STATI GENERALI DEL PATRIMONIO INDUSTRIALE 2026

a cura di
Edoardo Currà, Fabio Fatiguso, Antonella Guida, Antonio Monte
Marina Docci, Graziella Bernardo, Elena Cantatore, Alessandro Mattioli, Claudio Menichelli

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5-8 Febbraio 2026

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Sommario

EVALUATING DIGITAL TWIN SOFTWARE AND SERVICES FOR INDUSTRIAL CONSTRUCTION. A COMPARATIVE ASSESSMENT OF ORUR-CUS SHEDS AND BUILDING

Valutazione di software e servizi Digital Twin per l'edilizia industriale. Valutazione comparativa di capannoni e edifici ORUR-CUS

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Keyword
Digital Twin; Industrial Construction; Tools Evaluation; Comparative Analysis.
Digital Twin; edilizia industriale; valutazione degli strumenti; analisi comparativa.

Abstract *Nowadays, the integration of advanced digital technologies into heritage practices has transformed both methodologies and approaches for built heritage management. Among these innovations, Digital Twin technology represents a promising tool for enabling dynamic, data-driven workflows that support recovery and valorization activities. However, their implementation within the industrial heritage context is currently limited, and challenges arise in determining the suitability of the available solutions for specific project requirements.*
This study offers a comparative evaluation of ten software and services, Dalux, Trimble Connect, Autodesk Viewer, Speckle, Cesium JS, Autodesk Tandem, Azure Digital Twins, Matterport, Fuzor, and Twinmotion, applied to the former Roman University Representative Board (ORUR) and the University Sports Complex (CUS) in Rome. Each solution is assessed based on criteria such as accessibility, interoperability, functionality performance, IoT integration, and collaborative features. The results aim to provide an evaluation of the different features, supporting users in selecting the most appropriate option according to the objectives of the application and specific requirements of the heritage context.

1. INTRODUCTION

The rapid digital transition in heritage practice has brought growing attention to Digital Twins (DTs). Widely adopted in manufacturing, process industries, healthcare, transportation, and energy[1], DTs pair a physical asset with a virtual one through bidirectional data flows to support monitoring, analysis, and decision-making. In the cultural heritage context, recent studies demonstrate diverse applications: Marra et al.[2] integrate an information system with a DT by modeling each artwork as container content sensors, enabling conservation-oriented monitoring and structural assessment of museum objects; Angjeliu et al. [3] develop a DT of Milan Cathedral using nonlinear finite-element modeling and hierarchical geometry to support inspection, damage prediction, and maintenance

[1] A. RASHEED, O. SAN, T. KVAMSDAL, *Digital twin: Values, challenges and enablers from a modeling perspective*, IEEE Access 8, 2020, 21980–22012. doi:10.1109/ACCESS.2020.2970143.
[2] A. MARRA, S. GERBINO, A. GRECO, G. FABBROCINO, *Combining integrated informative system and historical digital twin for maintenance and preservation of artistic assets*, Sensors 21, 2021, 5956. URL: http://dx.doi.org/10.3390/s21175956. doi:10.3390/s21175956. (October '25)
[3] G. ANGJELIU, D. CORONELLI, G. CARDANI, *Development of the simulation model for digital twin applications in historical masonry buildings: The integration between numerical and experimental reality*, Computers Structures 238, 2020, 106282. doi:10.1016/j.compstruc.2020.106282

planning, with prospects for virtual sensors and environmental effects. Other work explores energy and operations: a cloud–edge architecture (Azure Digital Twins) leverages sensor data and machine-learning forecasts for energy efficiency and smart maintenance in historic buildings[4]. At the urban and participatory scale, the ROCK platform connects physical and virtual heritage and enhances citizen participation to support regeneration of historic centers[5]. Even more, mixed-reality pipelines show promise for interpretation and access, with AR workflows combining historical/spatial data, dense surface models, and HBIM for in-situ visualization of heritage buildings[6].
Across these examples, DTs are generally characterized by high fidelity representations, dynamic state synchronization, identifiability of physical–digital assets, and adaptive behavior through feedback; they are often multi-scale, multidisciplinary, and hierarchically structured to align analyses and interventions with the complexity of heritage assets[7].
Despite all these applications, there is a lack of comparative evaluations of DT solutions expressly tailored to the requirements of industrial heritage use cases.
To address this gap, this paper presents a comparative assessment of ten software/services applied to a sports-related industrial architecture case (the ORUR–CUS complex in Rome), to identify the strengths, limitations, and overall performance in this specific context.

2. THE FORMER ROMAN UNIVERSITY REPRESENTATIVE BOARD (ORUR) AND THE UNIVERSITY SPORTS COMPLEX (CUS) IN ROME

The ORUR-CUS represents a modern architectural solution for an industrial sports complex. It was designed in 1967 by Enrico Mandolesi, one of the most prominent and influential professors of the Sapienza University in Rome, to achieve a fast, inexpensive, and reliable structure through the use of experimentation and new building techniques, mainly revolving around prefabrication[8].
Located beside the main Sapienza campus, near Piazzale del Verano and the Monumental Cemetery of Verano, the connection between these areas is interrupted by the presence of the Via Tiburtina. This high-speed road connects the district of San Lorenzo to the Tiburtina station, further isolating the ORUR-CUS from the western side of the city center.
The structure consists of two independent volumes, one with a prevailing horizontal development, utilizing a spatial tubular truss beam and load-bearing bare reinforced concrete walls, where the CUS is located. The other asset, with a vertical development, houses the offices of the former ORUR (now DiSCO Lazio), built with the standardization of three steel beam profiles.
These features make the complex an exemplary case for digital documentation and management, combining the study of modern technological solutions with the need to support condition tracking toward reuse (fig. 1-2).

[4] Z. NI, P. ERIKSSON, Y. LIU, M. KARLSSON, S. GONG, *Improving energy efficiency while preserving historic buildings with digital twins and artificial intelligence, IOP Conference Series: Earth and Environmental Science* 863, 2021, 012041. URL: https://doi.org/10.1088/ 1755-1315/863/1/012041. doi:10.1088/1755-1315/863/1/012041. (October '25)
[5] B. TURILLAZZI, G. LEONI, J. GASPARI, M. MASSARI, S. BOULANGER, *Cultural heritage and digital tools: the rock interoperable platform*, International Journal of Environmental Impacts: Management, Mitigation and Recovery 4, 2021, 276–288. doi:10.2495/EI-V4-N3-276-288.
[6] E. DEZEN-KEMPTER, D. L. MEZENCIO, E. D. M. MIRANDA, D. P. DE SÁ, U. DIAS, *Towards a digital twin for heritage interpretation-from hbim to ar visualization,* 2020, URL: http://papers.cumincad.org/cgi- /works/paper/caadria2020_141. (October '25)
[7] M. SINGH, E. FUENMAYOR, E. P. HINCHY, Y. QIAO, N. MURRAY, D. DEVINE, *Digital twin: Origin to future, Applied System Innovation* 4, 2020 doi:10.3390/asi4020036.
[8] A. STAZI, *La sede dell'ORUR-CUS a Roma*, in *L'Industria delle Costruzioni*, n°43, 1974, pp. 3-18, (Progetto: E. Mandolesi).


Figg. 1-2. The ORUR-CUS in Rome.

Excessive heat gain, driven by the metal roofing and the translucent skylight, produces temperatures that are incompatible with safe athletic activity, a condition exacerbated under peak occupancy when the combined presence of spectators and athletes compounds internal loads. In light of these findings, optimizing the lighting and HVAC systems emerges as the most impactful pathway to reduce emissions and improve occupant comfort simultaneously. To operationalize this objective, the project proposes a digital twin, initially focused on the primary weight room and gym area, which enables real-time monitoring of equipment utilization, detection of anomalies, and prompt feedback to building systems. This one-to-one linkage between the physical asset and its virtual counterpart is intended to support data-driven control, continuous commissioning, and informed decision-making across both public and private use patterns.

Within this broader research perspective, the specific aim of the present paper is to assess existing software and services, summarized in the comparative matrix, and identify the environments best suited for implementing the proposed digital twin.

3. FRAMEWORK AND APPLICATION OF THE COMPARATIVE ANALYSIS

3.1. Methodological approach

Given these architectural and urban characteristics, this research adopts a structured evaluation workflow that creates a clear digital record of the ORUR–CUS (fig. 3) and tests lightweight, browser-based viewers on core tasks, such as view, navigate, section, measure, annotate, and share, while keeping the option to attach simple environmental data (e.g., temperature, humidity). The setup relies on portable, widely supported formats, plug-in-free web access on laptops and phones, simple link sharing, and consistent test conditions to keep results comparable. Functional and technical requirements, as interoperability, real-time monitoring, and multi-user collaboration, are further taken into account in order to define the criteria for the tool selection.

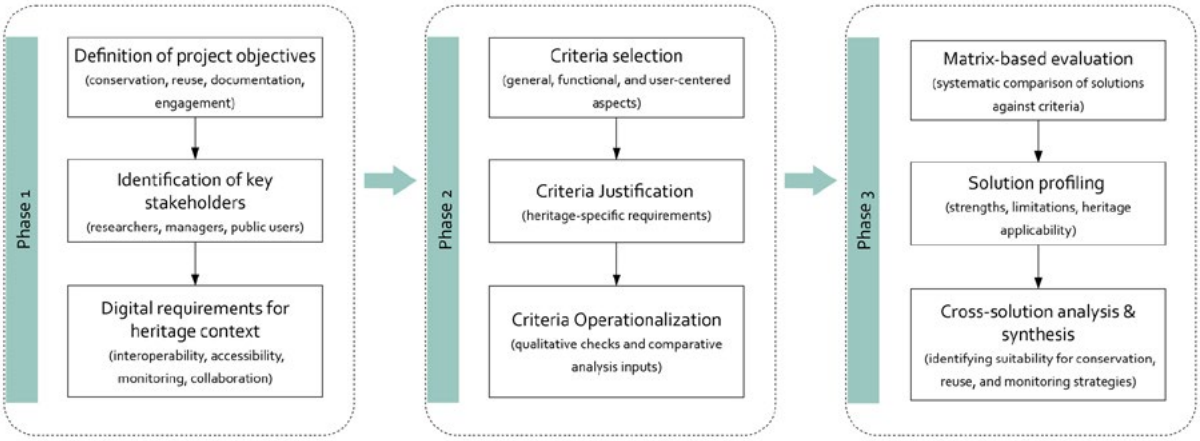

Fig. 3. Three-phase framework for the ORUR–CUS software and services assessment.

Building on Phase 1, seven criteria were chosen to cover the full user journey from first open to collaborative use and, when needed, basic monitoring[9-10]:

- Accessibility: it should be easy to open and use: plug-in-free browser access on desktop and mobile, simple link sharing for view-only access, and a free/education tier for testing.
- Compatibility: it has to read and export widely supported formats for models and point clouds (e.g., RVT, OBJ, FBX, GLTF, E57/LAZ) and exchange tabular data (e.g., CSV/JSON). Preference is given to stable identifiers and basic APIs/SDKs so information can move across tools without lock-in.
- Web-based performance requires the viewer to run via WebGL/WebGPU in a standard browser, load a medium model in a reasonable time, and remain smooth during navigation and sectioning on ordinary laptops and phones. This criterion captures the practical limits of front-end compatibility and back-end performance.
- IoT / real-time monitoring: where available, the tool should ingest simple time-series (e.g., CSV uploads or basic REST/MQTT feeds), bind them to rooms or elements, and provide clear history/threshold views with optional alerts and data export.
- Functionality: core tools needed for the study must be present and reliable: view and navigate, section and measure, walk/orbit, property query, explode/cutaway, notes/markup with images, saved views, and export of annotations.
- Sharing: it has to be straightforward to share the model through a link, ideally without forcing viewers to create an account. Basic permission control (public, invite-only, role levels) and exportable comment/issue records are evaluated.
- Learnability: it should be usable with minimal onboarding. Time-to-first-task (publish → measure → share), number of steps/clicks for common actions, clarity of the UI/help, and error feedback are observed to assign a score.

Once the criteria are defined, the next step regards the application to the case study on the ten selected solutions in order to evaluate the performance.

[9] D. M. BOTÍN-SANABRIA, S. MIHAITA, R. E. PEIMBERT-GARCÍA, M. A. RAMÍREZ-MORENO, R. A. RAMÍREZ-MENDOZA, AND J. DE J. LOZOYA-SANTOS, *"Digital Twin Technology Challenges and Applications: A Comprehensive Review*," Remote Sens., vol. 14, no. 6, 2022, pp. 1–25, doi: 10.3390/rs14061335.

[10] D. JONES, C. SNIDER, A. NASSEHI, J. YON, AND B. HICKS, *"Characterising the Digital Twin: A systematic literature review*," *CIRP J. Manuf. Sci. Technol.*, vol. 29, no. 2019, pp. 36–52, doi: 10.1016/j.cirpj.2020.02.002.

3.2. Results and Discussion

The results of the application can first be summarized as an overview of the solution features (fig. 4).
Dalux, thanks to its simplified graphics, is a high-speed cloud viewer. It features a Revit plug-in that allows for multiple updates to the model, directly replacing the old one. Although it is not open-source software, it offers a free personal plan that allows users to utilize the software to its full potential. It enables project sharing via web links, and it does not allow native integration of IoT products.
Trimble Connect is a cloud coordination platform that integrates with Revit and loads, updates, and displays 3D models on the web extremely quickly, thanks to a plug-in that—unlike other software—is highly customizable. Connect is compatible with almost all 3D formats, including the IFC standard. Even if it is not open source, it offers a free plan. The platform natively integrates IoT products within the model.
Autodesk Viewer is an excellent starting point for understanding how to integrate a Revit model into the cloud, as both are Autodesk software. It does not have a native plug-in in Revit; the user needs to upload the .rvt file directly to the site, which will generate a web visualization of the BIM. It allows sharing of the project link without an Autodesk account and is the only web viewer under consideration capable of rendering 3D views.
Speckle's user experience is unrivalled, with a highly well-designed user interface and graphics. It is the fastest open-source interoperability service (with web viewer) among those reviewed and offers new features such as light and shadow customization. Thanks to its open-source nature, Speckle offers 28 plug-ins that connect it to all major 3D modeling software.
Cesium.js is a geospatial framework designed for digital twins of cities. It offers several features that differ from those of the other software under review, such as placing the model directly in a 3D basemap using the geolocation of the point cloud. Like Speckle, it is open source and based on the same core technology, three.js, a library capable of performing 3D rendering with relatively little computational power.
Autodesk Tandem is the most comprehensive DT operations platform among those under consideration. It is equipped with all the basic features for 3D visualization, is native to IoT devices, and allows the creation of an integrated dashboard with all data, which can be used directly as a front-end user interface. Although it is not open-source, it offers a free plan with essential features.
Fuzor is an excellent 3D renderer. It has proprietary software that must be purchased, with no option to try the program through a free trial or student account.
Twinmotion is built on Unreal Engine, a software capable of creating very fast 3D renders, which is why it is often used for creating 3D games by its parent company, Epic Games.
Azure Digital Twins is a compelling PaaS service for DT graphs and IoT integration. It is not open source, and even the free version requires credit card details, which the user can use to purchase additional computing power or cloud storage space.
Matterport is an innovative capture-hosting service for digital twins. It is based on the creation of digital spaces, captured using cameras sold by Matterport itself, or produced via a 3D scan from the Matterport app on a smartphone. It does not support importing BIM models into a space that has not been scanned using a phone. The software can serve as a basis for BIM creation by importing the digital space into Revit using a plug-in.

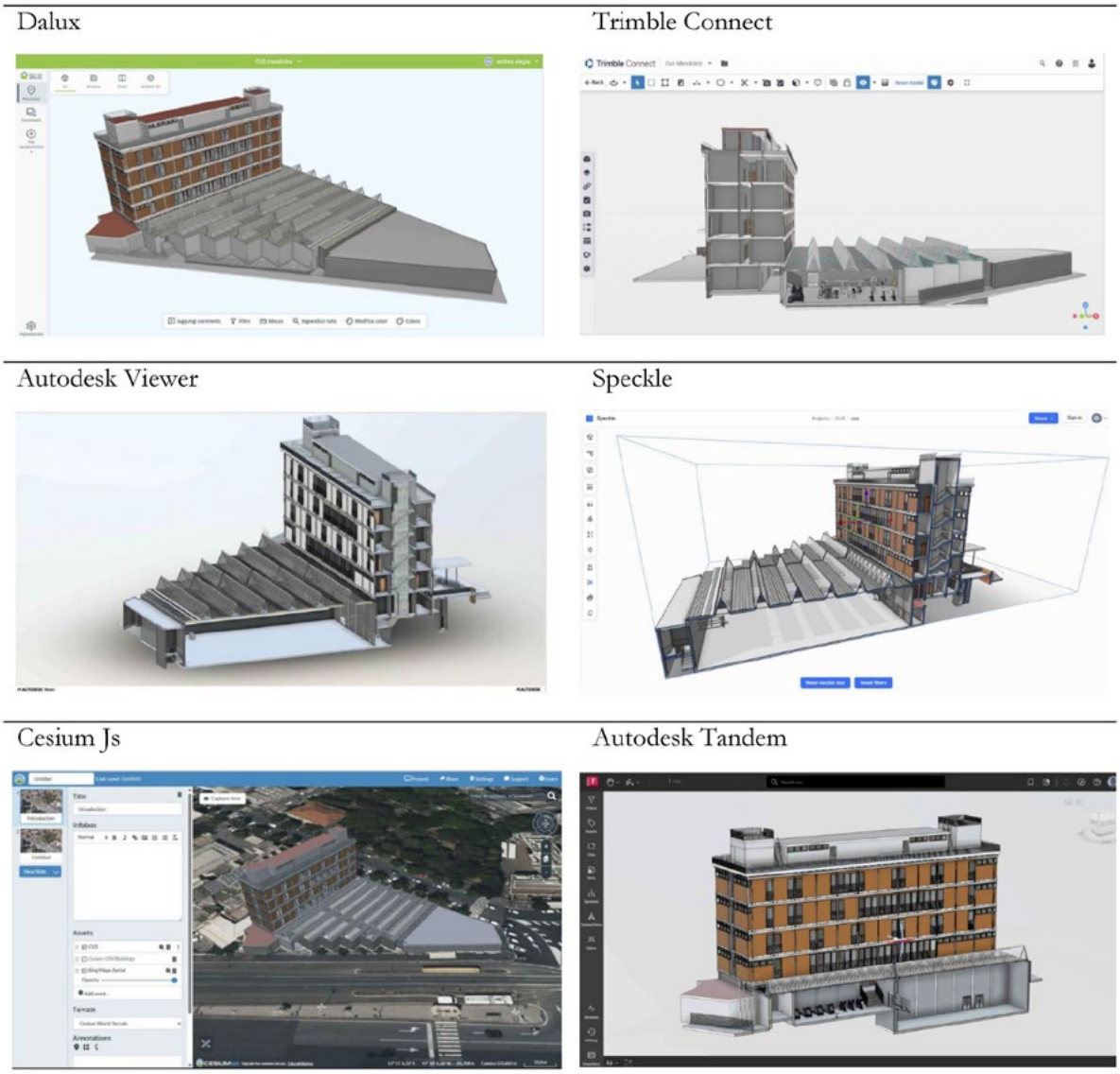

Fig. 4. Comparative visualization of the ORUR-CUS model in a selection of solutions: Dalux, Trimble Connect, Autodesk Viewer, Speckle, Cesium.js, and Autodesk Tandem (clockwise from top left).

Following the solution-by-solution analysis, the comparative matrix (fig. 5) identifies cross-patterns in accessibility, compatibility, and integration. Open-sources options such as Speckle and Cesium.js contrast with proprietary ecosystems, where free tiers are common but with different scopes. Native support for .rvt and IFC from Autodesk Viewer, Trimble Connect, and Fuzor handle both workflows directly or via dedicated plug-ins, while others rely on intermediate formats or constrained pipelines. Web-based access is provided natively by operations-oriented solutions (e.g., Trimble Connect, Autodesk Tandem, Azure Digital Twins, and, where applicable, Fuzor/Cesium), and missing in tools focused on model exchange or rendering.

		Autodesk Viewer	Dalux	Fuzor	Trimble Connect	Speckle (Three.js)	Twin Motion	Cesium Js	Autodesk Tandem	Azure Digital Twins	Matter Port
Accessibility	Open source	X	X	X	X	✓	X	✓	X	X	X
	Free Plan	✓	✓	X	✓	✓	✓	✓	✓	Need credit card info	✓
	Paid Plan	10 €/month	X	110 €/month base	13 €/month base	9 €/month base	505€/year + tax	149 €/month base	3400 $/year base	Account based on credits	11 €/month base
Compatibility	.Rvt	✓	✓	X	✓	✓	✓	✓	✓	X	X
	.Ifc	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Others	Native with all the majors 3D formats: .3ds .fbx .obj .gltf .skp .dwg	A plugin in Revit enables automatic upload in Dalux	A plugin in Rhino 3D enables upload in Fuzor Native with .fbx .skp	A plugin in Revit enables automatic upload in Trimble Connect	A plugin in Revit enables automatic upload in Speckle	A plugin in Revit enables automatic upload in twinmotion	Native with .obj .fbx .gltf	Compatible only with .Rvt and .ifc	Native with gltf	A plugin enables upload from Matterport to Revit
Web based		✓	✓	X	✓	✓	X	✓	✓	✓	✓
IOT		X	X	✓	✓	X	X	✓	✓	✓	✓
Functionality	Measure	✓	✓	X	✓	✓	X	✓	✓	X	✓
	Cut	✓	✓	X	✓	✓	X	X	✓	X	X
	Orbit	✓	✓	X	✓	✓	✓	✓	✓	X	✓
	Digital Walk	✓	Native support of Dalux 360° Camera SiteWalk	X	✓	X	X	X	✓	X	Native support of Matterport 360° Camera Guided Tour
	Explode	✓	X	X	X	✓	X	X	X	X	X
	Notes	✓	✓	X	✓	✓	X	✓	✓	X	✓
Sharing		✓ Web-based Url No Account needed	✓ Web-based Url. Dalux account needed	X	✓ Web-based Url No Account needed	✓ Web-based Url No Account needed	X	✓ Web-based Url No Account needed	✓ Web-based Url Autodesk account needed	X	✓ Web-based Url Matterport account needed
Learnability		4/5	4/5	0/5	5/5	5/5	0/5	2/5	5/5	0/5	3/5

Fig. 5. Comparative matrix of the ten solutions summarizing accessibility, file compatibility (RVT/IFC), web/IoT support, core functions, sharing, and learnability.

From a functional point of view, the majority of the software and services cover essential review actions (measure/orbit/notes), but advanced interactions (section/cut, walk-through, explode) and dashboarding capabilities are concentrated in solutions designed for coordination or operations.

Overall, the matrix positions Trimble Connect and Autodesk Tandem as the most balanced for multi-stakeholder projects (sharing + IoT + lifecycle features), Speckle as the most agile and extensible for open workflows, and Autodesk Viewer as a low-friction baseline for faithful BIM publication.

4. CONCLUSIONS

This research explored and evaluated ten digital-twin solutions of a sports-related industrial architecture, the ORUR-CUS complex in Rome, through a use-case-driven comparison. The results of this analysis are the first step towards implementing real-time tracking of humidity, temperature, illuminance, and air quality. Autodesk Tandem, thanks to its features, will be employed to host the BIM and gather data from the sensors. Afterwards, this data will be processed in the environment and compared to the different thresholds set within the building[11].
For the gym area, the threshold will be set to give a warning for temperature and humidity outside the predefined ranges. This warning will activate an automation or send a notification to the users, allowing them to address the issue and change the real-time parameters in the physical world. As a result, it restores the link between the real model and the digital one.
Ultimately, future work will focus on enhancing comfort and operational oversight in a facility not initially designed to contemporary sustainability standards, with the primary goal of deploying the pilot, validating alert logic and response workflows, and evaluating the long-term impacts on comfort and energy performance.

[11] H. WANG, Y. QIAN, Y. KUANG, *ET AL*. *How occupant positioning systems can be applied to help historic residences manage energy consumption: a case study in China Build*, Environ., 249, 2024, Article 111110,10.1016/j.buildenv.2023.111110

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