Utilising bSDD for BIM-based Heritage Asset preservation

Karol Argasiński, karol.argasinski.dokt@pw.edu.pl
Faculty of Architecture, Doctoral School, Warsaw University of Technology, Poland

Artur Tomczak, artur.b.tomczak@ntnu.no
Department of Civil and Environmental Engineering, Norwegian University of Science and Technology (NTNU), Trondheim, Norway

Abstract
Accurate and comprehensive data representation is crucial for heritage conservation. Building Information Modelling (BIM) offers an excellent platform for meticulously documenting and managing cultural legacy assets. The IFC schema allows for the capture of geometrical and relational features. However, more than the semantic layer of IFC is required for the complexity of culturally relevant data. Historical objects deserve high information richness, following a common framework that enables unambiguous interpretation and interoperability. This paper proposes utilising the buildingSMART Data Dictionary (bSDD) service with an ontology-based MIDAS heritage dictionary to support BIM data curation and increase the adoption of semantic standards. Distributing MIDAS through bSDD allows for easy, efficient and consistent object labelling. This study emphasises the significance of information consistency, accuracy, and usability in documenting historical objects within BIM, and the proposed method has been proven effective in various applications. These benefits provide reassurance of the value and impact of our research.

Keywords: BIM, heritage asset preservation, bSDD, data dictionary, ontology

1 Introduction
The accurate and comprehensive representation of data is paramount in heritage conservation, as it ensures the fidelity and integrity of cultural heritage (Kuroczyński et. al. 2023). High-quality data capture and detailed representation allow for accurate documentation, which is essential for understanding an object's original condition and the context of its creation and use. This meticulous approach helps conservators and researchers make informed decisions about restoration and conservation, thus preserving the object's authenticity. Furthermore, the comprehensive representation of data facilitates interoperability between different technology platforms, increasing the possibility of sharing and collaborating on conservation efforts worldwide. By accurately representing historic objects, we protect their physical condition and preserve their cultural significance for future generations, thus enabling further research, education and appreciation.

2 Common approach
The integration of digital innovations and traditional conservation methods faces several challenges. There is a notable gap between digital advancements and conventional practices, often leading to inefficiencies. One critical issue is the transition from digital surveys (point cloud data) to 3D models, frequently resulting in models with minimal or no semantic information attached, reducing their practical value. For example, different scanning technologies might use varying terminologies and data structures, making it difficult to merge datasets without significant loss of information, which is a crucial semantic interoperability limitation. Additionally, scanning interoperability limitations present substantial hurdles, complicating combining data from different sources. Moreover, the complexity of culturally relevant data adds another layer of difficulty, as it requires careful consideration and handling to preserve its significance and accuracy (Argasiński & Kuroczyński 2023).

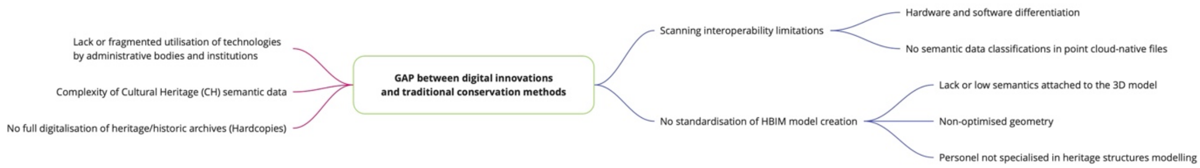

Figure: The gap between digital innovations and traditional conservation methods.

To address these challenges, conservation offices must master digital technologies, including conducting digital surveys, creating accurate and detailed models, and managing asset data efficiently. Implementing a Heritage BIM (Building Information Modelling) framework can significantly enhance these processes by providing a standardised approach to data management and model creation. These challenges highlight the need for improved methodologies and technologies to bridge the gap between digital and traditional conservation efforts.

2.1 Building Information Modelling in the context of cultural heritage (HBIM)

The application of BIM to heritage and historical asset preservation, commonly referred to as Heritage BIM (HBIM), has gained significant traction in recent years. This approach integrates the principles of BIM with the specific needs of cultural heritage conservation, providing a powerful tool for the documentation, analysis, and management of historic structures.

HBIM facilitates the creation of detailed 3D models that integrate various types of information, such as historical data, architectural details, and structural assessments. This comprehensive documentation is essential for understanding heritage assets' current state and historical evolution, enabling better decision-making for their preservation and restoration.

Integrating HBIM in managing heritage buildings allows for improved maintenance planning and execution. By providing a centralised repository of information, HBIM supports efficient project management, reduces costs, and minimises delays typically associated with restoring historical buildings (Khan et al 2022).

One of the significant challenges in heritage conservation is the fragmentation of information and lack of collaboration among different stakeholders. HBIM addresses this by offering an interoperable platform that facilitates communication and information exchange among architects, engineers, conservators, and other professionals involved in heritage projects.

HBIM often incorporates advanced technologies such as laser scanning and photogrammetry to capture accurate geometric data of heritage structures. This data is then used to create precise 3D models, which can be further enriched with historical and contextual information.

HBIM supports various conservation activities by providing a robust framework for documenting and monitoring the condition of heritage assets. It enables the simulation of different restoration scenarios, helping conservators choose the most appropriate interventions.

A study on the application of HBIM for the conservation of Galleria dell'Accademia di Firenze historical museum (Monchetti et al 2023) highlighted how HBIM could be effectively used for managing and maintaining cultural heritage sites. The project involved creating a 3D model that integrated structural information and facilitated maintenance activities. The project of the City Walls of Pisa demonstrated the use of an HBIM pipeline to conserve large-scale architectural heritage (Giuliani et al 2024). Integrating 3D models with historical data and other documentation provided a comprehensive understanding of the heritage assets, supporting their preservation.

2.2 State of the art on ontologies for heritage buildings

Standardised terminologies improve data interoperability, making sharing, integrating, and analysing information across systems and organisations easier. Enhanced search capabilities allow efficient records retrieval, while a common language supports research, analysis and pattern identification. In the Heritage BIM (HBIM) community, integrating dedicated heritage dictionaries such as Getty AAT and similar resources, as seen in research projects such as DURAARK, has proved invaluable (López et al 2018). These dictionaries help categorise and label heritage building elements, which is essential for effective data management and retrieval. In addition, they support conservation efforts by providing accurate documentation of conditions and interventions, ensuring accurate communication and recording of conservation work.

Taxonomies provide a hierarchical structure for classifying data and sub-categories. They are relatively static and focus on simple classification systems, ensuring consistency and common terminology across datasets.

Thesauri play a crucial role in classifying heritage sites, providing a structured and standardised vocabulary for describing different aspects of these buildings. They provide the consistency of terminology necessary for accurate recording and retrieval, improving communication between heritage professionals. The thesauri's detailed descriptions and hierarchical structures help users understand the exact meaning and relationships between terms, facilitating comprehensive and nuanced classifications. Overall, thesauri support the adequate documentation, research, conservation and management of heritage resources.

Ontologies go beyond classification by defining the types, properties, and inter-relationships of entities within a domain. They are dynamic and can incorporate complex relationships and inference rules, making them suitable for more profound domain-specific knowledge representation.

Integrating taxonomies with ontologies in BIM allows for a robust knowledge organisation system. Taxonomies provide the necessary hierarchical structure, while ontologies add depth with properties and relationships. This combination effectively manages and visualises historical data, making linking different datasets and deriving meaningful insights easier.

Knowledge Graphs: Creating knowledge graphs based on ontologies can enhance the management of historical BIM data. These graphs help visualise the relationships between historical objects and their attributes, supporting advanced applications such as predictive maintenance and restoration planning.

MIDAS Heritage (Historic England 2024) is a British standard for recording cultural heritage information on various assets such as buildings, monuments, archaeological sites and shipwrecks. It outlines the minimum information required and procedures for understanding, protecting, and managing heritage assets. Used by government organisations, local authorities, heritage sector organisations, and researchers, the first edition was published in 1998 by the Royal Commission on the Historical Monuments of England, and the second edition in 2007 by English Heritage (renamed to Historic England) (Historic England 2024). The standard was developed for the Forum on Information Standards in Heritage (FISH) to address standards and recording issues in the heritage sector.

2.3 Combining heritage vocabulary ontologies with HBIM

Pauwels (2017) and Simeone (2019) highlight the potential of integrating BIM and semantic web technologies, specifically focusing on the semantic enrichment of BIM for built heritage representation. Maietti (2017) further emphasises the role of semantic BIM in connecting different users and supporting the interpretation of cultural heritage models. Lastly, Fonnet (2017) introduces mixed reality in conjunction with historical building information models for building preventive maintenance, which can further enhance the preservation outcomes of Cultural Heritage Assets.

Highly relevant in the context of applying semantic standards to BIM is the buildingSMART Data Dictionary (bSDD) service – a free platform from buildingSMART International for distributing data dictionaries (bSDD 2024) coming from various independent organisations. The platform is based on ISO 23386 (ISO 2020) standards for data dictionaries and ISO12006-3, the framework for classifications (ISO 2022). The bSDD helps streamline the standards and provides them to users in their authoring software. Integrating bSDD and BIM ontology-based heritage dictionary within BIM environments can significantly enhance the documentation, maintenance, and semantic interoperability of Cultural Heritage Assets.

2.4 Research question

In the research, we analyse how integrating bSDD and ontology-based heritage dictionaries within BIM environments can enhance the effectiveness and quality of documentation, maintenance, and semantic interoperability of cultural heritage assets, thereby improving preservation outcomes and ensuring a richer narrative of these assets. We explore how such integration can provide a comprehensive and accessible representation of heritage assets, facilitating documentation, analysis, and predictive modelling for conservation needs.

3 Methodology

This research employs a proof-of-concept approach to demonstrate the practical use of the MIDAS heritage classification in BIM-authoring software, thanks to the integration with the bSDD platform. The research methodology consists of four steps: mapping the classification system with bSDD data structure, publishing in bSDD, conducting the case study, and analysing the results. In the project, we use existing classification (MIDAS), software applications (bSDD and BlenderBIM) and the BIM dataset provided by the author. The dataset was obtained through 3D scanning of the monument site, followed by modelling the geometry of elements and semantic enrichment using IFC classes (see Figure 1).

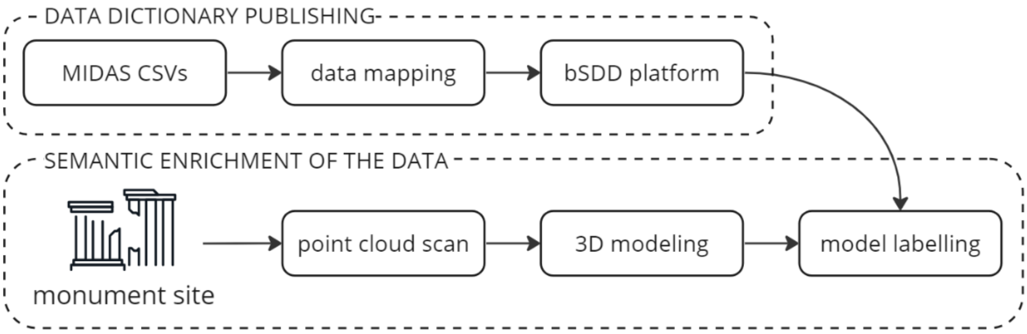

Figure 1. The workflow applied in this study

3.1 Publishing MIDAS in bSDD

We start with a spreadsheet-based classification system downloaded from the FISH website (FISH 2024) that has to be mapped and converted into a bSDD data structure. The mapping is made using the bSDD input Excel template. First, we list all classes by their names, IDs, and definitions. Then, the hierarchical structure is reflected using the ParentClassCode column and information provided by MIDAS in the *thesaurus_term_relations.csv* spreadsheet. Additionally, mapping between MIDAS terms and IFC can be expressed in the *RelatedIfcEntityNamesList* column. The conversion from spreadsheet to the desired JSON format is made using a Python script provided by the platform (bSDD 2024). Publishing is done through the graphical web interface of bSDD, which provides feedback on potential warnings and errors in the input data. After publishing, the content has a Preview status, allowing you to change it to the same version. The service offers the option to activate the content, lock the version from changes, prevent deletion, and provide end-users with a guarantee of the content's immutability and longevity.

3.2 Classifying data in BIM authoring software

Our input data is the IFC model of a heritage residential building. Further semantic enrichment by assigning appropriate classes from MIDAS is performed using BlenderBIM. BlenderBIM is an open-source application based on the IfcOpenShell library, extending the interface and adding BIM capabilities to Blender, which is a popular free, open-source 3D computer graphics software (BlenderBIM 2024, IfcOpenShell 2024, Blender 2024). BlenderBIM integrates with the bSDD API, an application programming interface that allows interaction with the database.

Using the tool's graphical user interface, we assign MIDAS classes to IFC objects containing general information and geometrical representation.

Result analysis: The final phase involves saving the data to the IFC file and opening it in another software – BIMvision – to preview the information. The performance is evaluated regarding information consistency, accuracy, and usability.

4 Case study

4.1 Publishing the MIDAS ontology from FISH in bSDD

We published three MIDAS thesauri relevant to the case study: *components, materials,* and *monument types*. *Components* include 1397 terms, such as *stoup* or *voussoir,* with their definitions, usually consisting of one sentence. *Materials* include 636 terms, from general to very specific, such as *Baveno Granite* or *Bethersden Marble*. The *monument types* classification describes a whole facility or a place and contains 7897 terms, like Abbey Gatehouse or Anti Submarine Searchlight Battery. All the published dictionaries can be previewed at https://search.bsd.buildingsmart.org/uri/fish.

MIDAS and IFC mapping was only partially done for the *components* dictionary, as for many specialist terms, it requires expert interpretation. We performed semi-automated mapping for common terms by finding keywords such as beam, column, etc., and matching them with their equivalents in the IFC schema. Some terms are semantically close but have different names in IFC; for example, MIDAS' *area* and *room* should be mapped to *IfcSpace.* A sample of the mapping between the two systems is presented in Figure 2, which also shows the hierarchical structure of both. Not shown in the figure, subelements like *Jib Door* were also mapped to their closest generalisation in IFC (here: *IfcDoor*).

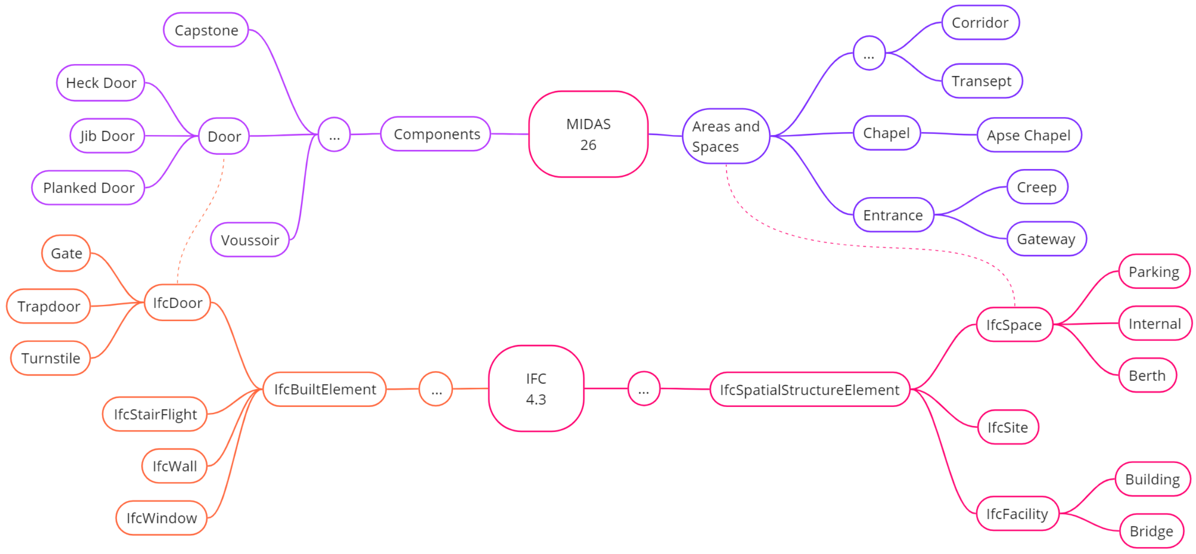

Figure 2. A sample graph of MIDAS and IFC data dictionaries mapping in bSDD.

4.2 Assigning a label to model elements

Once published the classification systems instantly become accessible in all integrated software through bSDD API. In our case study, the initial model already contains objects classified using the foundation classes (IFC). For example, the element highlighted in Figure 3 is not a generic object (IfcBuildingElementProxy) but the element of class *IfcBeam* of a predefined IFC type *CORNICE.*

The IFC classification stops at a particular information depth, but the IFC schema allows extending data with further semantic meaning by assigning classification references. In the case of the element from Figure 3, after launching the dedicated module in BlenderBIM, after typing 'cornice' in the search bar or using the 'Filter Active IFC Class' option, the application provides a list of terms from MIDAS related to cornices. In the case study, the expert decides to classify the object as an '*Angle Modillion'*.

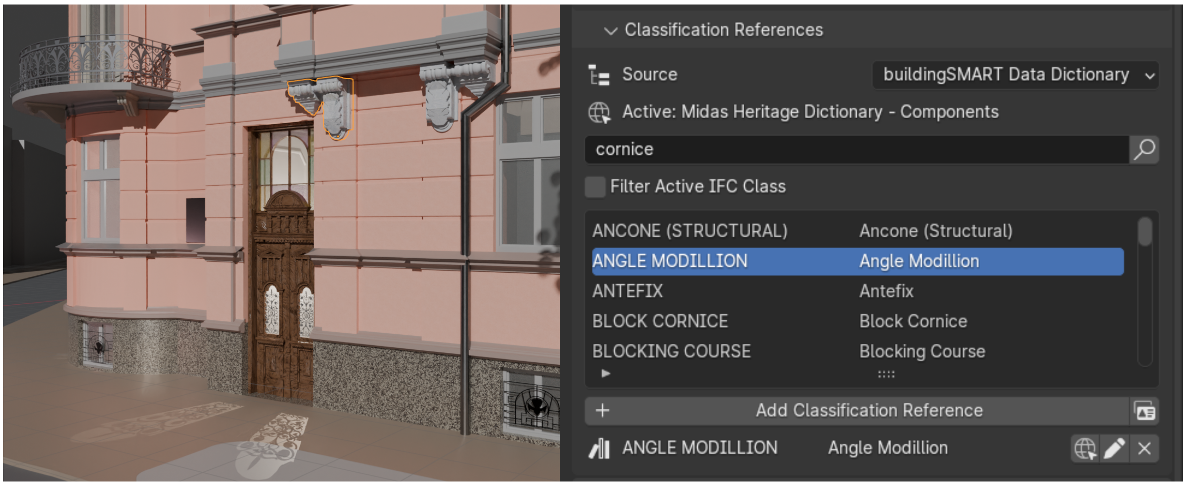

Figure 3. Assigning MIDAS classification code from bSDD to 3D element using BlenderBIM interface.

The saved model is then opened in the IFC viewer, and we can see the information added in the previous step shown in the *Classification* tab (figure 4). Apart from the code and name, we also observe the system's uniform resource identifiers (URI) and particular classes. Because of how bSDD generates URIs, they also serve as hyperlinks that point to websites providing additional information about the owner organisation, license, optionally relations to other classifications and more. The bSDD offers many attributes, most of which are dictated by the ISO 23386 standard about data dictionaries (ISO 2020). However, those are not stored directly in the model, and the user needs an online connection to view them in a browser or pull them via API.

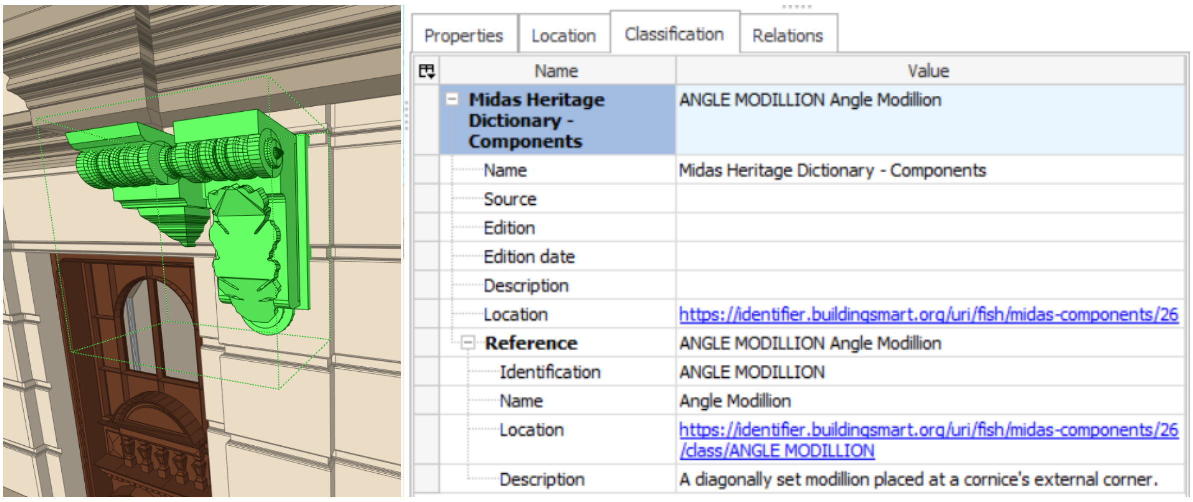

Figure 4. Previewing IFC model with proper references to MIDAS classification and URI identifiers in BIMvision.

5 Discussion

Integrating BIM with heritage conservation offers significant potential for increasing the accuracy and effectiveness of conservation efforts. By enriching the representation of heritage assets in BIM, conservators can create detailed, multi-dimensional models that incorporate structures' physical and historical complexities. Furthermore, predictive modelling within BIM assists in predicting conservation needs, enabling proactive conservation and resource allocation. Standardisation and accuracy of generated datasets are of paramount importance. While it may be impractical to incorporate extensive expertise into generic IFC standards, it is crucial to standardise terms and definitions among professionals collecting data. While republishing existing data as Linked Data may seem redundant, the bSDD facilitates using different software platforms, promoting interoperability and shared understanding. Furthermore, automating metadata for archival documents, such as historical/heritage evidence cards of monuments, can streamline data entry and improve the accessibility and usability of historical information. These advances demonstrate the practical applicability and effectiveness of BIM in heritage preservation.

6 Conclusion

The MIDAS Heritage Classification model was successfully mapped and published through bSDD, and it immediately appeared in the native authoring software of our choice (Blender/BlenderBIM). This enabled modellers to select from a predefined list, summarising the enriched narrative of cultural assets through the proposed approach. The necessity for enhancing heritage conservation standards was emphasised, pointing to future research and application directions. Finally, this was achieved through a standardised, interoperable platform, facilitating consistent and accurate heritage object labelling.

Conflict of Interest

One of the authors is an employee of buildingSMART International, the organisation behind the bSDD service and is managing its development. The knowledge of the service was applied to aid the research. However, this research is not meant to promote or favour any solution, and the paper was written without any connection to the organisation. The same organisation co-organises the conference, but the work has been sent for anonymous peer review, eliminating the potential source of bias.

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