Make Osor Great Again: Accessible Archaeology Between Island and Cloud
Naj Osor znova postane velik: dostopna arheologija med otokom in oblakom

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Abstract
Osor, a small settlement, embodies the tension between exceptional archaeological significance and limited contemporary accessibility. Once a key maritime and ecclesiastical centre of the northern Adriatic, it is today marked by demographic decline, infrastructural constraints, and strong tourism seasonality. This article conceptualises accessibility as a multidimensional heritage problem that extends beyond physical access to include interpretation, knowledge circulation, and public engagement. Focusing on digital heritage tools, particularly the concept of a digital twin, it argues that digitally mediated access can transform archaeological research into a distributed educational and cultural infrastructure. Osor is presented as a pilot case for rethinking heritage promotion, interpretation and presentation in small and remote sites, aligning archaeological interpretation with sustainability, innovation, and learning.
Keywords: archaeological heritage, digital heritage, accessibility, digital twin, sustainable tourism

Izvleček
Osor, majhno naselje, ponazarja razkorak med izjemno arheološko vrednostjo in omejeno sodobno dostopnostjo. Nekdanje pomembno pomorsko in cerkveno središče severnega Jadrana danes zaznamujejo demografski upad, infrastrukturne omejitve in izrazita sezonskost turizma. Prispevek obravnava dostopnost kot večplastni dediščinski problem, ki poleg fizičnega dostopa vključuje tudi interpretacijo, diseminacijo znanja in vključevanje javnosti. S poudarkom na digitalnih dediščinskih orodjih, zlasti na konceptu digitalnega dvojnika, pokaže, kako lahko digitalno posredovana dostopnost arheološko znanje preoblikuje v razpršeno izobraževalno in kulturno infrastrukturo. Osor je predstavljen kot pilotni primer za premislek o promociji, interpretaciji in prezentaciji dediščine na majhnih ter oddaljenih najdiščih.
Ključne besede: arheološka dediščina, digitalna dediščina, dostopnost, digitalni dvojnik, trajnostni turizem

Introduction

Osor is a small settlement located at the narrow channel separating the islands of Cres and Lošinj in the northern Adriatic, Croatia. Despite its small area and population, archaeologically and historically it was an important urban site of the eastern Adriatic due to its strategic maritime crossing point that enabled control of navigation routes linking the Kvarner Gulf with the wider Adriatic basin (Doneus et al. 2017, 763–4). In the past, the canal connecting Cres and Lošinj has enabled its development into regional centre of exchange and administration. Today's Osor is far from its historical role and this duality between historical importance and current marginality defines its contemporary state. On the one hand, the town is situated on archaeological remains, ecclesiastical architecture, urban structures, and ritual landscapes. On the other hand, Osor today is characterized by demographic decline, limited economic activity, and strong seasonal

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dependence on tourism concentrated in summer months. As a destination, it remains peripheral in relation to major Croatian tourism hubs, and its heritage visibility outside professional audiences is low. This discrepancy between rich heritage and physical isolation is not unique just to Osor, but it is emphasised due to its insular location and infrastructural issues. Access to Osor is shaped by island mobility infrastructure, seasonal ferry timetables, and climatic factors that affect daily connectivity. These conditions impact the flow of visitors and also the circulation of knowledge, as archaeological research results are largely disseminated through academic publications and exhibitions rather than through integrated public interpretation frameworks.

In this article we will try to show that Osor presents an ideal laboratory for developing new and contemporary models of heritage accessibility that include digital technologies and sustainable tourism principles (Maietti 2023). Instead of proposing activities for the increased physical visitation, we are approaching the issue of accessibility as a multi layered concept that combines physical presence, interpretation, and digital reach. The metaphor used in the title 'between island and cloud' expresses the transition from spatially and informationally limited heritage toward distributed, digitally mediated heritage infrastructures. The concept to 'Make Osor Great Again' is intentionally playful, but analytically serious. It does not propose a return to a historical golden age of urban importance but instead searches for a strategic solution for promotion and use of Osor's archaeological heritage within contemporary cultural, educational, and technological ecosystems. This is grounded in the basic assumptions that archaeological knowledge has limited impact on society if it remains available mostly to specialist circles, that small and remote heritage sites require alternative dissemination models beyond mass tourism and that digital tools enable various forms of heritage access without increasing physical pressure on fragile locations or locations with limited physical accessibility. These assumptions are in line with current European policy frameworks that emphasise sustainability, resilience, and innovation in cultural tourism (Rababeh et al. 2024, 2). They also reflect transformations in heritage studies and practices, where digital mediation is not just a possibility for representation, but it becomes a useful infrastructural layer able to connect research, education, and public engagement (Niccolucci et al. 2022; Hutson et al. 2023; Cassar et al. 2025). Osor has an ideal potential as a pilot site for such an approach based on several factors: the long duration and interdisciplinarity of archaeological research, the clear spatial limits of the historic town, the existence of both material and immaterial heritage assets, and the practical constraints on visitor numbers. These elements make it an exemplary case for testing how archaeological knowledge can be translated into forms of access that are not dependent on physical visit of the site.

Archaeological and Historical Context[1]

Archaeological research shows that Osor's location at the junction of Cres and Lošinj formed the basis for development of long-term strategic importance. Settlement occupation extends from prehistory onward, with increasing complexity during the Bronze and Iron Ages, when maritime exchange intensified across the northern Adriatic (Doneus et al. 2017, 763). Its hinterland and maritime environment formed an integrated landscape. During the Roman period it became a municipium. The construction of the canal separating Cres and Lošinj, whether Roman in origin or later modified, enhanced its position as a maritime gateway. In the early medieval period, Osor had the role of an episcopal seat, with ecclesiastical authority extending across surrounding islands (Pactat et al. 2021, 8). Churches and monastic complexes are material remains that reflect its past role as a religious and political centre (Marić et al. 2014). Vene-

1 For the results of the recent scientific research within the project Osor beyond the myth, consult the remaining articles in this issue.

tian domination and later Habsburg administration reshaped its urban functions, but it is important to note that the gradual shifts in trade routes and geopolitical priorities led to a decline in regional importance. This enables us to interpret Osor as a microcosm of Adriatic history, reflecting transitions from prehistoric networks to Roman imperial structures, from ecclesiastical power to early modern marginalisation. Its urban fabric preserves these layers in compressed form, making the town an exceptional site for interpretation.

Recent archaeological research, especially within the project Osor beyond the myth, has significantly expanded knowledge of Osor's urban and landscape archaeology. New results position Osor not as an isolated town but as the core of a wider archipelagic system involving both terrestrial and maritime components. Material culture from excavations includes ceramics, sculpture, architectural fragments, and everyday objects that reflect both local production and long-distance exchange. These finds are preserved and partially displayed in the Archaeological Collection of Osor. The collection provides an essential interpretive point, linking physical artefacts with urban space and historical narrative. Yet, despite this research richness, public interpretation remains relatively fragmented. Archaeological results are presented through exhibitions, publications, but they lack a unified narrative framework connecting landscape, material culture, and social history. This fragmentation reflects structural issues common to small heritage sites: limited institutional capacity, seasonal staffing, and dependence on tourism seasonal cycles. Besides monuments and artefacts, Osor presents a cultural landscape in which built heritage, natural environment, and ritual practices are intertwined. This landscape dimension is important for understanding Osor's heritage value. Archaeology here is not limited to particular sites but also reflected in spatial relations between town, sea, and hinterland. Therefore, its interpretation can integrate environmental history, mobility, and socio-economic change. It also provides a basis for connecting archaeological interpretation with contemporary challenges such as climate change, sea-level rise, and sustainable land use.

Accessibility as a Heritage Problem

Physical accessibility in Osor is shaped by its insular geography. Although Cres and Lošinj are connected by a bridge, access to the archipelago depends on ferry routes from the mainland and is subject to weather conditions and seasonal fluctuations that affect tourists but also researchers and educators. School groups, for example, face logistical and financial barriers to organising visits, particularly outside the peak tourist season. In general, physical accessibility to archaeological sites is a growing concern, especially for those with disabilities (Cantarellas 2023, 519–22). Historic urban sites often present physical barriers, and archaeological areas can be left as islands of ruins, fenced and inaccessible (Ribeiro et al. 2012, 4149; La Mantia 2024, 156). The transport (in)connectivity, biodiversity, cultural heritage, and carrying capacity are all crucial elements to consider when developing strategic plans for areas with specific characteristics (Cecić 2023, 87–96). Physical accessibility also intersects with infrastructure limitations. Osor does not have accommodation facilities and transport infrastructure to host larger number of visitors. While this protects the integrity of the historic town, it also limits the scale of heritage outreach through traditional tourism models. These conditions generate a paradox: Osor's archaeological and historical value is high, but its practical accessibility is low. The consequence is a communication gap between research production and public promotion. Knowledge circulates within academic networks but has no strategy to reach broader audiences.

Accessibility is not only spatial but also epistemic. Even when visitors reach Osor, interpretation depends heavily on their prior knowledge and on limited material. Archaeological collection and heritage signage provide information, but rely on static display formats that are

not able to fully present and explain the complexity of archaeological processes or historical change, and the upgrade and inclusion of new research insights is slow. This informational problem reflects a wider challenge in archaeology: translating research into acceptable forms to non-specialist publics. Without mediation, archaeological remains appear as fragments detached from everyday experience, so interpretation becomes interface between scientific knowledge and social meaning. Digital interpretation tools, such as AR, 3D reconstructions, and interactive narratives, address this gap by embedding explanation directly into spatial experience (De Bonis et al. 2022, 92–101). They also enable multilingual access, adaptability to different age groups, and integration with educational curricula. The application of virtual reality in the interpretation of cultural heritage is at an exceptionally high level worldwide, while in Croatia, it is still in development (Pleše 2024, 16–7). Simply including scientific information in digital technology is not enough. It is necessary to develop diverse types of digital tools and interpretation levels to make content more accessible and engaging for users, encouraging learning and exploration. Finally, accessibility raises several questions: who controls heritage narratives, who participates in interpretation, and who benefits from tourism. A digitally based accessibility strategy requires institutional integration: shared data standards, cooperative content development, and joint responsibility for maintenance and updating. Such integration aligns with contemporary models of participatory heritage management, where knowledge production and dissemination are collaborative (Čadovska 2012, 23).

Osor shows the contradiction faced by many small heritage towns: exceptional historical depth combined with limited physical reach. Archaeological research depicts the town's importance as a maritime and cultural node in the northern Adriatic, yet these findings remain unevenly translated for the public. Accessibility, therefore, becomes the central analytical problem, as access to place, knowledge, narratives, and learning opportunities. In the following parts of this article we will show that this problem can be addressed through a strategic combination of tourism policy, cultural programming, and digital heritage tools, especially the development of a digital twin of Osor, that can transform and translate archaeological research data into an educational infrastructure capable of extending Osor's reach from the island to the cloud.

Tourism and Policy Frameworks

The development of heritage tourism in Osor must be contextualised within Croatia's broader tourism and cultural policy frameworks, which increasingly prioritise sustainability, diversification, and cultural value. The Sustainable Tourism Development Strategy of the Republic of Croatia to 2030 establishes sustainability as the guiding principle for tourism growth, emphasizing quality over quantity, environmental responsibility, and integration with local communities (Strategija razvoja održivog turizma do 2030. godine 2023). This strategy explicitly identifies cultural heritage as a resource for creating distinctive and resilient destinations, particularly outside major urban and resort centres (Cukrov 2010, 106; Nikolić 2021, 32). The importance of sustainable heritage protection is recognized in international policies (UNESCO, ICOMOS), necessitating national and regional conservation and management plans (Rababeh, et al. 2024, 2). For small heritage towns such as Osor this is particularly relevant. Traditional mass tourism models are neither feasible nor desirable given the town's spatial constraints and fragile archaeological fabric. Instead, the national strategy's emphasis on thematic tourism, digital innovation, and education-based experiences provides a conceptual framework within which Osor can reposition itself as a site of knowledge, learning, and cultural encounter rather than just as a sightseeing destination. The development of archaeological tourism requires the involvement of the local population and educational ac-

tivities for valorisation, as well as their participation in heritage management (Cindrić 2021, 67). The Croatian Tourism Act (Zakon o turizmu 2023) and related policy instruments also stress the importance of destination management and stakeholder coordination, suggesting integrated planning between tourism boards, municipalities, cultural institutions, and civil society. In this sense, Osor's heritage cannot be treated in isolation but must be a part of coordinated governance structures that align tourism promotion with heritage conservation and dissemination of scientific research results.

At the regional scale, the Tourism Development Strategy for Cres and Lošinj (Horwath HTL 2021) articulates a vision of the archipelago as a sustainable, high-quality destination rooted in nature, health tourism, and cultural identity The document highlights the need to reduce seasonality, strengthen thematic products, and improve the interpretation of cultural resources (Čorak 2013, 22; Rudančić and Ćućić 2019, 7–8; Nikolić 2021, 31). Within this, Osor has a role as a historical and archaeological point and not a resort-oriented settlement. Its potential is in complementing beach destinations through heritage-based experiences. The strategy recognises the importance of small towns and villages as carriers of authenticity and local character, suggesting that targeted investment in interpretation and infrastructure can generate added value without large-scale physical development. Efforts in Mali Lošinj demonstrate how sustainability can be translated into tangible advantages, including preserving the environment, fostering the local economy, and safeguarding cultural identity, despite challenges like pronounced seasonality. Regional planning documents further emphasise the role of digital technologies in destination branding and visitor engagement. Digital platforms are identified as tools for storytelling, itinerary planning, and educational outreach, enabling destinations to communicate complex narratives and to reach audiences beyond those physically present (Floričić et al. 2023, 73). For Osor, this orientation aligns directly with the need to overcome insularity through mediated forms of access.

Cultural heritage governance in Croatia operates across multiple institutional levels, involving the Ministry of Culture and Media, regional conservation offices, museums, and local authorities. In Osor, this governance structure intersects with tourism institutions such as the Mali Lošinj Tourist Board and regional destination management bodies. While this multi-level system provides legal protection for monuments and archaeological sites, it can also lead to fragmentation in interpretation and promotion. The challenge is in bridging the heritage protection and tourism use. Archaeological sites are subject to strict conservation rules, which can limit physical access and development. On the other hand, tourism seeks visibility, narrative, and visitor engagement. Digital heritage tools offer a mediating layer between these elements by enabling interpretation without physical intervention in sensitive areas. The integration of digital strategies into tourism governance would be a technical innovation but also an institutional one, as it requires shared data infrastructures, collaborative content production, and long-term maintenance commitments. We must warn that Osor's development as a digitally accessible heritage site depends as much on governance capacity as on technological feasibility.

The Osor Musical Evenings represent a key contemporary practice through which Osor's heritage is reactivated and reinterpreted. By situating classical music performances within spaces, the festival shows possibilities for the adaptive reuse of archaeologically and historically significant structures. In this context, music operates as an intangible heritage practice that animates material remains, producing meanings that extend beyond scholarly interpretation and embed archaeology within lived, ritualised experience (Pleše 2024, 31). Despite its strong cultural and symbolic impact, the festival remains concentrated in the summer season, reflecting broader Adriatic tourism patterns and limiting its contribution to sustainable heritage manage-

ment. Proposals to expand the festival through educational, research-oriented, and interpretive programmes have been emphasised as a means of strengthening Osor's role as a year-round archaeological and cultural site (Čorak 2013, 23). In this sense, the Osor Musical Evenings function not only as a cultural event but as a form of archaeological mediation, contributing to place branding grounded in the past and local legitimacy, which must resonate with the community before achieving wider recognition (Cukrov 2010, 106).

Digital Heritage Tools

Augmented reality and virtual reality have become popular tools in heritage interpretation. Users can visualise lost structures, explore inaccessible areas, and engage with historical narratives in immersive ways (Quattrini et al. 2016, 383; Fazio et al. 2019, 511; De Bonis et al. 2022, 92). In archaeological contexts, AR overlays can superimpose reconstructions onto present-day ruins, and VR environments can simulate entire landscapes and urban spaces across time periods (Kingsland 2023, 63; Rodríguez-Garcia et al. 2024). These technologies are particularly useful for making remote, fragile, or physically inaccessible sites available to a wider audience, including underwater archaeological sites (Haydar et al. 2011, 312; Bruno et al. 2017, 1). In Osor, AR and VR have already been implemented in the form of the Osorski vremeplov, which allows visitors to experience reconstructed views of twelve locations within the historic town through VR headsets (Pleše 2024, 31). This initiative represents an important proof of concept, demonstrating that digital reconstruction can enhance visitor understanding without requiring extensive physical interventions in protected areas. However, current implementations remain site bound. A more systematic approach would integrate AR and VR into a broader interpretive ecosystem, linking them with archaeological databases, educational content, and tourism platforms. Such integration would transform isolated digital experiences into components of a comprehensive digital heritage infrastructure. The increased accessibility and interactivity of these digital displays can strengthen the connection between heritage and individuals, which contributes to long-term preservation efforts (Pleše 2024, 23).

Serious games are designed to combine entertainment with learning, making them very useful for heritage education (Mortara et al. 2014, 319; DaCosta and Kinsell 2022). They can simulate excavationa, trade networks, or settlement dynamics, and allow users to experiment with historical scenarios. This participatory dimension changes and shifts heritage interpretation from passive reception to active exploration, providing immediate feedback (Hulin 2021, 2; García et al. 2024; Thise et al. 2025, 318). They can help disseminate archaeological findings and methodologies, encouraging players to engage with reconstructed historical settings (Kingsland 2023, 63; Murtas and Lombardo 2024, 1). For Osor, serious games could model Bronze and Iron Age settlemens, maritime trade routes, or urban transformations. Players could decide about resource management, defence, or ritual practice, and this way learn about the logics of past communities. Such simulations would not replace scientific interpretation but translate it into experiences. Serious games also support inclusion of younger audiences and using different learning styles. When integrated in education, they help develop heritage literacy, historical empathy, and perception of archaeology (Kilis et al. 2025, 1).

Among participatory digital tools, Minecraft Education Edition has bacome effective platform for heritage interpretation and teaching. Its block-based environment allows users to reconstruct historical sites collaboratively, basedon archaeological evidence and pedagogical objectives (Fernández and Medeiros 2019; Hobbs et al. 2023, 138; Krappala et al. 2024). Heritage projects across Europe have used Minecraft to model castles, towns, and landscapes, integrating history, geography, and environmental studies. In Osor, Minecraft could be used to recreate

the different phases, enabling students to explore spatial organisation, building techniques, and environmental relationships (Mørch et al. 2021). Such reconstructions could be linked to curricular topics in history and geography, integrating Osor in broader narratives of Mediterranean and island societies. The pedagogical potential of Minecraft is its capacity to merge play with structured learning. Teachers can design tasks that require students to interpret archaeological data, compare reconstructions with modern layouts, and reflect on processes of change over time (Cassone et al. 2019, 28; Mørch et al. 2021; Steier and Davidsen 2021, 198; Krappala et al. 2024).

AR, VR, serious games, and Minecraft should not be treated as isolated innovations but as interconnected elements of a digital heritage ecosystem. Each tool is made for different audiences and uses: AR enhances on-site experience, VR enables remote exploration, serious games support experiential learning, and Minecraft fosters collaborative construction of knowledge. For Osor, integration means that all these tools use a common data from archaeological research results, spatial models, and interpretation. This can be conceptualised as a digital twin of Osor's archaeological landscape, serving as the basis for diverse applications. Such a digital twin would ensure consistency across platforms and enable updates as new research emerges.

Digital Twins in Archaeology

The concept of the digital twin originates in engineering and manufacturing, where it denotes a dynamic digital replica of a physical system that is continuously updated through data exchange. In contrast to static 3D models, digital twins are characterised by their capacity to integrate heterogeneous data streams, represent temporal change, and support simulation and scenario testing (Liu and Wang 2024, 1019; Kleijn et al. 2024). When applied to cultural heritage and archaeology the term is referring to multi-layered digital representations of archaeological objects, sites, anfd landscapes that combine geometry, metadata, interpretive narratives, and analytical functions (Niccolucci et al. 2022; Cassar et al. 2025). In archaeological practice, early digital representations focused on photogrammetric or laser-scanned 3D models of artefacts and monuments. These models served for documentation and visualisation but remained isolated from broader interpretive systems. The digital twin extends this approach by including models that links spatial geometry with stratigraphy, material culture, environmental data, and historical interpretation (Parrinello and Picchio 2023). This allows dynamic updating and interactive connection of the digital replica with the physical object (Parsinejad et al. 2021, 72).

Digital twins are understood as infrastructures for archaeological knowledge, rather than merely as visual outputs (Cassar et al. 2025). They integrate excavation records, geophysical survey data, environmental reconstructions, and architectural hypotheses into a single navigable environment. Such environments support public dissemination and scientific analysis (Liu et al. 2024). At the architectural scale, digital twins of individual monuments allow the modelling of construction phases, structural behaviour, and conservation interventions (Hutson et al. 2023). What distinguishes these applications from earlier digital heritage tools is their emphasis on process, as digital twins are designed to be updated as new data becomes available, preserving the research lifecycle within the model itself. Digital twins have also been adopted as tools for public archaeology, expanding access to sites that are remote, fragile, or partially inaccessible. By hosting digital twins on web platforms or integrating them into AR/VR applications, heritage institutions can offer immersive experiences without exposing physical remains to mass visitation (Bertoldi 2021, 1444; Parsinejad et al. 2021, 72; Banfi et al. 2023, 176). These platforms integrate multimedia to enhance visitors' experiences and dissemination (Liu et al. 2024). Such uses align with broader trends in open science and open heritage, where data sharing and public engagement are considered integral to re-

search practice. Digital twins enable a form of distributed heritage presence, where the archaeological site exists simultaneously in situ and online (Niccolucci et al. 2022). This dual existence supports both conservation goals and access to knowledge. However, public-facing digital twins also raise ethical and interpretive questions. Who controls the narrative in the model? How are local perspectives represented? What commercial uses are permitted? These questions show the need for governance frameworks that treat digital twins as cultural assets rather than purely technical tools.

The Digital Twin of Osor

Osor's archaeological richness, spatial compactness, and logistical constraints make it an ideal candidate for the development of a digital twin. The town's historic core can be modelled at high resolution, while its surrounding landscape can be represented through GIS layers and terrain models. Archaeological data from excavations and surveys would provide the empirical basis for reconstruction, while historical sources supply contextual narratives. The central rationale for a digital twin of Osor would be accessibility (Bertoldi 2021, 1444). A digital twin would enable access to Osor's past for audiences who cannot travel to the island, including school groups, international learners, and persons with mobility impairments. It also enables off-season engagement. Furthermore, a digital twin would allow Osor's archaeological data to be mobilised across multiple platforms: AR applications, VR experiences in museums, serious games, and Minecraft Education modules. This way, the digital twin would function as a backbone infrastructure that ensures consistency and scientific integrity across all digital outputs (Niccolucci et al. 2022; Shimoda et al. 2025, 1360). Based on comparative cases, digital twin of Osor should consist of geometric model (3D model of the town and its landscape), chronological layers (separate reconstructions for major periods), data annotations (excavation units, bibliography, radiocarbon dates), uncertainty encoding (excavated remains, hypothetical reconstructions), narrative modules (trade, religion, daily life, and similar).

In educational contexts, the digital twin of Osor would be used as a learning environment (Kilis et al. 2025, 1; Shimoda et al. 2025, 1360). Students would navigate the model, compare historical phases, and engage in tasks. The digital twin supports constructivist pedagogies by allowing learners to manipulate data and test hypotheses. When linked with Minecraft Education, the twin can provide the scientific reference layer for student-built reconstructions. Minecraft worlds can thus be based in archaeological reality, while still allowing creative exploration (Mørch et al. 2021; Krappala et al. 2024). Such an approach aligns with interdisciplinary curricula that integrate history, geography, environmental studies, and digital literacy. Osor would become a case study for understanding island societies, trade networks, and human-environment interaction in the northern Adriatic. On-site AR experiences can draw directly from the twin, overlaying reconstructions onto present-day ruins. VR applications can transport users to different periods of Osor's history (De Bonis et al. 2022, 92). Because all applications draw on the same underlying twin, updates in archaeological interpretation can propagate across platforms. This would ensure to avoid the fragmentation that occurs when each digital product is developed independently. It would also ensure that public representations remain aligned with current and updated scientific research.

Developing and maintaining a digital twin requires long-term institutional collaboration that clearly defines responsibilities for data curation, content updates, and user access. Ideally, this framework would involve collaboration between academic institutions, museums, local authorities, and tourism boards. From a sustainability perspective, the digital twin contributes to conservation by reducing pressure on physical remains. It also supports economic sustainability by generating digital heritage products that can be used in education, tourism, and cultural programming (Maietti 2023).

Conclusion

Osor shares common characteristics with many heritage sites: historical depth combined with limited contemporary reach. Archaeological research has revealed its importance as a maritime and cultural point in the northern Adriatic, yet this knowledge remains limited to the wider public. The proposed case of Osor sows a transformation in archaeological practice: from site-centred preservation toward networked heritage infrastructures. Traditional heritage management has focused on protecting physical remains and regulating visitor access. While these objectives remain neccessary, they must be complemented by strategies that enable the circulation of knowledge and digital twins offer a possibility to develop this kind of system (Liu and Wang 2024, 1019). They include archaeological data within platforms that are accessible, updateable, and pedagogically usable. In doing so, they transform archaeology from localised scientific research into a distributed educational resource. However, digital access should not replace physical experience but enrich it, ensuring that virtual experiences remain connected with material remains.

The Osor case suggests that small heritage towns can act as testbeds for innovative models because their scale enables manageable experimentation. Rather than competing with large urban heritage centres, they can specialise in integrative, research-based digital interpretation. We have tried to offer the solution in redefining access through digital mediation. By integrating tourism strategies and digital heritage tools, Osor can become a site of learning and interpretation. The concept of a digital twin of Osor represents the basis for this kind of approach. As an infrastructure linking research, education, and public engagement, it enables consistency, transparency, and scalability across AR, VR, serious games, and Minecraft-based learning environments (Kilis et al. 2025, 1). It also aligns with sustainability principles by reducing physical pressure on the site. 'Make Osor Great Again' thus becomes a call for smart presence: from island to cloud, from excavation to education, from isolation to connection. In this model, Osor's past is not just preserved but activated as a resource for contemporary understanding, learning and use of the new knowledge for future resilience.

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References

Banfi, F., E. Dellu, C. Stanga, et al. 2023. 'Representing Intangible Cultural Heritage of Humanity: From the Deep Abyss of the Past to Digital Twin and XR of the Neanderthal Man and Lamalunga Cave (Altamura, Apulia).' *International Archives of the Photogrammetry, Remote Sensing and* Spatial Information Sciences 48-M-2:171–8.

Bertoldi, S. 2021. 'C.A.P.I. Project in the Making: 3D Applications at Poggio Imperiale between Materiality and Virtual Reality (Poggibonsi, Italy).' *Open Archaeology* 7 (1): 1444–60.

Bruno, F., A. Lagudi, G. Ritacco, et al. 2017. 'Development and Integration of Digital Technologies Addressed to Raise Awareness and Access to European Underwater Cultural Heritage: An Overview of the H2020 i-MARECULTURE Project.' In *OCEANS 2017 – Aberdeen*. IEEE.

Čadovska, I. 2012. 'Funkcionalnost hrvatskih baštinskih digitalnih zbirki.' MA thesis, Sveučilište J. J. Strossmayera u Osijeku.

Cantarellas, M. À. S. 2023. 'Archaeological Heritage for All: A Heritage Site Accessibility Tool (HSAT) for Open-Air Archaeological Sites.' *Archaeologies* 19 (3): 515–36.

Cassar, A., D. Baker, and M. Ioannides. 2025. 'From Digital Twin to Memory Twin: A Holistic Framework for Cultural Heritage Documentation, Interpretation, and Adaptive Reuse.' *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* 48-M-9:203–10.

Cassone, L., M. Romero, T. Viéville, C. De Smet, and M. Ndiaye. 2019. *Proceedings of the ANR #CreaMaker Workshop: Co-Creativity, Robotics and Maker Education*. HAL. https://hal.science/hal-02093488v1.

Cecić, M. 2023. *Turizam na otocima.* Institute for Tourism.

Cindrić, A. 2021. 'Modeli valorizacije arheološke baštine Istre.' MA thesis, Sveučilište Jurja Dobrile u Puli.

Čorak, S. 2013. *Program razvoja održivog turizma Grada Mali Lošinj.* Grad Mali Lošinj.

Cukrov, T. 2010. 'U potrazi za turistima: međunarodni dan muzeja 2009.' *Informatica Museologica* 40 (1–2): 103–8.

DaCosta, B., and C. Kinsell. 2022. 'Serious Games in Cultural Heritage: A Review of Practices and Considerations in the Design of Location-Based Games.' *Education Sciences* 13 (1): 47.

De Bonis, M., H. N. Nguyen, and P. Bourdot. 2022. 'A Literature Review of User Studies in Extended Reality Applications for Archaeology.' In *2022 IEEE International Symposium on Mixed and Augmented Reality (ISMAR), Singapore, 2022: Conference Proceedings*. IEEE.

Doneus, N., M. Doneus, and Z. Ettinger-Starčić. 2017. 'The Ancient City of Osor, Northern Adriatic, in Integrated Archaeological Prospection.' *Hortus Artium Medievalium* 23 (2): 761–74.

Fazio, L., M. Lo Brutto, and G. Dardanelli. 2019. 'Survey and Virtual Reconstruction of Ancient Roman Floors in an Archaeological Context.' *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* 42-2/W11:511–518.

Fernández, J. G., and L. Medeiros. 2019. 'Cultural Heritage and Communication through Simulation Videogames – A Validation of Minecraft.' *Heritage* 2 (3): 2262–78.

Floričić, T., I. Šker, and H. Maras Benassi. 2023. 'Enhancing Digital Promotion of Cultural Attractions: Assessing Websites, Online Marketing Tools and Smart Technologies.' *Business Systems Research Journal* 14 (1): 72–88.

García, D. C., M. P. Cáceres Reche, M. de la E. Cambil Hernández, and M. E. Lorenzo-Martín. 2024. 'Digital Game-Based Heritage Education: Analyzing the Potential of Heritage-Based Video Games.' *Education Sciences* 14 (4): 396.

Horwath HTL. 2021. *Strategija razvoja turizma: Mali Lošinj i Cres*. Grad Mali Lošinj.

Haydar, M., D. Roussel, M. Maïdi, S. Otmane, and M. Mallem. 2011. 'Virtual and Augmented Reality for Cultural Computing and Heritage: A Case Study of Virtual Exploration of Underwater Archaeological Sites.' *Virtual Reality* 15 (4): 311–27.

Hobbs, L., S. Behenna, S. Bentley, and C. J. Stevens. 2023. 'Near and Far: Engaging Students with Place through Minecraft.' *Geography* 108 (3): 134–41.

Hulin, T. 2021. 'Co-design et scénarisation interactive d'une expérience ludique.' *Revue de recherches francophones en sciences de l'information et de la communication* 10. https://refsicom.org/996.

Hutson, J., J. Weber, and A. Russo. 2023. 'Digital Twins and Cultural Heritage Preservation: A Case Study of Best Practices and Reproducibility in Chiesa dei SS Apostoli e Biagio.' Preprint, Research Square. https://www.researchsquare.com/article/rs-2429775/v1.

Kilis, N., E. Martinopoulou, G. Terzoglou, et al. 2025. 'AI Tools for Generating Digital Heritage Twins Enhancing Storytelling in Educational Games.' *Digital Applications in Archaeology and Cultural Heritage* 36:e00451.

Kingsland, K. 2023. 'Archaeogaming and the Re-Use of Digital Archaeological Materials: Generating Serious Games for the Villas

of Roman Sicily.' PhD diss., University of South Florida.
Kleijn, M. de, K. Clevis, J. García González, et al. 2024. 'Art and Archaeology in an Interactive Time-Traveling Online and Museum Experience: A Case Study on the Via Appia Antica.' *Digital Applications in Archaeology and Cultural Heritage* 33:e00342.
Krappala, K., L. Kemppinen, and E. Kemppinen. 2024. 'Achievers, Explorers, Wanderers, and Intellectuals: Educational Interaction in a Minecraft Open-World Action-Adventure Game.' *Computers and Education Open* 6:100172.
La Mantia, C. 2024. 'The Accessibility of Archaeological Areas in Urban Contexts: The Valorisation of the Archaeological Areas of San Giorgio and Castello San Pietro in the Wake of the I-Access Project.' In *Conservation of Architectural Heritage (CAH): Developing Sustainable Practices,* edited by M. L. Germanà, N. Akagawa, A. Versaci, and N. Cavalagli. Springer.
Liu, W., M. Lu, Y. Chen, and K. Yan. 2024. 'Digital Twin Applications in an Archaeological Site: A Virtual Reconstruction of the Pishan Site, Zhejiang, China.' *Journal of Chinese Architecture and Urbanism* 6 (1): 1735.
Liu, Z., and J. Wang. 2024. 'Protection and Utilization of Historical Sites Using Digital Twins.' *Buildings* 14 (4): 1019.
Maietti, F. 2023. 'Heritage Enhancement Through Digital Tools for Sustainable Fruition – A Conceptual Framework.' *Sustainability* 15 (15): 11799.
Marić, I., S. Bully, M. Jurković, and M. Čaušević-Bully. 2014. 'Le monastère Saint-Pierre d'Osor (île de Cres): huitième campagne d'études archéologiques.' *Hortus Artium Medievalium* 20 (2): 463–76.
Mørch, A. I., C. S. Eielsen, and L. Mifsud. 2021. 'Using Minecraft to Reconstruct and Roleplay Local History: Intersubjectivity, Temporality, and Tension.' In *Proceedings of the 14th International Conference on Computer-Supported Collaborative Learning - CSCL 2021,* edited by C. E. Hmelo-Silver, B. De Wever and J. Oshima. International Society of the Learning Sciences.
Mortara, M., C. E. Catalano, F. Bellotti, G. Fiucci, M. Houry-Panchetti, and P. Petridis. 2014. 'Learning Cultural Heritage by Serious Games.' *Journal of Cultural Heritage* 15 (3): 318–25.
Murtas, V., and V. Lombardo. 2024. 'Deeply Digging in Serious Games for Archaeology.' Paper presented at the 2024IEEE Gaming, Entertainment, and Media Conference (GEM), Turin, Italy. https://doi.org/10.1109/GEM61861.2024.10585660.
Niccolucci, F., A. Felicetti, and S. Hermon. 2022. 'Populating the Digital Space for Cultural Heritage with Heritage Digital Twins.' *Data* 7 (8): 105.
Nikolić, S. 2021. 'Analiza i mogućnosti unapređenja turističke promocije kvarnerskih otoka.' MA thesis, Sveučilište VERN.
Pactat, I., M. Čaušević-Bully, S. Bully, et al. 2021. 'Origines et usages du verre issu de quelques sites ecclésiaux et monastiques tardo-antiques et haut médiévaux du littoral nord croate.' In *Il Vetro in Transizione (IV-XII SECOLO): produzione e commercio in Italia meridionale e nell'Adriatico,* edited by A. Coscarella, E. Neri, and G. Noyé. Themata 2. Edipuglia.
Parrinello, S., and F. Picchio. 2023. 'Digital Strategies to Enhance Cultural Heritage Routes: From Integrated Survey to Digital Twins of Different European Architectural Scenarios.' *Drones* 7 (9): 576.
Parsinejad, H., I. Choi, and M. Yari. 2021. 'Production of Iranian Architectural Assets for Representation in Museums: Theme of Museum-Based Digital Twin.' *Body, Space & Technology* 20 (1): 61–74.
Pleše, V. 2024. *Primjena virtualne stvarnosti u interpretaciji kulturne baštine u Hrvatskoj.* MA thesis, University of Zagreb.
Quattrini, R., R. Pierdicca, E. Frontoni, and R. Barcaglioni. 2016. 'Virtual Reconstruction of Lost Architectures: From the TLS Survey to AR Visualization.' *The International Archives of the Photogrammetry, Remote*

Sensing and Spatial Information Sciences 41-B5: 377–81.
Rababeh, S., R. A. Hanaqtah, and S. Abu-Khafajah. 2024. 'Leveraging Digitized Heritage Technologies for Smart Management: Heritage Safeguarding and Interpretation Framework.' *Heritage* 7 (12): 6891–915.
Ribeiro, G. S., L. B. Martins, and C. M. G. Monteiro. 2012. 'Methodological Proceedings to Evaluate the Physical Accessibility in Urban Historic Sites.' *Work: A Journal of Prevention, Assessment & Rehabilitation* 41 (S1): 4149–56.
Rodríguez-Garcia, B., H. Guillén-Sanz, D. Checa, and A. Bustillo. 2024. 'A Systematic Review of Virtual 3D Reconstructions of Cultural Heritage in Immersive Virtual Reality.' *Multimedia Tools and Applications* 83:89743–93.
Rudančić, A., and D. Ćućić. 2019. 'Strategy as an Instrument of Sustainable Development of the Croatian Islands.' *Interdisciplinary Management Research* 15:979–97.
Shimoda, I., S. Im, T. Oishi, R. Nakamura, L. Kajiwara, and W. Chen. 2025. 'Safeguarding Banteay Chhmar Through Digital Twins: Integrated Approaches for Research, Management, and Conservation.' *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* 48-M-9-2025:1357–64.
Steier, R., and J. G. Davidsen. 2021. 'Adapting Interaction Analysis to CSCL: A Systematic Review.' In *Proceedings of the 14th International Conference on Computer-Supported Collaborative Learning (CSCL 2021),* edited by C. E. Hmelo-Silver, B. De Wever, and J. Oshima. International Society of the Learning Sciences .
Strategija razvoja održivog turizma do 2030. godine. 2023. *Narodne novine,* no. 2. https://narodne-novine.nn.hr/clanci/sluzbeni/full/2023_01_2_18.html.
Thise, A., D. Laboury, and P. Hallot. 2025. 'Video Games as a Tool for Heritage Mediation, Application on the Monument of Sennefer in the Theban Necropolis, Egypt.' *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences* 10-M-2-2025:317–25.
Zakon o turizmu. 2023. *Narodne novine,* no. 156. https://narodnenovine.nn.hr/clanci/sluzbeni/full/2023_12_156_2382.html.

Summary

This article examines Osor, a small settlement on the islands of Cres and Lošinj, as a case study for rethinking archaeological accessibility in contexts characterised by high heritage value and limited physical reach. Archaeological and historical research has demonstrated that Osor played a strategically important role in the northern Adriatic from prehistory through the Roman and early medieval periods, functioning as a maritime gateway, administrative centre, and episcopal seat. Today, however, Osor is marked by demographic decline, infrastructural constraints, and strong dependence on seasonal tourism, which together limit both visitor access and broader public engagement with archaeological knowledge.

The article approaches accessibility as a multidimensional heritage problem that extends beyond physical access to include the circulation of knowledge, interpretation, education, and participation. While Osor's insular location and fragile archaeological fabric make mass tourism neither feasible nor desirable, these same constraints position the town as an ideal testing ground for alternative, digitally mediated models of heritage access. Archaeological research in Osor is rich and interdisciplinary, yet its results are primarily disseminated through academic channels and fragmented exhibitions, leaving a gap between research production and public interpretation.

Within this framework, the article situates Osor in relation to Croatian national and regional tourism and cultural policy, which increasingly emphasise sustainability, thematic tourism, and digital innovation. Cultural practices such as the Osor Musical Evenings are examined as examples of how intangible heritage can activate archaeological and historical spaces, while also revealing the limitations of seasonally concentrated cultural programming. The analysis shows that heritage-based

development in Osor must prioritise quality, interpretation, and learning rather than visitor volume.

The core proposal of the article is the development of a digital twin of Osor as an infrastructural solution to accessibility. Conceptualised as a dynamic, multi-layered digital representation of the town's archaeological landscape, the digital twin would integrate spatial models, excavation data, historical interpretation, and narrative content. It would function as a backbone for diverse digital applications, including augmented and virtual reality, serious games, and educational platforms such as Minecraft, ensuring scientific consistency and adaptability over time. By enabling access independent of physical presence, the digital twin would extend Osor's archaeological knowledge 'from island to cloud', supporting education, public engagement, and sustainable heritage management without increasing pressure on the site itself.

The article concludes that small and remote heritage towns like Osor can serve as laboratories for innovative heritage models. By integrating archaeological research, digital technologies, and sustainable tourism strategies, Osor demonstrates how archaeological knowledge can be transformed into a distributed cultural and educational resource, reinforcing both heritage protection and contemporary relevance.

Povzetek

Prispevek obravnava Osor, majhno naselje na otokih Cres in Lošinj, kot študijo primera za premislek o dostopnosti arheološke dediščine v okoljih z izjemno dediščinsko vrednostjo in omejenim fizičnim dosegom. Arheološke in zgodovinske raziskave kažejo, da je imel Osor od prazgodovine do rimskega in zgodnjesrednjeveškega obdobja v severnem Jadranu strateško vlogo kot pomorsko vozlišče, upravno središče in škofijski sedež. Danes pa se sooča z demografskim upadom, infrastrukturnimi omejitvami in izrazito sezonsko odvisnostjo od turizma, kar omejuje tako obisk kot širšo javno dostopnost arheološkega znanja.

Prispevek dostopnost obravnava kot večplastni dediščinski problem, ki presega fizični dostop in vključuje kroženje znanja, interpretacijo, izobraževanje ter sodelovanje javnosti. Zaradi otoške lege in občutljive arheološke strukture množični turizem v Osorju ni ne izvedljiv ne zaželen, hkrati pa te omejitve mesto določajo kot idealno okolje za razvoj alternativnih, digitalno posredovanih modelov dostopa. Arheološke raziskave v Osorju so obsežne in interdisciplinarne, vendar so njihovi rezultati večinoma dostopni strokovni javnosti, medtem ko je javna interpretacija razdrobljena in omejena.

V tem kontekstu prispevek Osor umešča v okvir nacionalnih in regionalnih kulturnih ter turističnih politik, ki vse bolj poudarjajo trajnost, tematski turizem in digitalne inovacije. Kulturne prakse, kot so Osorske glasbene večeri, so analizirane kot primeri aktivacije zgodovinskih in arheoloških prostorov skozi nesnovno dediščino, hkrati pa razkrivajo omejitve sezonsko osredotočenega kulturnega dogajanja. Razprava pokaže, da mora dediščinski razvoj Osorja temeljiti na interpretaciji, učenju in kakovosti izkušnje, ne pa na količini obiskovalcev.

Osrednji prispevek, ki ga ponuja članek, je razvoj digitalnega dvojnika Osorja kot infrastrukturne rešitve za vprašanje dostopnosti. Digitalni dvojnik je razumljen kot dinamična, večplastna digitalna predstavitev arheološke krajine, ki povezuje prostorske modele, podatke izkopavanj, zgodovinsko interpretacijo in pripovedne vsebine. Deloval bi kot skupna osnova za različna digitalna orodja, kot so obogatena in navidezna resničnost, resne igre ter izobraževalne platforme, pri čemer bi zagotavljal znanstveno konsistentnost in možnost posodabljanja. S tem bi omogočil dostop do arheološkega znanja neodvisno od fizičnega obiska ter razširil dediščinsko prisotnost Osorja »od otoka do oblaka«.

Prispevek zaključuje, da lahko majhna in oddaljena dediščinska mesta, kot je Osor, delujejo kot laboratoriji za inovativne pristope k upravljanju in posredovanju dediščine. Z integracijo arheoloških raziskav, digitalnih tehnologij in trajnostnih turističnih strategij Osor ponuja model, v katerem arheološko znanje postane razpršen kulturni in izobraževalni vir z dolgoročno družbeno vrednostjo.