platforms is introducing a new paradigm in the management of spatial information, as they are capable of storing large quantities of heterogeneous data, enabling it to be organised, continuously updated and transformed into services to support decision-making. Interactive dashboards, multi-scale queries, real-time monitoring, scenario simulation and predictive analytics are now some of the key features that enable the integration of spatial data and digital models to be fully utilised (Piras et al., 2024; Azari et al., 2025; Rani & Yadav, 2026). Data becomes an integral part of dynamic decision-making processes, capable of supporting the entire life cycle of infrastructure, buildings and territorial resources (Cepa et al., 2024). The interaction between GIS, BIM and data-driven platforms is particularly important in contexts where production chains are spread across the territory and the management process involves natural resources, infrastructure, buildings and logistics activities simultaneously.

In such cases, it becomes necessary to create a digital environment that can maintain the continuity of information throughout all operational phases and preserve the link between the resource's place of origin, the operations carried out and its final destination. The availability of georeferenced information that can be continuously updated and shared amongst different parties is, in fact, an essential requirement for ensuring traceability, transparency and effectively supporting informed decision-making.

This research has been developed as part of the Wood 4 Green and ITI Trasimeno projects (Bianconi et al., 2024; 2025). The Wood 4 Green project promotes the regeneration of the

Figure 1. Masterplan of the Pietrafitta Innovation Hub, showing the spatial organization of the main functional buildings. Graphic design by the authors.

Pietrafitta area (Figure 1) and the Val Nestore through a development model based on sustainable forest resource management, establishing a local timber supply chain and integrating technological innovation, research and renewable energy production (Figure 2). Meanwhile, the ITI Trasimeno programme has resulted in the development of the PITER integrated territorial platform: a georeferenced digital infrastructure that compiles and organises territorial, environmental, urban planning and socio-economic data in a unified information environment. This environment is designed to support territorial planning and management activities.

The selected case study concerns the new research hub planned for the Pietrafitta area and provides an experimental framework for testing the integration between the spatial data available on the PITER platform and a BIM model of the building intended for timber storage and processing activities. Starting with the survey and georeferencing of individual trees, the system tracks their progress throughout the various stages of log management, handling and storage. The aim is to define a methodological framework for integrating GIS, BIM and data-driven platforms to manage the traceability of forest resources.

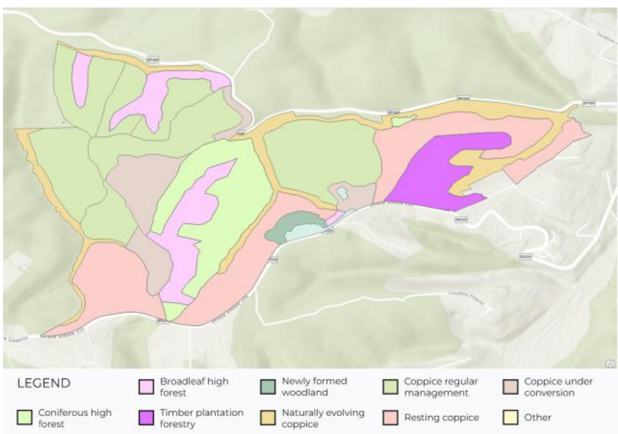

Figure 2. Spatial distribution of forest stands within the Piegaro Certified Forest, classified by forest type and silvicultural management.

First, the proposed method addresses the issue of semantic and structural data alignment. Then, it defines an interoperability model capable of linking spatial information, logistical processes and building components within a single digital ecosystem. This contributes to the development of replicable digital tools for the sustainable management of complex systems.

2. Methodological framework

2.1 State of the art

In recent years, research into the integration of GIS and BIM systems has reached a high level of maturity. While early studies focused on converting models between different software environments, more recent research has concentrated on defining methodological frameworks that can preserve the geometric, semantic and relational consistency of information during data acquisition, transformation, updating and sharing processes (Noardo et al., 2020).

The literature highlights the different conceptual organisation of the two information domains as the main challenge. BIM describes individual structures using an object-oriented approach, whereby each element possesses geometric, functional and performance properties. In contrast, GIS represents complex territorial phenomena using spatial relationships, thematic categories and multi-scale models. These differences are particularly evident in semantic models, reference systems, levels of detail, and the representation of relationships between objects, meaning that simple data conversion is insufficient to ensure true interoperability (Sacks et al., 2018; Biljecki et al., 2016).

To address these challenges, much of the research has focused on integrating the Industry Foundation Classes (IFC) and CityGML standards. These are recognised as the main reference models for BIM and three-dimensional territorial representation, respectively. Meanwhile, the work of buildingSMART International and the Open Geospatial Consortium has facilitated the definition of shared specifications and new interoperability models. This has contributed to establishing the GeoBIM paradigm as a research field dedicated to integrating spatial data and building models (OGC, 2021; ISO 19166:2021; Noardo et al., 2019). In this context, interoperability is increasingly understood as a process of harmonisation between information models, rather than merely a matter of format compatibility. The scientific debate has broadened further with the proliferation of data-driven platforms and spatial digital twins. These environments integrate data from various sources, including IoT sensors, geomatics surveys, satellite imagery, administrative databases, and digital models. This data is then transformed into services for monitoring, scenario simulation, and decision support (Jones et al., 2020; Fuller et al., 2020; Zhu & Wu, 2022). From this perspective, GIS and BIM are two components of a broader digital infrastructure in which information is valuable because it can maintain dynamic relationships between data from different domains.

The application of these approaches to the forestry sector is still a relatively recent development (Müller et al., 2019). The digitalisation of silvicultural activities has mainly been driven by precision forestry techniques based on remote sensing, LiDAR surveys, GNSS and high-resolution satellite imagery. These techniques have significantly improved forest inventory, monitoring and planning operations (Liang et al., 2018). Concurrently, the increasing emphasis on certification within the timber supply chain has prompted the development of systems dedicated to resource traceability via unique identifiers, RFID technologies, barcodes and management platforms that can document the various stages of the production process (Kaulen et al., 2023). Despite these advances, the literature highlights that the various components of the supply chain are still managed using separate tools that are rarely integrated. By contrast, few studies maintain continuity of information on resources throughout the entire process, dynamically linking forest stands, harvesting operations, material movement and the spaces in which it is processed or stored (Keefe et al., 2022).

2.2 Methodological workflow

The methodological workflow is designed to create an integrated, replicable information environment that can link spatial, geometric, semantic and management data relating to the forestry supply chain. Therefore, the transition between the two environments must ensure correct georeferencing of the model and readability of the BIM parameters for use in conjunction with spatial data in subsequent querying, analysis and management operations. From a technical perspective, the workflow aims to ensure continuity of information between systems based on different logics. BIM is used as a georeferenced information source linked to the spatial system, while GIS extends the use of BIM data to infrastructural and spatial scales. This makes the data available for resource traceability, monitoring logistics flows, verifying storage capacities and supporting management activities.

The workflow was divided into five main phases (Figure 3): structuring the territorial and forestry database; modelling the case study in a BIM environment; georeferencing and integrating the model into ArcGIS Pro; developing geoprocessing tools for managing batches and movements; and configuring dashboards for data consultation and monitoring.

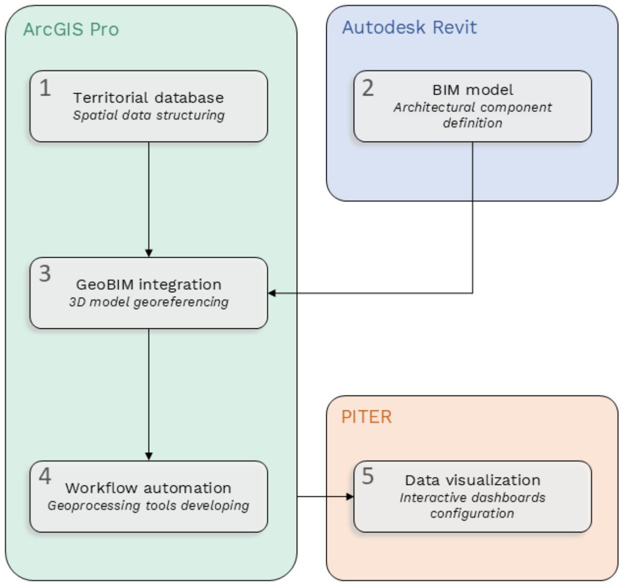

Figure 3. Methodological workflow. Graphic design by the authors.

The main stages of the workflow were developed in ArcGIS Pro using a geodatabase as the single geographical database. This ensured consistency in the relationships between the various information layers and facilitated subsequent interoperability with the BIM model and data-driven platform. The first stage involved defining the territorial reference units and subdividing the forested areas into homogeneous polygons that corresponded to the various silvicultural types present in the area. Each parcel was given a unique *Parcel_ID* code and subsequently linked to a Forest Management Unit (*FMU_ID)*, representing the management unit for which monitoring, felling and timber handling activities are planned. The database (Figure 4) was subsequently populated with a point layer representing the trees. Each tree is modelled as a georeferenced feature and identified by a unique code (*Tree_ID*). The main dendrometric parameters used in forest management were then assigned to this code. These include species, diameter at breast height (DBH), height and life cycle stage. Each tree was also linked to its respective forest parcel via the *Parcel_ID* field. The material resulting from felling operations is aggregated into batches (*Timber_Batch*), each of which is identified by a unique code (*Batch_ID*) and characterised by its associated timber volume. This volume is calculated based on the volume of the individual logs making up the batch, to which an allowance is added to account for air gaps.

Finally, two more tables were introduced to complete the relational structure of the database. One is the *Tree_Batch* table, which establishes a many-to-many relationship between trees and batches, since the same tree may have belonged to different batches at different times. Each record in the table is therefore accompanied by a pair of temporal attributes (the date the tree entered the batch and the date it exited), which define its validity period and enable the precise historical composition of each batch to be reconstructed at any given moment. The second table is *Movement_Log*, in which each record represents a single movement of a batch from a source room to a destination room. This includes a timestamp and the operator responsible. These two tables enable the sequence of movements undergone by a single log to be reconstructed, even in the absence of direct tracking of individual items at each transition.

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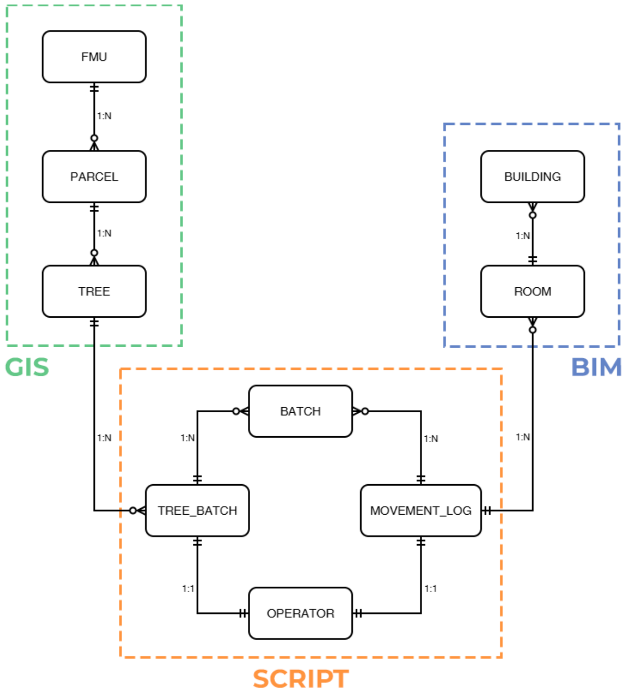

Figure 4. Entity-relationship diagram of the geodatabase. Graphic design by the authors.

Following the structuring of the spatial database, the workflow was extended to include information modelling of the case study in Autodesk Revit. The model was developed with a limited level of geometric detail while still being consistent with the objectives of the BIM–GIS experimentation. Outdoor spaces were modelled in a simplified form and buildings not directly involved in the experiment were represented using basic volume models. The internal layout of the storage building has been defined by identifying specific rooms, to which information parameters have been assigned, such as a name and an identification code. In addition to the geometric parameters generated by the model, such as the room's perimeter, area, volume and height, specific management-related parameters have been defined. The Boolean parameters *Truck Access* and *Forklift Access* indicate whether the room is accessible to heavy goods vehicles for loading and unloading and to forklift trucks for the internal handling of materials, respectively. These parameters distinguish between areas directly linked to vehicle-accessible logistics and those intended for control, storage, temporary storage or logistical transit prior to the dispatch of goods.

Before importing the model developed in the BIM environment into ArcGIS, it was georeferenced using the WGS 84/UTM Zone 33N (EPSG:32633) reference system, which is consistent with that used in the spatial database. This involved setting up the project’s shared coordinates and associating the model with the planimetric coordinates and elevation of the site and survey point to ensure the model was correctly positioned within the GIS environment. The Revit file was then imported directly into ArcGIS Pro as a BIM layer and the model’s alignment with the cartography, road infrastructure and other spatial layers was verified. Two geoprocessing tools were developed in ArcGIS Pro, starting from the integrated information environment. These tools are written in Python using the ArcPy library and correspond to two distinct stages of the operational workflow (Figure 5). The first tool creates batches and records the arrival of logs inside the building. Based on a selection of features in the *Tree* layer, the tool generates the required batches to manage the selected trees, each with a unique sequential identifier in the format LOT-AAAA-NNNN (where 'AAAA' is the current year and 'NNNN' is a four-digit counter calculated by scanning through the existing identifiers for the current year). Each batch is associated with a point-based symbolic geometry located within the Quality Control room.

At the same time, the tool populates the membership relationships in the *Tree_Batch* junction table and updates the *Status* attribute of all the involved elements. No changes are made to their original geometry; the change in status is solely reflected on the map through the thematic symbology of the *Tree* layer. This layer has been pre-configured to use unique values from the *Status* field to distinguish between present and removed elements. Finally, the movement is recorded in the *Movement_Log* table as a single record containing the destination room, timestamp, operator and number of elements involved.

The second tool starts with a selection of batches and moves the identified items to the destination room. The room names are parameters of the tool, allowing it to be reused for all transitions specified by the process (Receiving Area → Quality Control, Quality Control → Timber Storage, Timber Storage → Temporary Storage, Temporary Storage → Outgoing Area) without the need for duplication. The tool checks that all the selected batches are located in the same room. If there is a discrepancy, the operation is aborted and an explicit notification is sent to the operator. If there is no discrepancy, however, the tool repositions the symbolic geometry of the batch in the new room and updates all active elements within the batches. This is done by querying the relational table *Tree_Batch*. This movement is also recorded in *Movement_Log* in the same format described above.

To support interactive data consultation by operators, two dashboards have been developed using ArcGIS Online tools. These dashboards query the entities in the data model described in the preceding paragraphs directly, without introducing any additional data structures, thereby ensuring that the dashboards remain constantly aligned with the current state of the geodatabase.

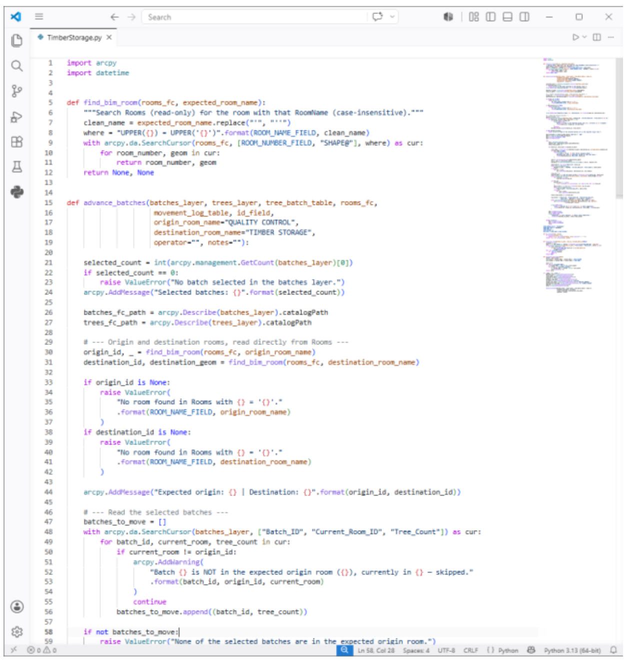

Figure 5. ArcPy script for automating timber batch movements.

The first dashboard has been designed to reconstruct the history of individual trees. The interface incorporates a map view of forest parcels classified by silvicultural type, overlaid on the point layer of surveyed trees. There is also a details panel displaying the basic and dendrometric attributes of the selected tree, such as species, diameter at breast height (DBH), height, volume, life cycle stage, current batch and storage bay. The central component is a *Tree Lifecycle* table populated by querying the *Movement_Log* table, which is filtered by the identifier of the selected tree. This returns, in chronological order, the entire sequence of stages that the tree has gone through, from the forest survey to movement during the various phases of warehouse processing. This includes the date, status and the responsible operator.

The second dashboard has been designed to provide an overview of the occupancy status of the building's storage areas. It combines a three-dimensional view of the building's BIM model, with individual rooms highlighted using colour coding, and a set of summary indicators in the form of pie charts. These show the percentage of occupied volume relative to the available free volume for each monitored room.

The volumetric capacity of each room was calculated using geometric data extracted directly from the BIM model. For each room, the gross volume was calculated on the basis of its overall geometric dimensions, by multiplying the corresponding width, depth and height values retrieved from the attributes of the object. However, as not all of this volume is available for storage – space must be set aside for aisles for the movement and manoeuvring of handling equipment, as well as for safety clearances from walls and structural elements – the gross volume is multiplied by a coefficient of 0.65. The usable volume obtained in this way forms the denominator against which the dashboard dynamically calculates the percentage of volume occupied by querying the batches currently associated with each room. This value is not stored as a persistent attribute in the geodatabase in line with the methodological decision not to maintain a redundant occupancy counter. The *Batches* table complements the indicators by listing all the batches currently present in the building. This table details the timber species, total volume, current storage room and date and time of entry.

3. Results

The methodological workflow was applied to a complex territorial case study comprising the Pietrafitta Innovation Hub (which served as the supply chain's logistics and infrastructure hub), the Piegaro Certified Forest (which was identified as the source of the forest resources) and the PITER platform (which was used as the project's mapping and information component). Based on Esri's ArcGIS technology, PITER constitutes an advanced digital infrastructure for the organisation, management and analysis of geographical data. Developed to meet the needs of local authorities, the platform provides municipal technical departments with a shared GIS environment for consulting spatial data and supports urban, landscape and environmental planning activities. Authorised users can access cartographic content, query information layers and use the available data to analyse and manage the territory in a coordinated manner through ArcGIS Online.

Based on the masterplan for the future Pietrafitta Innovation Hub, the general site plan was imported into Autodesk Revit in order to develop a three-dimensional information-rich model of the case study. The modelling process focused primarily on creating a searchable information base rather than producing a highly detailed geometric representation of the buildings. This methodological choice stems from the experimentation's objective, which is to optimise the management, organisation and traceability of flows within the timber supply chain, rather than merely to produce an architectural representation of the complex. For this reason, the model was developed with limited geometric detail whilst still associating an adequate amount of information with the elements. Outdoor spaces were modelled in basic form and buildings not directly involved in the experiment were represented using simplified, generic models comparable to elementary volumes. Despite this simplification, these elements have also been assigned information parameters that are useful for identification, classification and subsequent querying within interoperable digital environments.

Specifically, the following functional categories have been identified: Laboratory; Accommodation; Conference Hall; Warehouse01, Warehouse02, Warehouse03, Warehouse04, Warehouse05 and Warehouse06. This coding system enables the various building units in the masterplan to be distinguished immediately and the model to be prepared for subsequent filtering, selection and analysis within GIS platforms or data management environments. One of the warehouse buildings was selected as the main case study and modelled in greater detail than the other structures in the complex. This building's name is Warehouse03 and it was designed as a prefabricated reinforced concrete structure with a square floor plan measuring 35 × 35 metres, an internal height of around 7 metres and a flat roof. While maintaining a level of geometric detail that is not construction-grade, the model distinguishes the main building components, such as floors, walls, openings and internal partitions.

The design of the warehouse provides for an internal division into five functional areas, arranged according to the operational sequence of the material flow: Receiving Area, Quality Control, Timber Storage Area, Temporary Storage and Outgoing Area (Figure 6). The Receiving Area is the first stage of the logistics process. Situated near the vehicle access point, it is used for unloading incoming materials and for transport vehicles to access the warehouse. From here, timber is transferred to the Quality Control Area for preliminary checks, verification and classification. It is then transferred to the Timber Storage Area, which is the largest section of the building. This area is designed for the organised storage of timber, managed by batch, category or stage of processing. The main function of this area is to ensure the timber is stored under controlled and traceable conditions. This enables each batch to be linked to specific information regarding its origin, quantity, loading status, destination and current stage in the processing chain. Materials that have been selected or are ready for loading can be placed temporarily in the Temporary Storage. This area is designed to separate materials ready for final handling from those still held in the main storage area. The process concludes in the Outgoing

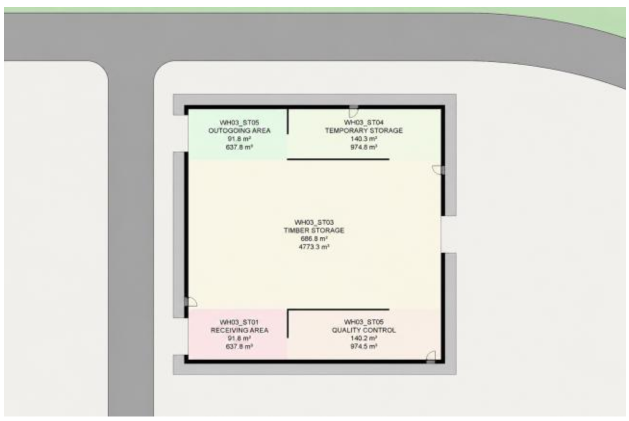

Figure 6. BIM floor plan of Warehouse03 showing the spatial organization of functional areas.

Area, which is designated for loading outgoing materials. This area also has a large vehicle access point situated on the opposite side to the receiving area. This layout establishes a linear operational flow from entry to exit, thereby reducing overlaps between incoming and outgoing vehicles, as well as internal handling operations carried out by forklift trucks.

The geodatabase was designed in accordance with the principles of relational normalisation to minimise data redundancy and ensure that each piece of data is represented in a single authoritative location. The geodatabase does not store calculated or aggregated fields whose values can be derived entirely from other existing system data. Such values are calculated dynamically at query time by dashboards or geoprocessing tools, thereby preventing data misalignment. For instance, rather than storing the percentage of volumetric occupancy for each room as an attribute, the warehouse management dashboard calculates it based on the currently associated batches.

This standardised approach also has a direct impact on integration with the BIM model. Importing the Revit model into ArcGIS Pro via native BIM file support generates read-only layers and tables. However, this constraint does not represent a limitation for the developed architecture: all information relating to status, capacity and history is stored and calculated exclusively on the GIS side, meaning the model's information an be used by geoprocessing tools and dashboards without the need for write access. This occurs, in particular, through the Rooms layer, which manages the subdivision of functional areas for the timber supply chain via the imported *RoomName* and *RoomNumber* fields.

The geoprocessing tools and dashboards were developed with the characteristics of the case study in mind. The implementation was configured based on the characteristics of the developed data model, including georeferenced trees and their parameters, timber batch structure and temporal relationships between trees and batches. The Script Tools were therefore parameterised according to the identifiers and operational rules defined for the case study. This enables the automation of batch formation, assignment of the current storage location, and chronological recording of movements. Starting with the selection of trees in the territorial component, the system enables the generation of a batch, its association with the elements of origin, representation of its position within the building and progressive updating of its status during transfer between various functional areas. The dashboards translate this relational structure into consultation tools, enabling both the reconstruction of an individual tree's life cycle and the monitoring of storage area occupancy.

The dashboards have also been integrated into the PITER platform, thereby extending the system's functionality from internal data management to data consultation within a shared territorial environment (Figures 7, 8). This integration allows users to access information about the forestry system and storage areas via the mapping component of the platform. Depending on their authorisation level, users may also be able to interact with the data for operational management purposes. Certain operators can update and modify management attributes, providing them with a tool that supports the monitoring, verification and management of supply chain processes while maintaining territorial and logistical information in a shared, updatable environment.

4. Conclusions

The developed methodological framework demonstrates how interoperable integration of GIS, BIM and data-driven platforms can ensure continuity of information between the territorial scale of forest resources and the architectural scale of storage spaces.

Applying this framework to the Pietrafitta case study has verified this continuity in practice. The territorial component, consisting of georeferenced trees and forest parcels organised into management units, is dynamically linked to the logistical component of the batches and the architectural component of the storage spaces. Query and monitoring tools maintain consistent relationships between these different levels of information. This result confirms the anticipation expressed in the introduction: GeoBIM integration acquires real operational value when territorial and building-scale representations are brought together within a unified digital environment, enabling information to accompany the resource dynamically throughout the management process, from its origin in the forest stand to its current location within the building.

The proposed operational interoperability model is based on a series of conditions that allow BIM and GIS environments to

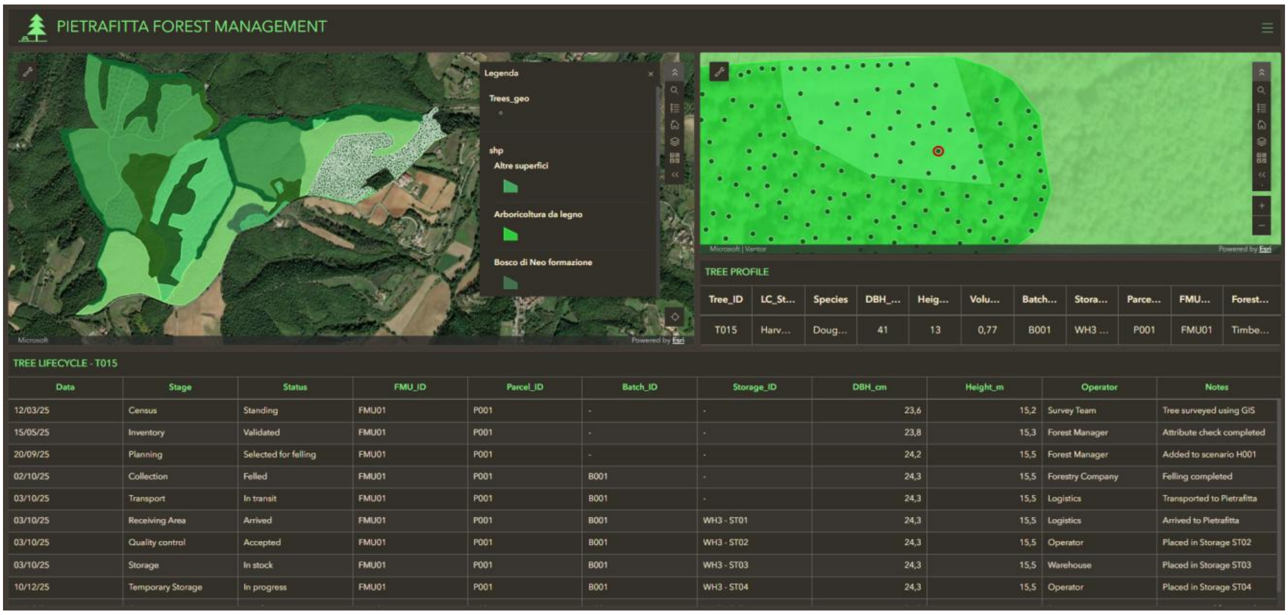

Figure 7. Forest management dashboard integrating spatial data, tree attributes and timber traceability.

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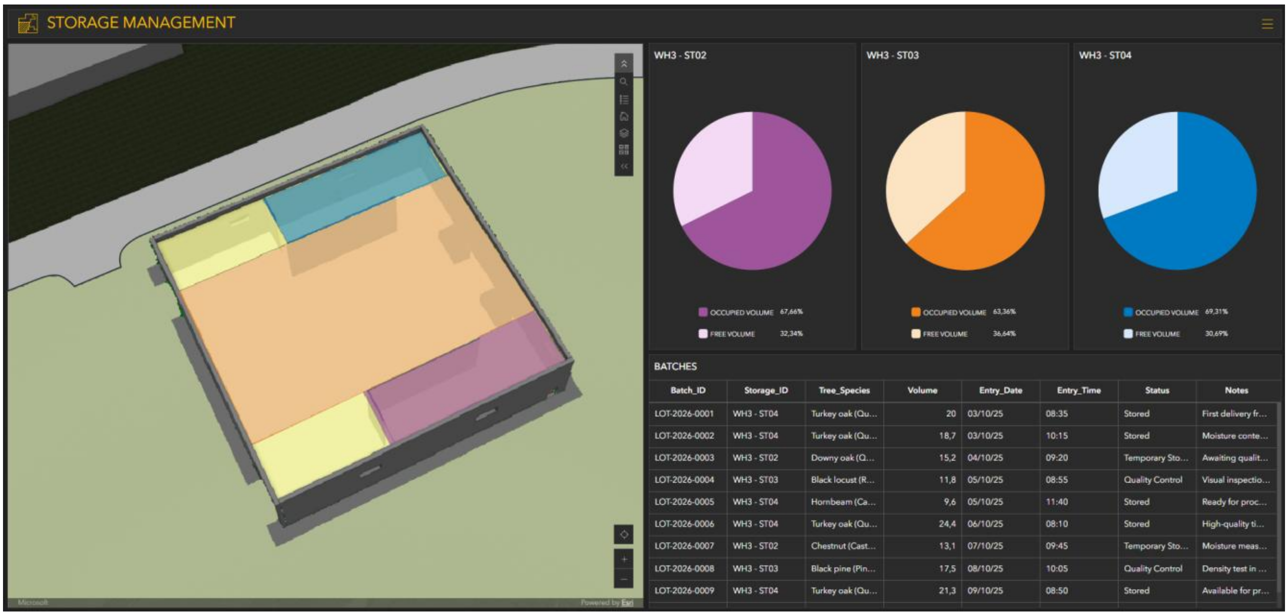

Figure 8. Storage management dashboard integrating 3D visualization, room occupancy rates and timber batch records.

interact coherently. The BIM model is georeferenced within the same reference system as the spatial database and employs unique identifiers consistent with those adopted in the GIS. These identifiers enable the linking of trees, timber batches and storage spaces. Geoprocessing tools then automate key management operations, while maps, 3D models and dashboards support monitoring and decision-making processes. The modular structure of the process further enables its replicability and application to different case studies, by redefining data, identifiers and operational conditions in line with the specific territorial and logistical characteristics of each context.

One technical aspect that deserves explicit mention is the read-only nature of data derived from the BIM model within the GIS environment. Rather than bypassing this condition, which is dictated by the way in which ArcGIS Pro natively interprets BIM files, it has been embraced in this project as a coherent architectural choice. In fact, all the system's dynamic information is calculated and stored exclusively in the GIS, while the BIM model serves as the geometric and semantic reference source.

However, this presents a potential limitation if certain parameters in the BIM model need to be updated, as it makes it necessary to explore mechanisms for controlled writing or bidirectional synchronisation between the two environments. One possible temporary solution would be to model and populate tables outside the BIM model that are linked to three-dimensional elements via IDs or ad hoc attributes.

In light of these considerations, another aspect that has not yet been widely explored emerges: the design of interoperable workflows for data management throughout the entire forest resource supply chain remains a marginal topic in GeoBIM literature, despite its potential for spatial management and the development of process-oriented digital twins. Against this backdrop, this paper aims to take the first steps in this direction by offering an exploratory methodological framework that can integrate GIS, BIM and a data-driven platform within a single information ecosystem. This will lay the foundations for developing more advanced solutions that are geared towards the dynamic traceability of territorial resources. It should be emphasised that the developed system represents an initial management prototype designed primarily to explore feasibility and integration methods. The functionalities implemented are therefore limited to the specific objectives of this exploratory phase.

However, there is considerable scope for expansion in subsequent phases of the framework's development. Further developments may involve extending the system's analytical capabilities to support the optimisation of internal material-handling routes, the simulation of alternative logistics scenarios and the assessment of processing times. Additional advances could include the integration of real-time synchronisation mechanisms with IoT sensors for the automated monitoring of storage-space conditions and material status, in line with emerging developments in territorial digital twins.

References

Azari, P., Li, S., Shaker, A., 2025. An Effective Approach to Geometric and Semantic BIM/GIS Data Integration for Urban Digital Twin. *ISPRS Int. J. Geo-Inf.* 14(12), 478. https://doi.org/10.3390/ijgi14120478

Batty, M., 2018. *Inventing Future Cities*. MIT Press, Cambridge (MA), USA.

Bianconi, F., Filippucci, M., Ceccaroni, S., 2024. *Wood 4 green. Strategie integrate per la rigenerazione territoriale.* Maggioli Editore.

Bianconi, F., Filippucci, M., Ceccaroni, S., Cornacchini, F., Cozzali, M., Meschini, M., Rossi, R., Suvieri, L., 2025. Trasimeno Smart Land: 3D geospatial data integration for sustainable territorial management. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XLVIII-4/W16-2025, 9–16. https://doi.org/10.5194/isprs-archives-XLVIII-4-W16-2025-9-2025.

Biljecki, F., Ledoux, H., Stoter, J., 2016. An improved LOD specification for 3D building models. *Computers, Environment and Urban Systems*, 59, 25–37. https://doi.org/10.1016/j.compenvurbsys.2016.04.005

Cepa, J.J., Alberti, M.G., Pavón, R.M., Calvo, J.A., 2024. Integrating BIM and GIS for an Existing Infrastructure. Applied Sciences, 14(23), 10962. https://doi.org/10.3390/app142310962

Deng, Y., Cheng, J.C.P., Anumba, C., 2016. Mapping between BIM and 3D GIS in different levels of detail using schema mediation and instance comparison. *Automation in Construction*, 67, 1–21. https://doi.org/10.1016/j.autcon.2016.03.006

Fuller, A., Fan, Z., Day, C., Barlow, C., 2020. Digital Twin: Enabling Technologies, Challenges and Open Research. *IEEE Access*, 8, 108952–108971. https://doi.org/10.1109/ACCESS.2020.2998358

Goodchild, M.F., 2007. Citizens as sensors: the world of volunteered geography. *GeoJournal*, 69(4), 211–221. https://doi.org/10.1007/s10708-007-9111-y

International Organization for Standardization (ISO), 2021. *ISO 19166:2021 Geographic information — BIM to GIS conceptual mapping (B2GM)*. ISO, Geneva.

Jones, D., Snider, C., Nassehi, A., Yon, J., Hicks, B., 2020. Characterising the Digital Twin: A systematic literature review. *CIRP Journal of Manufacturing Science and Technology*, 29, 36–52. https://doi.org/10.1016/j.cirpj.2020.02.002

Kaulen, A., Stopfer, L., Lippert, K., Purfürst, T., 2023. Systematics of Forestry Technology for Tracing the Timber Supply Chain. Forests, 14(9), 1718. https://doi.org/10.3390/f14091718

Keefe, R. F., Zimbelman, E. G., Picchi, G., 2022. Use of Individual Tree and Product Level Data to Improve Operational Forestry. Current Forestry Reports, 8(2), 148–165. https://doi.org/10.1007/s40725-022-00160-3

Liang, X., Hyyppä, J., Kaartinen, H., Lehtomäki, M., Pyörälä, J., Pfeifer, N., Holopainen, M., Brolly, G., Pirotti, F.,

Hackenberg, J., Huang, H., Jo, H.W., Katoh, M., Liu, L., Mokroš, M., Morel, J., Olofsson, K., Poveda-Lopez, J., Trochta, J., Wang, D., et al., 2018. International benchmarking of terrestrial laser scanning approaches for forest inventories. *ISPRS Journal of Photogrammetry and Remote Sensing*, 144, 137–179. https://doi.org/10.1016/j.isprsjprs.2018.06.021

Müller, F., Jaeger, D., Hanewinkel, M., 2019. Digitization in wood supply—A review on how Industry 4.0 will change the forest value chain. *Computers and Electronics in Agriculture*, 162, 206–218. https://doi.org/10.1016/j.compag.2019.04.002

Noardo, F., Arroyo Ohori, K., Biljecki, F., Krijnen, T., Ellul, C., Harrie, L., Stoter, J., 2019. GeoBIM Benchmark 2019: Design And Initial Results, *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XLII-2/W13, 1339–1346, https://doi.org/10.5194/isprs-archives-XLII-2-W13-1339-2019

Noardo, F., Ellul, C., Harrie, L., Overland, I., Shariat, M., Arroyo Ohori, K., Biljecki, F., Stoter, J., 2020. Opportunities and challenges for GeoBIM in Europe: developing a building permits use-case to raise awareness and examine technical interoperability challenges. *Journal of Spatial Science*, 65(2), 209–233. https://doi.org/10.1080/14498596.2019.1627253

Open Geospatial Consortium (OGC), 2021. *OGC GeoBIM Initiative*. Open Geospatial Consortium, Wayland (MA).

Piras, G., Muzi, F., Zylka, C., 2024. Integration of BIM and GIS for the Digitization of the Built Environment. *Applied Sciences*, 14(23), 11171. https://doi.org/10.3390/app142311171

Rani, J., Yadav, S.K., 2026. Sustainable Urban Design and Management: The Role of BIM and GIS Integration Mekawy M. (Ed.), *Building Information Modeling and Geographic Information Systems for Next-Generation Spatial Intelligence*, pp. 169-208. IGI Global Scientific Publishing. https://doi.org/10.4018/979-8-3373-4058-6.ch007

Sacks, R., Eastman, C., Lee, G., Teicholz, P., 2018. BIM Handbook: A Guide to Building Information Modeling for Owners, Designers, Engineers, Contractors, and Facility Managers. https://doi.org/10.1002/9781119287568

Xia, H., Liu, Z., Efremochkina, M., Liu, X., Lin, C., 2022. Study on city digital twin technologies for sustainable smart city design: A review and bibliometric analysis of geographic information system and building information modeling integration. *Sustainable Cities and Society*, 84, 104009. https://doi.org/10.1016/j.scs.2022.104009

Zhu, J., Wu, P., 2022. BIM/GIS data integration from the perspective of information flow. *Automation in Construction*, 136, 104166. https://doi.org/10.1016/j.autcon.2022.104166