An Integrated Geomatic and HBIM Workflow for the Digital Resurrection of Historical Sites

Mohammadreza Mehdizadeh[1], Filiberto Chiabrando [1], Beatrice Tanduo [1]

[1] Department of Architecture and Design (DAD), Politecnico di Torino, Viale Pier Andrea Mattioli, 39, 10125 Torino – (mohammadreza.mehdizadeh, filiberto.chiabrando, beatrice.tanduo)@polito.it

Keywords: HBIM (Heritage Building Information Modeling), virtual reality, virtual heritage, interactive representation, Interactive virtual environment.

Abstract

This research investigates the usage of technologies to represent architectural heritage by examining how instruments such as Heritage Building Information Modeling (HBIM) and Virtual Reality (VR) can be triggered to present a lost cultural heritage. The focus here is the "Turin 1911 World's Fair," a dismantled heritage site held in the Valentino Park, Turin, in 1911. That can serve as a methodological sample for a digitally integrated approach, which was developed through a combination of historical documents and the scan-to-HBIM process common in HBIM modeling. The project yields a high-fidelity digital twin that represents the lost heritage and a VR platform that enables visitors not to experience the site just as an illustration, but to immerse themselves inside an operative component in the interpretation of architectural history and modern technologies in design. This method fosters new dialogues between past and present and critical reflection on spatial transformation, and presents a generative and narrative tool to enhance analytical depth and public perception. This study ultimately proposes a shift in historical storytelling toward an experimental narrative in which technology, perception, and history unite to create new forms of cultural heritage.

1. Introduction

The "Turin 1911" project represents a significant initiative in the field of digital humanities, focusing on the systematic reconstruction of the 1911 International Exposition (Della Coletta, 2023). The project addresses the unique challenges of documenting and visualizing architectural heritage that no longer exists (Della Coletta, 2023). Because the exhibition was designed as a temporary event, most pavilions were ephemeral structures of wood and plaster, dismantled or destroyed shortly after the fair concluded (Einaudi, 2020).

The objective is to create a digital archive through the integration of HBIM, GIS/WebGIS and VR technologies that serves both as a scientific tool for researchers and an immersive educational experience for the public (Banfi F. C., 2025).

By using advanced computational tools, the project transforms fragmented archival materials into high-fidelity 3D environments, enabling the "re-contextualization" of historical sites within their original urban fabric (Chiabrando, 2019).

The project combines accurate 3D survey data with advanced modeling and visualization techniques to create interactive virtual environments (IVEs) that bridge the gap between tangible architectural heritage and its intangible historical and cultural significance (Banfi, 2025).

This paper outlines the technical workflow employed in the project, divided into three core phases: the theoretical reconstruction of structures within a BIM environment, the management of complex ornamental details via external formats, and the transition to real-time rendering engines for immersive VR exploration.

Through this methodology, the project demonstrates how "theoretical objects" derived from historical documents can be successfully integrated into contemporary digital ecosystems to preserve the memory of vanished cultural landscapes (Einaudi, 2020).

2. HBIM Modeling, Methods, and Challenges

2.1 Definition and Fundamentals

HBIM is a multidisciplinary process that adapts standard Building Information Modeling (BIM) methodologies for the conservation, management, and documentation of historical structures (Banfi, 2025). While traditional BIM focuses on the efficiency of new construction using standardized parametric libraries, HBIM prioritizes historical accuracy and the representation of complex, irregular geometries inherent in heritage sites (Lopez, 2025). The term was first introduced by Murphy, McGovern, and Pavia in 2009, who defined it as a BIM system that uses parametric objects reconstructed from historical data.

The primary objective of HBIM is to create a comprehensive digital repository that facilitates restoration, long-term maintenance, and public engagement (Lovell, 2023).

2.2 Methodology

By integrating data from terrestrial laser scanning (TLS), mobile laser scanning (MLS), uncrewed aerial vehicle (UAV) surveys, photogrammetry, archival photographs, historical records and detailed measurements, this methodology provides a versatile tool for generating HBIM models, realistic visualizations, and credible historical reconstructions.

It is crucial to emphasize that while the overall methodological framework is universally applicable, each heritage object requires an individual approach that considers the availability and quality of source materials (Klapa, 2025). The scope and detail of the reconstruction process are significantly influenced

https://doi.org/10.5194/isprs-archives-XLIX-B4-2026-577-2026

by archival resources, including technical drawings, photographs, historical descriptions, narratives, and other documentary records (Klapa, 2025). The following sections outline the three different modeling approaches used in the reconstruction of the architecture related to Turin 1911 project.

2.2.1 Archival Drawing-Based Reconstruction

This approach is employed as most of the physical buildings no longer exist, requiring "theoretical reconstruction" based entirely on historical evidence. Since the 1911 World Fair pavilions were ephemeral and dismantled after the event, the modeling process relies on scanned hand-drawn designs, including plans and different elevation views (Figure 1).

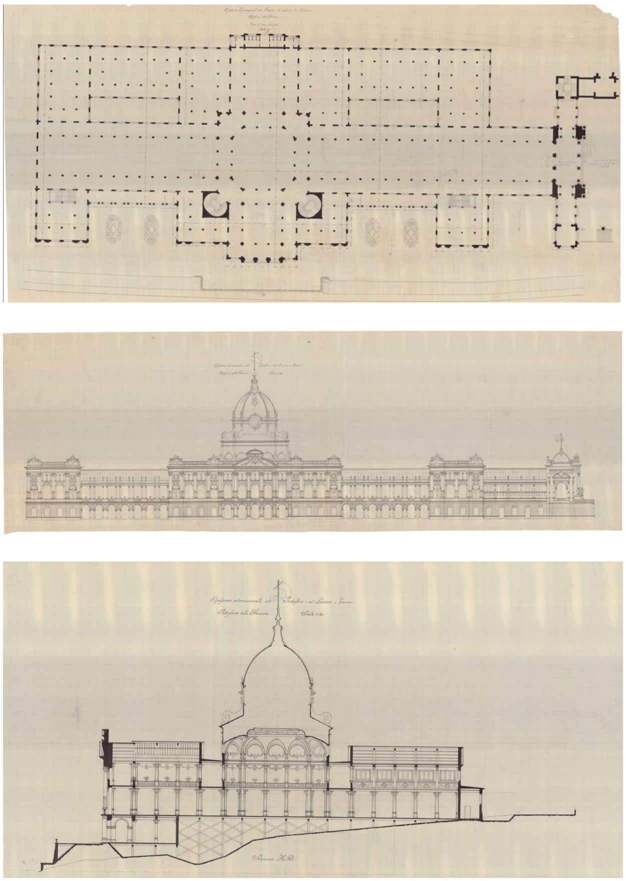

Figure 1. Pavilion of France plan, elevation, and section drawings, original scale 1:100 (Archivio Stefano Molli - Fondazione Marazza).

To ensure accuracy, multiple archival design drawings of the same elevation are cross-referenced and matched with historical photographs to verify the final intended design (Figure 2).

This approach requires manual interpretation of 2D data to create 3D parametric families in BIM software, since there is no physical surface to achieve a traditional 3D survey.

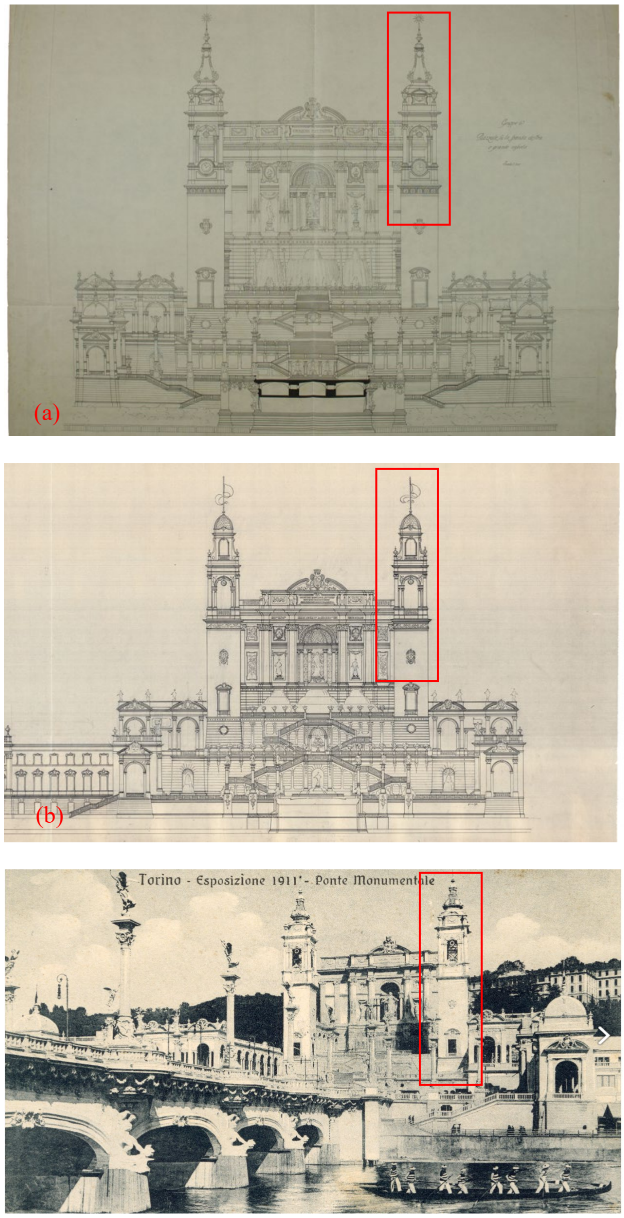

Figure 2. Comparison of two different drawings of the same elevation of the monumental complex pavilion: (a) original scale 1:100, (b) original scale 1:200 (Archivio Stefano Molli - Fondazione Marazza), with a photo of the same view (Cristina Della Coletta Private Collection).

2.2.2 Geomatic Data Acquisition

This approach represents the current technological standard in digital documentation by Laser Scanning or photogrammetry.

Historical buildings like the Valentino Castle (Figure 3) and the Medieval Hamlet still exist and have been documented in this manner, providing an opportunity to use them as point cloud bases for 3D modeling.

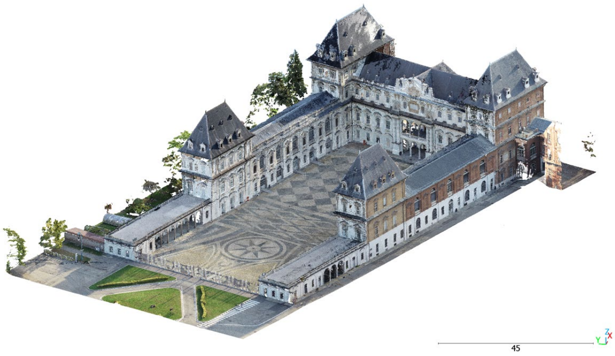

Figure 3. 3D Point cloud of the survey in the Valentino Castle area

This geomatic workflow enables a traditional "Scan-to-BIM" process, in which the 3D model is built directly from precise metric data of existing structures.

2.2.3 Hybrid Fusion of Archival Data and As-is

The third approach involves fusing historical and contemporary data as it existed during the fair. This is achieved by connecting the most accurate historical site plan of the Valentino Park during the fair (Figure 4) to UAV and aerial photogrammetric data data acquired from current terrain scans (Figure 5).

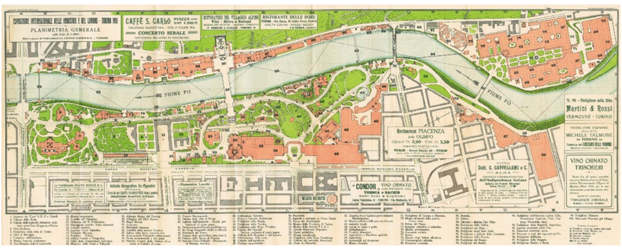

Figure 4. Map (Turing Club Italiano)of Valentino Park for the Turin 1911 World's Fair (Cristina Della Coletta Private Collection).

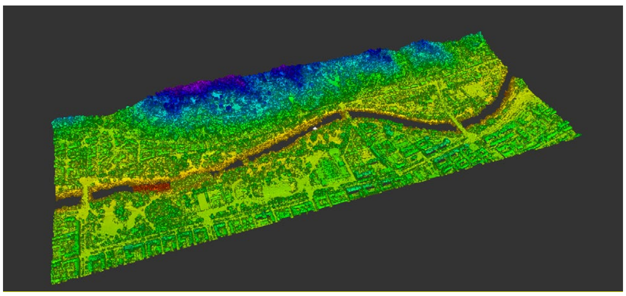

Figure 5. Point cloud data of the Valentino Park (actual shape) derived from aerial and UAV photogrammetric campaign

By merging these two datasets, the model will be able to reflect the topographical changes and the approximate placement of vanished pavilions within the current site plan as closely as possible.

This methodology can ensure more accuracy for the digital reconstruction with respect to the drawings, also geographically grounded in the real-world coordinate system provided by modern scanning.

2.3 Technical and Procedural Challenges

When generating 3D models from archival documentation, the initial phase involves systematically importing 2D technical drawings into the BIM environment. Generate 2D views such as levels and elevations, with respect to the drawings' quotations, and place the specific drawing within the corresponding 2D view and rescale them using the explicit dimensions noted to serve as a precise graphic template that ensures metric fidelity.
Once these references are accurately calibrated and verified, the general modeling of the "theoretical objects" commences directly atop these scaled drawings, transforming 2D information into a parametric 3D representation (Figure 6).

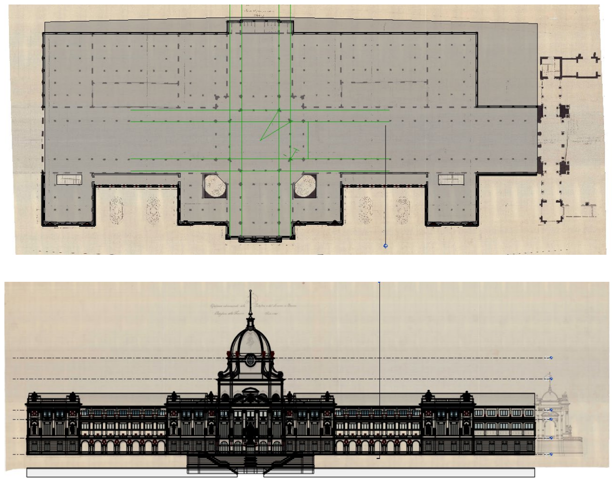

Figure 6. Plan and elevation view of the France pavilion modeled in BIM software (Revit), based on the 2D drawings.

The availability of detailed layout reference drawings that provided the metric and formal basis facilitates the development of parametric families such as columns and arcs (Figure 7).

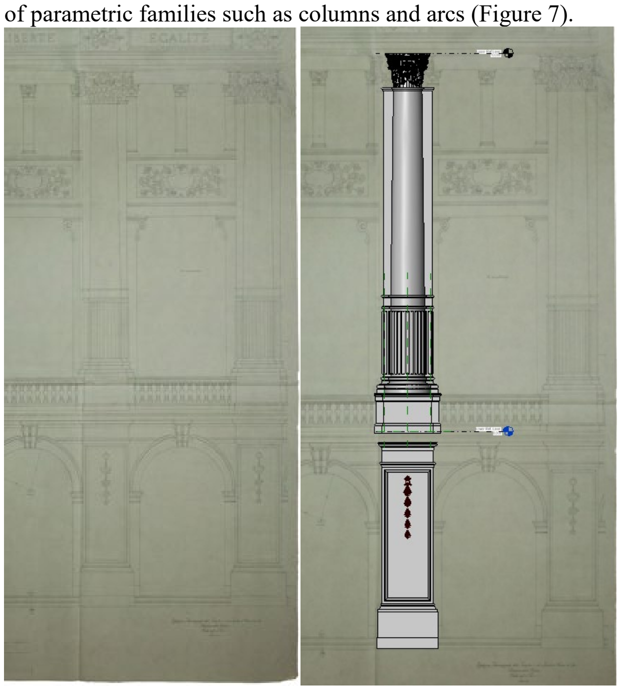

Figure 7. Parametric family modeling of the columns on the west elevation of the France pavilion, based on a layout drawing, original scale 1:10 (Archivio Stefano Molli - Fondazione Marazza).

However, the software has inherent limitations in native modeling of complex, irregular geometries such as historical ornaments and statues.

To preserve the architectural realism essential to this project, pre-existing meshes are incorporated in .dwg and .dxf formats.

This hybrid workflow enables the inclusion of intricate decorative details that would otherwise be unattainable with standard parametric modeling tools (Figure 8).

Figure 8. Family modeling of an imported statue and ornaments of the Belgium pavilion, based on a layout drawing, original scale 1:10 (Archivio Stefano Molli - Fondazione Marazza).

The deployment of historical ornaments into an HBIM workflow faces some specific technical obstacles, in this case, integrating two-dimensional archival data into a three-dimensional parametric environment.

Based on the "Turin 1911" case study and established HBIM methodologies, the following challenges list the process of importing .dwg and .dxf files as architectural ornaments in the BIM software:

- **Geometric Incompatibility and Non-Parametric Behavior:** When .dwg or .dxf files are imported into Revit, they are considered as static "import symbols" rather than native parametric families. This makes it difficult to adjust dimensions or parameters globally without re-editing the original file.

- **Performance and Mesh Density:** High-detail ornaments typically consist of dense mesh geometry. Importing multiple high-poly .dwg files can lead to significant software latency and larger file sizes, complicating the management of a large-scale scene.

- **Normalization of Complexity:** There is a constant tension between geometric precision and functional behavior; standard BIM software is optimized for regular, modern geometries, often failing to interpret the highly irregular or organic shapes accurately.

- **Coordinate Alignment and Scaling:** Matching archival drafts to a 3D model requires precise scaling. Imported .dwg ornaments must be manually aligned to the objects modeled in Revit. This process relies heavily on historical photographs and multiple elevation drafts to verify the correct placement and depth.

- **Material Mapping for VR Transition:** Files imported as .dwg often lose complex material assignments during the transition from Revit to Unreal Engine via Datasmith. This necessitates additional manual work in the game engine to re-assign physically based rendering (PBR) textures to ensure the ornaments react realistically to lighting in the final VR experience.

- **Data Fragmentation:** Because these ornaments are external imports, they may not initially carry the same semantic metadata as native Revit families. Ensuring that these decorative elements are linked to the correct historical archival references within the HBIM database requires deliberate manual tagging.

The spatial synchronization of 2D historical layouts, specifically the 1911 plan of Valentino Park, with 3D contemporary datasets, such as the as-is point cloud, improved the accuracy of modeling adjustment of the site's historical topography.

This alignment process enabled reconstruction of the terrain as it existed, providing a foundation for the digital placement of the ephemeral pavilions. By merging these disparate data sources, the HBIM reflects not only the architectural volumes but also the specific land contours and site conditions of the period (Figure 9).

3. HBIM-to-VR Link and VR Preparation

3.1 Transitioning from HBIM to Virtual Reality

Incorporation of HBIM with immersive VR demonstrates the potential to enhance the digital valorization and accessibility of cultural heritage sites.

The transition from a static HBIM to an immersive VR experience represents the possibility of converting digital data documentation to an IVE. In the Turin 1911 project, this process of revisualising can be essential for historical configurations as they are no longer physically visible.

While Revit provides the structural and semantic foundation, Unreal Engine serves as the real-time rendering platform for high-fidelity lighting and material calculations, along with the gadgets and possibilities VR offers users.

3.2 Import and Spatial Configuration in Unreal Engine

Although there are several standardized data exchange formats, such as IFC for BIM and OBJ/FBX for meshes, this study uses the Datasmith exporter tool as the bridge between the architectural model and the game engine. It brings entire constructed scenes and complex assemblies into Unreal, regardless of how large, dense, or heavy those scenes may be (Epic Games, 2024).It is essential to import the HBIM archive one by one and separate their assets, creating new folders for each to locate and manage them individually within the Unreal Engine's Content Browser. This separation allows control over single pavilions and the terrain model, enabling spatial adjustments without affecting the entire fairground. Using the dedicated VR template offered at the startup menu provides an already structured starting point, as it includes a pre-configured VR Pawn and input mappings modified for head-mounted displays.

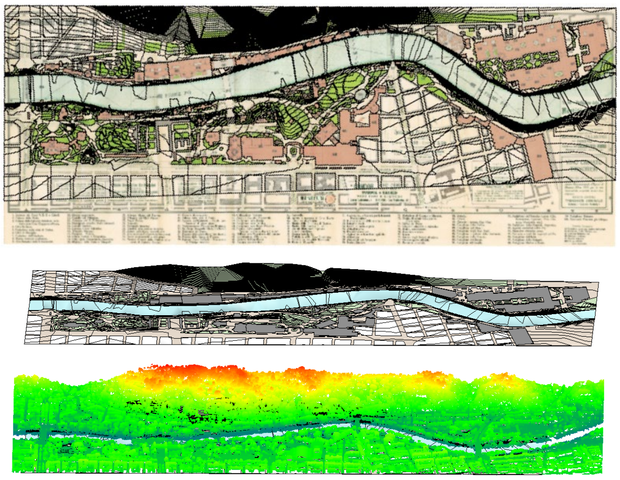

Figure 9. Terrain model of the Valentino Park in 1911 based on aligned 2D and 3D data in Revit.

3.3 Material Enhancements and the Starter Content

A significant advantage of the VR template alongside the "Starter Content" pack is the immediate access to a library of textures ready to be utilized in the process of generating materials. These assets can replace basic Revit material placeholders with physically based rendering (PBR) materials that react realistically to light (Figure 10).

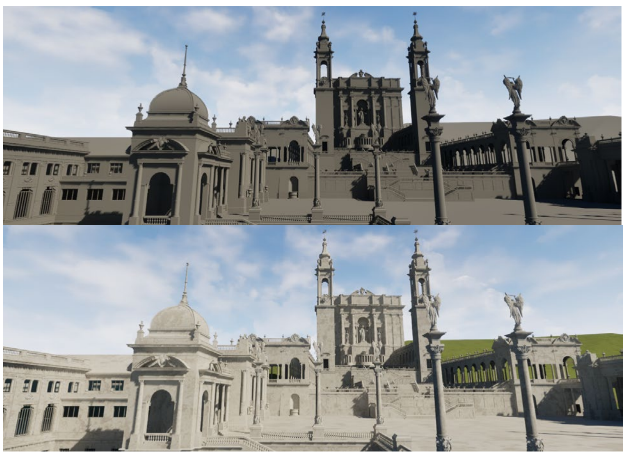

Figure 10. Comparison of the scene with Revit's default material (top), and applying PBR materials that the Starter Content of Unreal Engine offers (bottom).

By applying these pre-configured textures to the HBIM geometry, the visual fidelity of the Turin 1911 pavilions is significantly enhanced, providing a more convincing sense of scale and materiality.

3.4 Lighting and Rendering for PC VR on Windows

Achieving a realistic experience in Windows-based PC VR requires specific lighting and rendering settings tailored to the hardware configuration to maintain high frame rates while preserving visual quality. With the hardware of the used computer being the Intel(R) Core (TM) Ultra 9 285K (3.70 GHz) processor, installed RAM of 128 GB, and VRAM of NVIDIA GeForce RTX 5070, the Project Settings features are set as follows to maintain 120 frames per second (FPS) (Figure 11):

- **Target Hardware:** The project's optimization setting is set to desktop, scalable. With default rendering hardware interface (RHI) on DirectX 12 and targeted shader format to Shader Model 6 (SM6).

- **Rendering Settings:** Dynamic Global Illumination and Reflection Method set to Lumen with the reduction of reflection capture resolution from 128 to 32. Applying the Virtual Shadow Map Method, Enabling Nanite on all meshes and Anti-Aliasing Method on Temporal Super-Resolution (TSR) with Multisample Anti-Aliasing (MSAA) on 4×MSAA.

- **Lighting Setting**: Environment Light Mixer Tool is an editor window where you can create and edit environment lighting components for sky, clouds, atmosphere lights, and sky lighting. The Directional Light simulates light that is being emitted from a source that is infinitely far away. This means that all shadows cast by this light will be parallel, making this the ideal choice for simulating sunlight with the intensity set to 1.2 lux. The Sky Light captures the distant parts and applies them to the scene as a light. That means the sky's appearance and its lighting/reflections will match. The Sky Atmosphere gives an approximation of light scattering through a planetary atmosphere's participating media, giving exterior scenes a more realistic or exotic look. The mobility of all three of these components are set to movable.

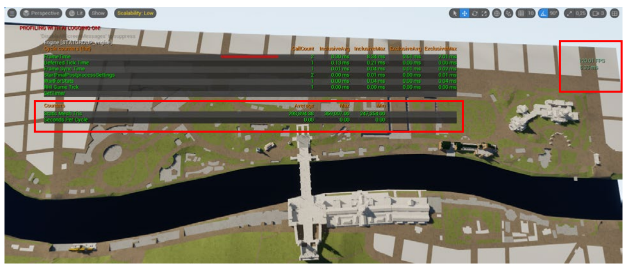

Figure 11. The scene with the view of all modeled pavilions containing an average of 298,894.38 triangles (static mesh tris) while maintaining 120 FPS.

3.5 VR Gadgets

An IVE offers various types of gadgets that can be driven through the node-based Event Graph platform of VR Pawn to the desired scenario, providing stakeholders with new experiences. In this study, specific gadgets that were installed on the VR Pawn include:

- **Teleportation:** There are two main methods of navigation in VR environments: teleportation and locomotion. The teleportation feature allows users to navigate the vast environment of Valentino Park by projecting a destination arc near the VR Pawn. This method was selected as, for inexperienced users, the locomotion technique can cause motion sickness when traversing a large-scale site (Figure 12).

Figure 12. Destination arc of the teleport feature.

- **Interactive Widget:** An interactive widget was designed and applied to the left-hand controller of the VR Pawn, providing the opportunity to navigate through different pages. This interface displays historical metadata, archival photos, or scanned hand-drawn designs for each pavilion separately, directly within the VR space. Additionally, it offers the option to teleport directly to distant pavilions, bypassing the time required for standard point-to-point teleportation across the expansive site (Figure 13).

Figure 13. Widget menu to apply information and properties.

3.6 Conclusion anf future works

This study demonstrates that it is possible to maintain a high-fidelity 3D model of a large-scale site like the Turin 1911 World Fair, even when dealing with massive scenes and several heavy models, including a total of 34.515.709 triangles (Sum Tris), the total memory footprint of the source mesh asset on memory (Size) equals to 1.843.450,375 KB and total memory consumed by lightmaps (LM) equals to 187.721,062 KB and a folder size approximately 40 GB on the disk (Figure 14).

The use of the Datasmith pipeline ensures that dense architectural data is preserved and manageable within a real-time engine. Ultimately, this methodology fosters a new dialogue between past and present by turning digital static archival documents into an operative component that can present a new interpretation of architectural heritage.

Future investigations should continue to explore methodologies for digitally integrating complex architectural elements within the HBIM environments. A primary area of focus is refining the techniques for importing historic ornament files into Revit, ensuring that complex sculptural details are preserved with high fidelity while maintaining functional parametric relationships.

Additionally, the expansive range of VR gadgets presents significant opportunities for research and developing scenarios, including the implementation of multi-user collaborative environments or dynamic time-of-day simulations to analyse the Turin 1911 Fair under varying lighting and atmospheric conditions, and studying the Foliage and Landscape system of Unreal Engine with its proper native features in order to bring greenery components to a vast distribution through optimized methods.

Research should also prioritize advanced optimization techniques directly within Unreal Engine to manage the high geometric complexity of the digital twin. This includes the utilization of Hierarchical Instanced Static Meshes (HISM) for repetitive meshes and Level of Detail (LOD) management systems. A critical objective for subsequent phases is the development of a standalone VR experience by creating an optimized Android application (.apk) that can be installed directly onto a mobile Head-Mounted Display (HMD). This experience can be rendered accessible to a wider audience, effectively removing the dependency on high-end tethered PC hardware.

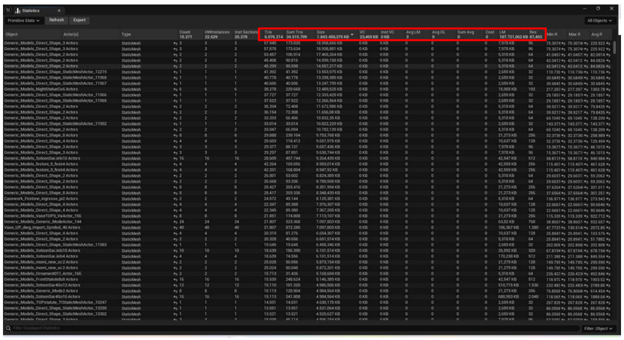

Figure 14. Statistics of the level containing total assets.

References

Banfi, F. C. (2025). XR Technologies for Enhanced Cultural Engagement: from HBIM to a Comparative Analysis of VR and WebVR Development Tools. 8.

Banfi, F. P. (2025). Cyber Representation in Experimental Architectural Restoration: Integrating HBIM, As-Designed BIM, and VR in a Multilevel and Multitemporal Immersive Ecosystem.

Chiabrando, F. S. (2019). Hybrid 3D Models: When Geomatics Innovations Meet Extensive Built Heritage Complexes. *ISPRS*.

Della Coletta, C. C. (2023). 3D WEBGIS APPLICATIONS FOR DIGITAL HUMANITIES STUDIES: THE TURIN 1911 PROJECT. *ISPRS*, 8. Retrieved from https://doi.org/10.5194/isprs-archives-XLVIII-M-2-2023-1501-2023

Einaudi, D. S. (2020). FROM ARCHIVE DOCUMENTATION TO ONLINE 3D MODEL VISUALIZATION OF NO LONGER EXISTING STRUCTURES: THE TURIN 1911 PROJECT. 8.

Epic Games, (2024). Retrieved from https://dev.epicgames.com/documentation/en-us/unreal-engine/datasmith-plugins-overview?application_version=5.4

Klapa, P. Ż. (2025). 3D Heritage Reconstruction Through HBIM and Multi-Source Data Fusion: Geometric Change Analysis Across Decades. *MDPI*.

Lopez, C. A. (2025). HBIM-Based Digital Surveying Challenges: The Larraín Palace Case. 7.

Lovell, L. J. (2023). The Application of Historic Building Information Modeling (HBIM) to Cultural Heritage: A Review.

Murphy, M. M. (2009). Historic building information modeling (HBIM).

https://doi.org/10.5194/isprs-archives-XLIX-B4-2026-577-2026