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PRESERVATION THROUGH DIGITIZATION - STANDARDIZATION IN DOCUMENTATION OF BUILD CULTURAL HERITAGE USING CAPTURING REALITY TECHNIQUES AND HERITAGE/HISTORIC BIM METHODOLOGY

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ABSTRACT:

Building Information Modelling (BIM) is an established approach in the construction industry that enables efficient collaboration between stakeholders and facilitates project management. However, when it comes to historical buildings, the application of BIM can be demanding due to the complex nature of these projects. Although BIM Uses in the construction sector are well-documented (Penn State University, 2013) and we are surrounded by amazing technologies, we do not yet have standardized international workflows on how to use those state-of-the-art techniques with Cultural Heritage Assets (Bruno and Roncella, 2019). Standardizing Cultural Heritage (CH) metric documentation and Heritage/Historic Building Information Modeling (HBIM) is challenging since each CH asset needs different information throughout the whole life cycle of the monument - both their physical and non-physical attributes, such as historical and cultural characteristics. Additionally, every work carried out on CH, such as knowledge acquisition, restoration, adaptation, etc., requires specific data inputs. Although there are guidelines books that offer some general proposals, they represent the maximum effort towards standardization. As a result, the field of HBIM has emerged as a relatively new area of scientific research that focuses on the digital representation of CH assets.

This research aims to develop a working method and templates for procurement workflow standardization that will facilitate the documentation of historic buildings and heritage assets in coordination with relevant historic preservation authorities for the BIM use case - asset register. The use of various measurement methods, the registration of captured point clouds, and the transfer of geometry to a BIM-compliant 3D information model and sustainable data storage are important aspects of this project.

1. INTRODUCTION

For more than 40 years we have had a technological expansion that is still ongoing today in the construction industry, mainly because of the vast spread of Computer-Aided-Design (CAD)/ Computer-Aided-Manufacturing (CAM) advancements, Lean methodology in automotive and aerospace industries and later BIM in construction. It should be emphasized that BIM is not software, but a method that helps in the operation and management of the various stages of the construction process during the whole life cycle of the asset. Automotive and aerospace industries analysed the issue with interoperability and predicted what a positive impact openness of data will have in the future by developing data formats like Standard for the Exchange of Product Data (STEP) (International Organization for Standardization, 2016). The same issue is still being debated around the Architecture, Engineering, Construction and Operation (AECO) industry.
Since buildings are also based on model elements, there was an immense ongoing problem with interoperability, which was answered roughly around 15 years after STEP was developed in mid-1980s – an International Foundation Class (IFC) 1.0 openBIM (buildingSMART International, 2019) format and classification was officially brought by buildingSMART in 1996. It allowed every actor who is connected to the building's life cycle process to participate in real-time and it is valid until today. It is said that now we have a methodology and standardization in the form of openBIM-linked geometrical and semantic data. Thus, it allows responsible parties to work in an interoperability manner with the use of any BIM software which can read/write openBIM datasets. Vendor-neutral, non-proprietary data exchange formats increase interoperability and facilitate the exchange of data across the supply chain and with the client that has been provided with different software packages (EU BIM Task Group, 2018). Discussing datasets, today we are also seeing a very rapid pace of data creation and dissemination. The use of BIM information processes in architecture is reserved mostly for new designs or contemporary assets which leaves a gap for heritage preservation itself.
In recent years, there has been a growing interest in HBIM among specialists in CH conservation (Koszewski et al., 2021). However, due to the lack of understanding and structure in authorities' institutions, it is hard to follow the accelerating development. No funds for Information and Communication Technology (ICT), no Information Technology (IT) resources, no skilled employers, etc. the development is not pacing forward. Above all, the listed issues create difficulty to classify activities related to HBIM precisely. While BIM has been widely used in the construction sector for many years with numerous publications (Eastman et al., 2018), HBIM research is still in its infancy. As such, there is a need for further investigation into the application of BIM to CH assets to enhance the collaboration between the construction industry and specialists such as in the field (Murphy et al., 2009).

Surveying methods are not standardized as well. Laser scanning techniques or photogrammetry, in combination with BIM methodology, provide an effective means of creating digital representations of CH assets. However, the process requires a high level of expertise and understanding of the complexities of

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historical buildings. There are guidelines which describe proposals for the reality capturing of heritage assets i.e Applied Digital Documentation in the Historic Environment (Frost, 2018) or Nowoczesne technologie w dokumentacji zabytków/*eng. Modern Technologies in the documentation of monuments* (Czajkowski, 2023). Even though those guidelines showcase proposals, unfortunately, they are generalizing and not giving thorough methods of work.

No standardization of surveying processes is a significant challenge that needs to be addressed to enhance the collaboration between the construction industry and CH conservation specialists. Further research and the development of standard protocols for surveying processes and data management in HBIM are needed to improve the effectiveness and efficiency of the approach.

The main issue is to ask ourselves, what potential standardized workflows should be determined for digital surveying methods and intervention, asset management and preservation of architectural heritage for the future? That concerns established both Level of Information Need (LOIN) (Polski Komitet Normalizacyjny, 2020) and data classification workflows (Polski Komitet Normalizacyjny, 2018).

2. STATE OF THE ART

The adoption of BIM in the context of historic/heritage assets presents unique challenges that require specialized standards and guidelines. These challenges are particularly relevant in Europe, where there is a wealth of historical monuments and infrastructure, including 545 out of 1,154 properties on UNESCO's World Heritage List (UNESCO World Heritage Centre, 2023).

So far, there are only a few recommendations which became available internationally to explain the usability of BIM for preservation, protection, and construction with the use of historical/heritage assets. The following article discusses several examples from different countries: Germany, United Kingdom, Singapore and Poland.

2.1 Germany

The construction activity on existing structures in Germany is estimated to be around 66.2%, with almost three-quarters of these structures being buildings with historic value lacking up-to-date documentation (Bundesstiftung Baukultur, 2020).

There are already defined paths for BIM-based procurements in Germany. Digitization of construction industry in Germany begin from 2015, when Minister Alexander Dobrindt announced the Plan of Work (Brammann and May, 2015). Due to that, BIM has been mandatory for federal infrastructure projects since the beginning of the year 2020. As next step, from 2022 all federal civil engineering projects must be done aim BIM.
In addition, German National BIM Guidelines are well developed with the main goal of creating sufficient newly designed structures and infrastructural projects (Working Group BIM4INFRA2020, 2018).

The plan does not take into consideration the path for specifics of heritage monuments – for those, there are still publications such as "Recommendations for construction documentation (Empfehlungen für Baudokumentationen)" (Eckstein et al.,1999) which considers classical/analog approaches of documenting CH. The implementation of HBIM in coordination with CH authorities and stakeholders becomes necessary to use the potential of management approach like efficiency or interoperability in relation to a heritage that is impermanent.

What is more, the Working Group "AG Bauforschung Landesämter Denkmalpflege" (Building Research State Offices for Monument Preservation) in Germany, where from 16 representatives of the federal states just 3 are currently engaged with BIM in the work on pilot BIM projects but without common understanding (Working Group AG Bauforschung Landesämter Denkmalpflege, 2023).

Last but not least, experts criticize that German academic environment is not adequately preparing the next generation of AECO specialists for the future requirements including preserving national heritage.

2.2 United Kingdom

Almost 70% of construction industry professionals were utilizing BIM on their projects in 2019, while the remaining professionals were generally familiar with its presence.
In 2019, UK BIM Framework Initiative to provide open approach and guidance to understand standards used during procurement has been developed and taken care of since (UK BIM Framework Group, 2019).
It can be ventured a statement that UK is a forerunner in BIM and in the application of this methodology. (NBS, 2020).
Manuals such as "BIM for Heritage" provide guidance to owners, end-users, and professionals in the heritage and construction fields, outlining the advantages of a BIM approach and providing support for successful implementation in heritage projects. Historic England is a public body that helps people care for English Heritage Assets. (Historic England Group, 2015).
Historic Environment Scotland on the other hand is providing guidelines which purpose is to utilize various data capture techniques for recording, analysing, conserving, and visualizing the historic environment (Frost, 2018).

2.3 Singapore

Singapore itself is one-of-a-kind case, where there are "ready-to-go" templates for public procurement which can be used in practice during the whole life cycle of the design. In the field of standards, Singapore's Corenet (Singapore Government, 2016) is the most comprehensive and digitized one (in the field of BIM) since it provides not only templates for the documentation but also manuals as well as template files for respective BIM authoring tools like Archicad and Revit. Thus, it makes project development much easier on every phase.

2.4 Poland

Last but not least, The National Institute of Cultural Heritage in Poland has no standards and guidelines regarding Historic/Heritage BIM uses in practical matter. There are only proposal in regards of reality capturing which appeared this year**.** The guideline "Modern Technologies in the documentation of monuments" which provides a coherent system of data collection, processing and presentation as a basis for conservation action.
The National Institute of Cultural Heritage in Poland has comprehensive conservatorship database – which are considering more classical approaches, not based in the digital matter.

In 2022, "BIM Working Group in Poland" which works under the Ministry of Development and Technology proposed several

different protocols and standardizations, but without any goals and targets according to heritage (Ministerstwo Rozwoju i Technologii, 2022). Still, there are no available document templates in official procurement regarding BIM in Poland. There are just proposed entities of documentation but those are still in the research phase. Standardized documentation is not available since BIM procurement is not functioning as a requirement.

Overall, the adoption of BIM in the context of historic/heritage assets requires specialized standards and guidelines that consider the unique challenges and considerations of these projects.

2.5 Conclusion

Most of the processes in procurement in General Directorate for Cultural Heritage Rhineland-Palatinate, Germany (GDKE) are analogue, although authorities show high interest in Implementing BIM methodology with the specification of Heritage/Historic Assets.
Polish Institute of Architecture is already using reality capturing technologies, but do not use digitized assets to work in BIM procurement. The data of scanned buildings can be reviewed, along with digitized archives of more than 70% monuments in Poland through Open-Access service (The National Institute of Cultural Heritage, 2018).
Still – there is lack of practical use of those technologies in future steps of preservation, intervention and renovation processes.

The research question is how state-of-the-art methods from AECO industries can be employed by municipalities and authorities to ensure preservation through conservation and/or intervention, in the context of the "Building Culture (Baukultur)" proclaimed in Germany Baukultur Report 2018/2019 (Bundesstiftung Baukultur, 2020).

There is still a lack of understanding about the specific information necessary for the digital documentation of cultural heritage.
Many important details related to data optimization and management are currently unstructured and generalized.
The below questions serve in a result as a response to the listing mentioned above:

- How can data and related processes be optimized to suit the needs of cultural heritage documentation?
- Which modeling methods are most relevant and appropriate to use in this context?
- Is a standardized metadata dictionary necessary for cultural heritage documentation?
- Are current classification methods for datasets and models sufficient for this purpose?
- Should digitized data be made openly available for use and learning?
- Should stored information be accessible through structured data such as IFC (Industry Foundation Class) and bSDD (buildingSMART Data Dictionary) open data standards and Linked Data?
- Who should be the rightful owner of datasets in terms of security and rights?
- how to use / access and manage the data through and by different actors, such as authorities (i.e. conservators), AECO industry and educational sector in order to create understanding and common intent.

Therefore, it is essential to understand the needs, requirements, and responsibilities in order to establish workflows that are beneficial for the cultural heritage sector.
The goal should be to present HBIM as a method and tool to deal with CH (serving the daily requirements of authorities in CH) and create data models, classifications, and storage processes that support the documentation, digitization, preservation, dissemination, and long-term presentation of cultural heritage for future research and reference.
The question arises of how to move built CH assets into the digital age and what requirements the CH sector might have regarding 3D models.
BIM processes and reality capturing can be used to create a reliable knowledge base for heritage, making the creation of HBIM models simpler and with fewer risks of errors.

3. CASE STUDY

The BIM approach facilitates the estimation of renovation and maintenance costs of a building and enables the prediction of the effects of renovation activities in the context of the technologies used.
Such BIM models can incorporate historical data, such as:
- digitized archival documentation from the Historic Preservation Office or the National Heritage Institute,

- indirect information from witnesses, former owners, - researchers passionate about capturing and representing historical context, value, and preserving heritage assets for future generations;
- architectural survey which contains detailed information about heritage value for the conservatorship office.

Figure 1. Surveying process with the usage of TLS: Leica RTC360 in Synagogue in Przysucha, Poland (© WUT & HSM, Karol Argasiński 2022)

This methodology can provide means of collaboration and data for conservators, contracting building research for documentation of historic buildings before demolition, or interventions (revalorization, renovation, restitution, and reconstruction).

The case study of this article is the Przysucha's Synagogue which is located in Masovian voivodeship, Poland. Built between 1764 and 1777 in the Jewish part of the town, it was devastated during the Second World War by the Germans. After the war, the building deteriorated until the 1960s, until work was undertaken to preserve it from further deterioration. The building is built on a rectangular plan measuring 29.6 by 19.6 metres in Baroque-Classical style from sandstone blocks. The synagogue is listed in the register of monuments of the National Heritage Institute. The building is now out-of-the-use (Modrzewski, 2019).

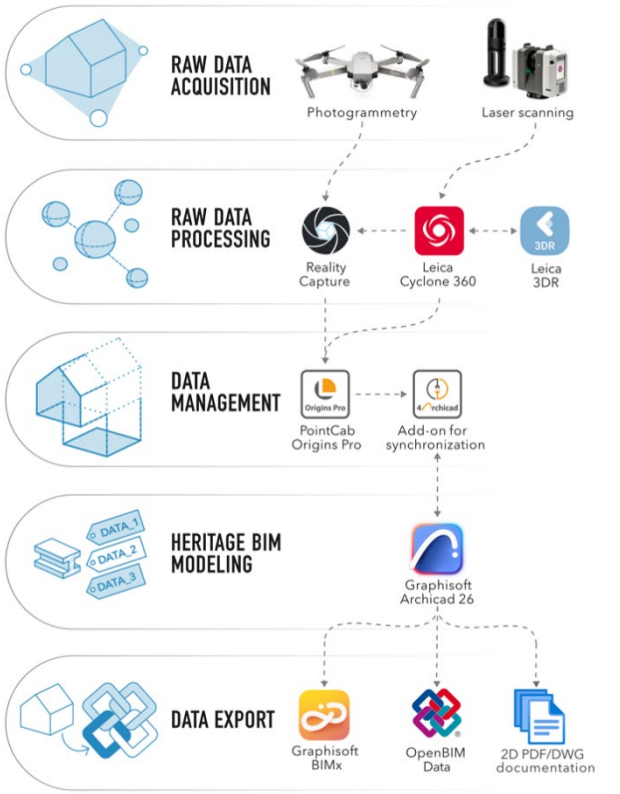

Figure 2. Heritage BIM data processing and curation proposal diagram (© AIMAINZ/Piotr Kuroczyński and WUT/Karol Argasiński 2023, CC BY-NC-SA).

The inventory with use of state-of-the-art reality capturing technologies was crucial due to a large number of areas that cannot be surveyed in a traditional way. This approach demonstrates that the aforementioned technologies not only make it possible to reach inaccessible places, but also allow non-contact examination of the historic fabric, which is often susceptible to damage, in addition, in short matter of time.

The monument was examined during two campaigns dated 10.05.2022 and 22.05.2022. For this purpose, the exterior, the facades, and the interior of the building were surveyed with the Leica RTC 360 laser scanner at 85 structured scanning positions which acquisition took 4:25h. In addition, the roof structure was scanned with Leica BLK2GO which took 30 mins, giving an unstructured point cloud of the roof. All above data was registered in Leica Cyclone 360 software (Leica Geosystems, 2022). Due to the narrow slope of the roof, it was not possible to see the roof surface from the ground. An aerial flight with the DJI Mavic Pro drone, with which a total of 151 images were taken, served to solve the problem. Later, those pictures were stitched into a photogrammetry model with the use of Reality Capture Software, giving coloured point clouds.

The architectural inventory of the object was developed with the usage of 3D laser scanning and will serve to archive the object, determine its condition, and obtain other data, which will be used in further documentation but also intervention processes as reusable information for planning and academic processes. The amount of point cloud RGB data produced estimates around 250GB.

After that, optimization process was necessary. PointCab Origins Pro software was next tool to be used, along with a plug-in for the exchange of high-quality data between the software and the BIM model environment. PointCab Origins software allows for the automatic creation of point cloud-based views which speeds up the process of developing scan data and does not require navigating through 3D space. The software, due to its built-in algorithms, has allowed point cloud data to be optimised from the aforementioned 250GB to around 23GB. That allowed to create proper views (sections, floorplans, elevations) and decimated RGB point clouds as a base for creating HBIM Asset.

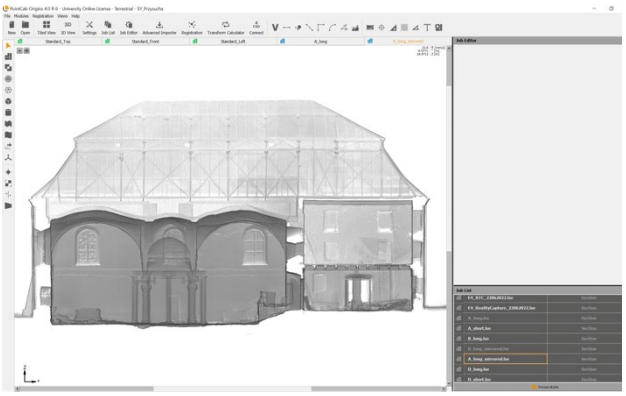

Figure 3. Przysucha Synagogue section in PointCab Origins Pro Interface (© AIMAINZ/Piotr Kuroczyński and WUT/Karol Argasiński 2023).

The BIM model creation was conducted in BIM authoring tool Graphisoft Archicad version 26 International (Graphisoft, 2023). Software served as a main tool not only to create a **digital twin of the building but also the assignment of specific data to all contained elements. This could be: dimensions, material, colour, structural function, physical properties and even cavities.**

A PropertySets classification database rich in heritage metadata was created following the British standard MIDAS Heritage for the information acquisition of monuments (English Heritage, 2012).

That database can aid in developing proposals for the extension of the openBIM data model towards CH and practical use for conservator offices' practice.

The BIM model ensures that the survey data is standardized, organized, and easily accessible for various purposes. Data prepared in this way can be useful not only for architects, but also for art historians, conservators or archivists.

Created asset can be of help in tasks specific to active actors in heritage conservation workflow, i.e.:

- A database can be used by heritage specialists who may require a detailed and comprehensive documentation of the cultural heritage asset, including its history, provenance, current condition, and any previous conservation work done on it to examine the condition of a building and further help

decide what processes need to be undertaken to either preserve the building or bring it into a usable condition;

- A digital model as an accurate basis for design and subsequent construction work - identifying potential risks and threats, such as environmental factors, human intervention, and natural disasters.
- A virtual timeline for archiving all building states on the basis of semantic and measurement data as well as planned measures;
- Building a digital archive of national heritage. It can be used not only to document the building, but also as an exhibit to disseminate knowledge about the building and its individual history;
- Specialists may require a detailed condition assessment of the cultural heritage asset, including the extent and nature of any damage, deterioration, or alteration. This may involve taking detailed photographs, measurements, and other observations which can be embedded into the digital model;

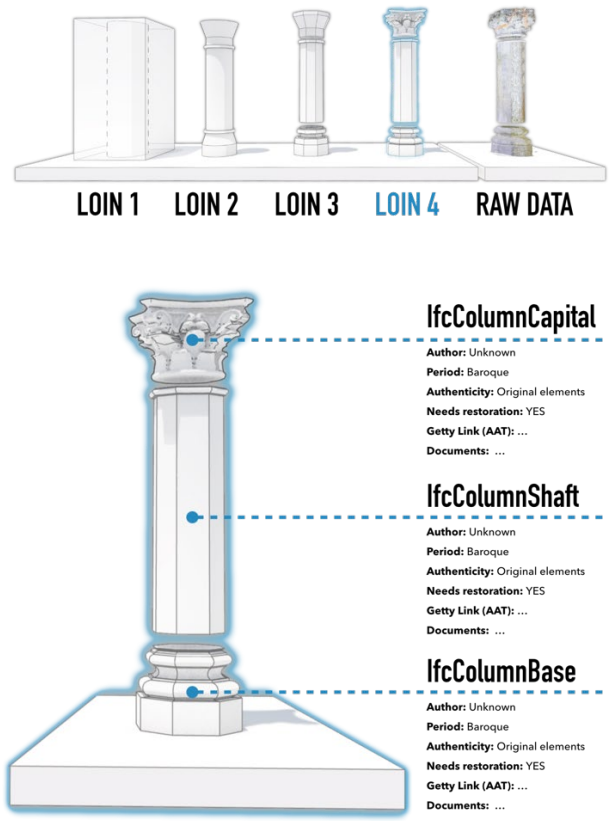

Figure 4. Level of Information Need Proposal in terms of Heritage Building Information Modelling Use (© AIMAINZ/Piotr Kuroczyński and WUT/Karol Argasiński 2023, CC BY-NC-SA).

- National Institute of Heritage may require collaboration with other professionals in the field, such as archaeologists, historians, architects, and engineers, to gain a comprehensive understanding of the cultural heritage asset and develop effective conservation strategies. This database is a publicly accessible file openBIM compliant IFC format, so it can be used by anyone throughout the research and design workflow. In addition, by using the BIM Collaboration Format (BCF), it is possible to communicate directly about the building elements and documentation attached to the HBIM model;
- As an environmental aspect, the BIM model can include a list of the materials used in the building and their condition in case the building is demolished, they can be reused on an urban-mining basis.

Based on that process, model in IFC format was exported in accordance to European Norm (Polski Komitet Normalizacyjny, 2020) and German analogue heritage guidelines used by conservators written by Eckstein (Eckstein, 1999).
Four different levels of geometry and information were defined since ISO 17412-1 which explains Level of Information Need (LOIN) allows for its own interpretation, allowing for a gradual mapping of the geometry and alphanumeric information up to deformation-appropriate modelling.

There is a need to provide a digitized form of an asset as a single source of truth of heritage database which must be created and standardized. This is particularly necessary so that the data obtained and presented in this way is not only available to all actors but above all understood and ready for further use by all those involved in the process. There are platforms such as Catenda Hub (Cantenda Team, 2023) that allow for the handling of volume objects or infrastructure investments in the form of Common Data Environment throughout the entire life cycle of an object - but there are no solutions available.

It is already known that the communication between parties/actors that will create, manage, and archive an asset must work in a collaborative manner. To communicate in the most open possible way, an idea was formed to use openBIM standards as a driving force of interoperability. It gives future possibilities not only in creating detailed HBIM models enriched with historical data regarding the current state, and archived digitized semantics but also as a field to create assets for reconstruction. Those rich heritage datasets embedded in the model can be also interlinked with data model describing linked-data resources like CIDOC CRM (CRM Special Interest Group, 2014) which can serve as a basis of creating specific guidelines regarding properties based on IFC Schema system which then can be linked in our model based on the use of buildingSMART Data Dictionary (buildingSMART International, 2021). It is important to mention that IFC Schema is a standardized structure of data which allows the user to add their own PropertySets in BIM authoring software. Those PropertySets can be used as metadata with certain heritage values about the surveyed monument.
That means that as in most cases with data models in RDF for documentation based on linked-data resources like CIDOC CRM, properties and records are written by hand – the same principle applies to the creation of user-based PropertySets.
Despite the fact that there are tools for data curation, those are exemplary methods of available solutions and not a universal, officially accepted standard of work when it comes to heritage.

Figure 5. Comparison of RAW data and HBIM model of Przysucha (© AIMAINZ/Piotr Kuroczyński and WUT/Karol Argasiński 2023).

The output of mentioned activities is a case study model for guidelines on how to capture, document and disseminate data about the building enabling the conservators to deal with it in an appropriate way, to be able to be part of the digitization in the built environment, to enable CH to be part of the digital turn. It provides comprehensive documentation of the object in four elaboration levels of geometry and information modelling via the IFC data exchange format.

4. METHODOLOGY

The coordinated cooperation between the Warsaw University Technology (WUT) and the Hochschule Mainz (HSM) has led to an evaluation and comparison of Polish and German approaches in the authorities of conservation and preservation.
Research is taking place regarding the documentation of the process from an academic and a commercial perspective (Information requirements such as EIR (Employer's Information Requirements) and other BIM Protocols) and possibilities of analysing the creation of standardized PropertySets and IFC-based data models which can help to define heritage-specific information with the usage of **openBIM Standards** provided by buildingSMART (buildingSMART International, 2019). The proposed workflows and input of heritage classification systems for monuments **(such as MIDAS/FISH**) may work as a universal standard and be tailored to the needs of each country.

In BIM procurement, it is important to establish the EIR and the BIM Execution Plan BEP which are core documents when it comes to BIM-based procurement. The EIR specifies the information that is required to be produced and shared during the BIM process, while the BEP outlines how the BIM process will be executed, managed and how BIM will be used.
The EIR and BEP are crucial to the success of BIM procurement because they establish clear communication and expectations between the client and the BIM service provider and/or contractor. Those documents provide a common framework for information exchange, collaboration, and decision-making, which helps to ensure that the project goals and objectives are met.
The EIR and BEP also help to ensure that the BIM process is executed efficiently and effectively. Mentioned documents provide a clear roadmap for the concerned actors, outlining their roles and responsibilities, the required information exchange, and the quality standards.

Proposed documents standards can include:

- Survey quality and requirements: The EIR can include specific requirements for the survey of a heritage asset, such as the level of accuracy required, the accuracy and precision of the data, and the methodology to be used. As the answer to EIR, the BEP can then outline the procedures for conducting the survey, including the roles and responsibilities of the survey team, the quality control measures to be applied, and the expected outcomes. By establishing clear information requirements and procedures for the survey of a heritage asset, the EIR and BEP can help to ensure that the survey is conducted to the required quality standards. This can include ensuring that the survey data is accurate, complete, and reliable and that it is collected using appropriate methodologies and equipment;
- Documentation and Visualization: BIM technology can be used to create 3D models of heritage buildings and sites, which can aid in their documentation and visualization. The EIR and BEP could establish the required level of geometry of 3D models, as well as the expected accuracy and precision of the models;
- Preservation and Conservation: BIM technology can also be used to assess the condition of heritage buildings and sites, and to develop strategies for their preservation and conservation. The EIR and BEP could establish the required information on the building materials, techniques, and systems, as well as the expected level of accuracy and precision of the information;
- Integration with Existing Systems: standardized documentation can be used to integrate information on heritage buildings and sites with existing systems, such as building management systems (BMS) and databases. The EIR and BEP could establish the required format and level of compatibility of the BIM information with existing systems;
- Collaborative Working: BIM technology can facilitate collaborative working among stakeholders involved in the heritage procurement process, including architects, engineers, heritage experts, conservators, art historians, and contractors. The EIR and BEP could establish the required level of collaboration and coordination among stakeholders, as well as the expected level of communication and information exchange based on openBIM data.

5. CONCLUSION

In the future, HBIM may serve as an invaluable tool for decision making and resource management throughout the life cycle of a monument.
Research has explored the information requirements and possibilities of analyzing the creation of standardized PropertySets and IFC-based data models to define heritage-specific information.
openBIM Standards provided by buildingSMART have been used in this regard the proposed workflows and heritage IFC Schema may serve as a universal standard tailored to the needs of individual countries.
The HBIM methodology has been proposed and explored as a potential universal standard in the documentation of the Przysucha Synagogue in Poland, and it is currently under discussion with the General Directorate for Cultural Heritage Rhineland-Palatinate (GDKE), Germany.
Guidelines and proposals for heritage-specific procurement documentation and Level of Information Needed (LOIN) have been developed in this research, and they are reflected in the description of the EIR and BIM BEP.

The aim of this research is to provide a standardized approach which promotes not only HBIM itself but helps to understand this particular methodology with complementary workflow from

laser scanning-based survey to asset management to the documentation of cultural heritage objects to ensure that important information is properly documented, stored, and easily accessible by all stakeholders.
The utilization of openBIM standards, such as IFC-based data models, will facilitate this process, providing a common language for different stakeholders to communicate and collaborate effectively.

Currently mentioned HBIM approach explored and proposed on the case study of Przysucha synagogue example is under discussion both with the GDKE on German side and National Institute of Heritage (NID) on Polish side. Guidelines and proposals for heritage specific procurement documentation are under development and being evaluated in higher education courses at HSM (Germany) and WUT (Poland). Course materials contain created EIR/BEP documentation, classification sets based on XML file type and specific project templates for Graphisoft Archicad and Autodesk Revit.

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Any additional supporting data may be appended, provided the paper does not exceed the limits given above.

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