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THREE-DIMENSIONAL BUILDING MODELING AS A DIGITAL STRATEGY FOR ENHANCING RURAL TOURISM PROMOTION

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Abstract

This article investigates the role of three-dimensional building modelling as a digital tool for promoting rural tourism and enhancing the visibility of underrepresented destinations. Rural areas often face challenges related to limited accessibility, low digital presence, and insufficient promotional resources, which constrain their tourism potential. To address these issues, the proposed approach integrates high-resolution spatial data, photogrammetry, and geographic information systems to generate accurate and interactive 3D building models of rural settlements. The methodology emphasizes cost-effective data acquisition and scalable modelling workflows suitable for small municipalities. The resulting 3D models are deployed within web-based visualization platforms and virtual tour environments to support destination marketing and visitor engagement. Results indicate that the use of 3D building models significantly improves the perceived attractiveness and spatial understanding of rural areas, facilitating remote exploration and informed travel planning. The study demonstrates that 3D modelling constitutes an effective and sustainable digital strategy for strengthening rural tourism promotion.

Key words*: 3D building modelling, rural tourism, digital heritage, spatial visualization, destination promotion.*

INTRODUCTION

Nowadays, we face an increasing tourism, weather it is urban or rural. The challenges in rural tourism promotion refer mainly to limited visibility, low digital presence, fragmented information, and lack of immersive visitor experiences, and therefore a division between urban and rural tourism destinations.

Digital technologies of three-dimensional modelling play an important role in promoting tourism destinations. In this context, it is important to mention the evolution from two-dimensional maps and static images to immersive three-dimensional environments (eg. VR, AR, or web-based platforms) that allow users to visualize, explore, manipulate, and experience virtual worlds in real-time and lead to a growing relevance of 3D building models in smart tourism, virtual tourism, and tourism destination marketing (Rosmani, 2014; Caciora et al., 2021).

3D building modelling generates detailed, three-dimensional digital representations of structures integrating both geometric form and semantic information (meaning/attributes), used to simulate, visualize, and analyse buildings as tourism offer. Digital models are characterized by their Level of Detail (LoD) – which determines the precision of their geometry – and their semantic richness, which defines the level of information embedded within the model, such as material, function, or interior layout (Brenner, 2005; Biljecki et al., 2016). Three-dimensional building models come with many advantages over conventional models, especially where tourism is considered. 3D models offer immersive, interactive experiences, such as virtual tours, 360° videos, and holographic projections, that improve marketing and destination, cultural heritage, and touristic attraction exploration. These digital techniques allow for detailed, realistic, and accessible, or "pre-visit" exploration, finally increasing visitor engagement, satisfaction, and intent to travel (Rosmani, 2014; Caciora et al., 2021).

However, comparing to urban digital tourism promotion, there are limited empirical studies on the application of three-dimensional building modelling specifically for rural tourism promotion. There is also a lack of evaluation frameworks linking three-dimensional models to tourism attractiveness and visitor engagement.

Considering all the aspects mentioned above, the present paperwork aims to investigate how 3D building modelling can function as a digital strategy to enhance rural tourism promotion. The main objective is to assess its role in improving touristic rural destination visibility, visitor understanding, and promote rural and natural values (Rosmani, 2014; Caciora et al., 2021).

MATERIALS AND METHODS

Due to the times we live in and the innovative opportunities offered by modern equipment currently available, the chosen topic for the present paperwork is the 3D modelling of an agritourist guesthouse located in a mountain hamlet, Apuseni Mountains, Romania, specifically for the purpose of promoting rural tourism. The preservation of this place through modern digital methods is the main priority, in order to promote it to all those who wish to understand and preserve the rural culture of our country, which is gradually disappearing due to the limited resources allocated to it.

The guesthouse in question is called "La Mărișcuța Citeră". It is a traditional house built in 1849, referred to by locals as the "Monument" House, located in the hamlet of Citeră, which belongs to the town of Zlatna, Alba County. The building represents a valuable source of traditions and historical heritage of the rural landscape. The "Monument" House holds particular importance as it is the oldest building on the site. It consists of two rooms and a basement and was constructed using adobe (a mixture of clay soil, straw, and equine/bovine manure), wood, and a manually crafted shingle roof. The foundation of the building is made of stone, while the interior structure is made of wooden posts and beams (Lacitera, n.d.).

Since 2021, many rehabilitation activities have been carried out, aiming to restore the site and transform it into a tourist area, which now comprises a total of ten buildings. The three-dimensional representation of the "Monument" House will be used to document, preserve, and facilitate the complete restoration of this building, both in the present and for future studies, through the creation of a virtual tour that will stimulate the public's imagination regarding such a place and encourage visitation (Lacitera, n.d.).

Data collection

The creation of high-quality three-dimensional models of buildings is contingent on the data collection method employed. Whether the images are meant for use in the field of architecture, cultural heritage, construction, or real estate, the manner in which they are captured has a direct impact on the accuracy, level of detail, and practical utility of the obtained model.

Terrestrial imaging is the process where images are captured from ground level. This method offers high detail for vertical surfaces, ornaments, entrances, and interiors. In order to achieve optimal results, it is essential to ensure consistent lighting, to avoid motion blur, and to maintain overlap of 60-80%. Terrestrial photogrammetry is a process that offers numerous advantages, including the capability to produce high-resolution textures for facades, comprehensive interior coverage, enhanced control over exposure and focus, but also a range of limitations, such as restricted access to roofs or elevated areas and a more protracted time commitment in the field (Brenner, 2005; Rosmani, 2014).

Conversely, the most prevalent technique for building reconstruction is aerial photogrammetry, which is ordinarily executed through the utilisation of drones. This method is highly effective in the image capture of roofs, facades, and the surrounding environment, with a particular emphasis on oblique photos. In order to achieve best results, it is imperative to adhere to the established flight parameters, with particular emphasis on the side overlap. The range of forward overlap was found to be between 75-85%, whilst the altitude was between 80-90%. It varies between 30 and 60 metres, contingent upon the height of the structure. Aerial photogrammetry has been proven to offer significant advantages, including efficient coverage of large areas, access to rooftops, and RTK/GNSS accuracy. However, it is important to note that there are also limitations, such as the capture of less detailed façade data and the restriction to narrow urban canyons (Brenner, 2005; Rosmani, 2014).

In the context of the present paperwork, the most reliable method for building reconstruction is hybrid, combining aerial and terrestrial imagery. This approach is suites best for restoration of

historical buildings, ensuring optimal coverage and detail across all elements of the structure. The integration of terrestrial and aerial imagery produces a high-fidelity 3D model, incorporating comprehensive details both of the roof, walls, and ground. The quality of the reconstruction is contingent not solely on the quantity of images available, but also on the consistency, overlap, lighting, and perspective variation of these images. The selection of capture methods and parameters should be made with consideration for factors such as the accessibility of the site, the level of detail required, and the availability of tools (Dreghici et al., 2016; Coza, 2025).

3D Modelling Workflow

The initial phase in the three-dimensional modelling workflow is the pre-processing one. During this first step, captured images and correlated data are analysed all together, and growth errors are eliminated. The photo histogram is uniformised, and images are calibrated if deemed necessary. Subsequently, the proper conversion of photographs into three-dimensional models is undertaken, adhering to the established workflow (Dreghici et al., 2016; Coza, 2025):

- The software's 'align photos' function involves the calculation of camera positions, resulting in the generation of a sparse point cloud. Following processing, a sparse point cloud representing the 3D space captured by the photographs will be displayed – Figure 1 a.
- The densifying of the point cloud enhances the intricacy of the model. In this step, the quality settings are configured, and depth filtering is established – Figure 1 b.
- The mesh is a 3D surface generated from the dense point cloud, which is used as the source data. Given that the model is a 3D object, not a terrain, the selected surface type is arbitrary. Upon completion, the model will possess a complete 3D geometry – Figure 1 c.
- Textures are a crucial element in achieving a realistic colour and appearance in the model. The texture will be mapped directly onto the 3D mesh, thereby enhancing visual realism – Figure 1 d.

While the software can generate high detail 3D models from captured images, it should be noted that the results are often presented in an arbitrary unit scale, unless the scale is set accordingly. It is important to recognise that, without scaling, measurements of distances, areas, and volumes will invariably differ from their real-world dimensions. The scale calibration is of high importance and is widely regarded as the best approach to ensure precision. The 3D model has emerged as a versatile solution that finds application in diverse domains, including surveying, archaeology, construction, mining, and numerous other fields (Coza, 2025).

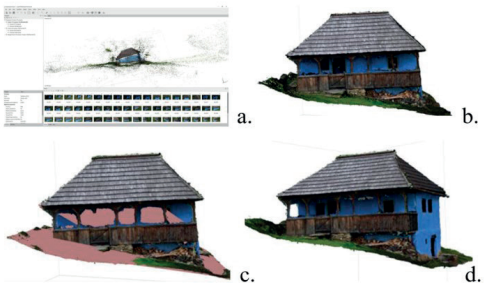


Figure 1. 3D modeling workflow: a. Photos alignment; b. Point cloud densifying; c. Mesh generation; d. Texture application (Coza, 2025)

By default, the software builds models based on image geometry, meaning measurements are relative rather than absolute. The process of converting the scale to real-world units is of high importance in achieving the needed transformation. This step is of crucial importance, as measurements become meaningful, allowing the calculation of distances, areas, and volumes in metric units, not inarbitrary values as opposed. The model is shown to be consistent with other datasets, thus allowing for integration with GIS data, CAD files and engineering designs. When executed with appropriate scaling, the model is capable of achieving both visual accuracy and reliability for quantitative analysis (Borsan et al., 2025; Coza, 2025).

Web-Based Visualization

The final step in the process will be the creation of a brief video comprising a 360-degree tour of the building (Figure 2). This will be used in future to promote both the area and the building on the guesthouse's official website. The software incorporates fundamental animation tools. The camera track feature allows the

generation of animations flythrough that is akin to those produced by professional studios. These animations are suite well to a variety of purposes, including presentations, reports, and online visualizations. Animated flythroughs have been demonstrated to enhance the visual appeal of three-dimensional models (Coza, 2025).

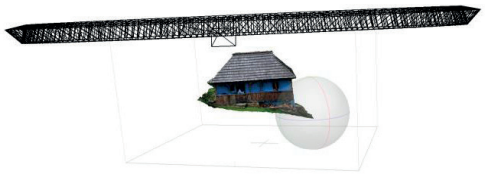


Figure 2. Video tour creation for web-based visualization (Coza, 2025)

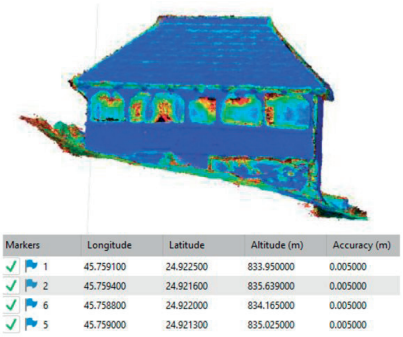
The usage of animated videos in professional contexts, including architecture, archaeology, land surveying, construction monitoring, and tourism promotion, represent a valuable tool. These videos present the capability to visualize the terrain and 3D building models from different angles, guide utilizers through a designated visualization route, virtually articulate model characteristics within online portfolios or client meetings and generate promotional information or instructional visuals.

In order to promote rural virtual tourism, it is essential to integrate the 3D model into digital platforms. Firstly, the 3D model must be rendered in a web-based visualisation format. Finally, the utilisation of mobile or VR-based tourism applications is necessary. The focus of mobile applications for rural tourism is on enhancing the physical experience through augmented reality (AR) and smart, location-based data, while virtual reality (VR) allows users to experience rural environments remotely, offering a "sense of presence" and emotional connection, which can inspire future travel or provide a substitute for those with limited mobility (Parra-Sanchez & Viviescas-Jaimes, 2024; Ilie et al., 2025).

Evaluation Methods

The evaluation of a 3D model is a process which is multi-layered in constitution, necessitating a balance between mathematical precision and visual and functional integrity. Regardless of whether one's profession lies within the fields of gaming, engineering, or 3D printing, the evaluation process is typically divided into three primary categories. The following aspects must be given due consideration (Grande et al., 2024; Coza, 2025):

- Geometric and structural accuracy (Figure 3). Geometric and structural accuracy metrics are utilised to ascertain the degree to which the three-dimensional data corresponds with its intended real-world dimensions or a reference "ground truth" model.
- Topology and performance (Figure 4). The evaluation of the model's construction is pivotal in determining its efficacy in software environments, such as game engines, or in the realm of animations.
- Visual and aesthetic quality. From the perspective of visual and aesthetic quality, the model's appearance under illumination is as significant as its structural design.



Markers	Longitude	Latitude	Altitude (m)	Accuracy (m)
1	45.759100	24.922500	833.950000	0.005000
2	45.759400	24.921600	835.639000	0.005000
6	45.758800	24.922000	834.165000	0.005000
5	45.759000	24.921300	835.025000	0.005000

Figure 3. Geometric and structural accuracy assessment (Coza, 2025): the confidence level of points in the dense point cloud and accuracy of control markers

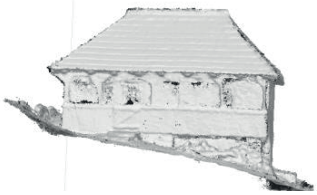


Figure 4. The class of points in the dense point cloud (Coza, 2025)

The evaluation of the 3D model from the perspective of tourism promotion entails the measurement of perceived attractiveness, usability, and engagement. Furthermore, a comparative analysis is to be conducted between

2D promotional materials and 3D models. Finally, qualitative feedback from tourists and local stakeholders is to be considered (Ahtik et al., 2025).

RESULTS AND DISCUSSIONS

The following results are derived from the 3D model of the "monument" house. The model's output is characterised by its accuracy, realism and level of detail (LOD) (Shashi & Jain, 2007; Rahman & Cahyono, 2023):

- The 3D model of the building that has been generated offers a high level of accuracy, with a margin of error of between 1 and 3 centimetres. Whilst it is generally acknowledged that this method provides slightly less precision than alternative techniques, such as LiDAR, it is nevertheless highly cost-effective and sufficient for applications in the field of rural tourism promotion. The accuracy of the generated 3D model depends primarily on three key elements: the resolution of the input images, the level of overlap between consecutive photographs, and the operator's level of experience.
- The 3D model of the building, obtained through photogrammetric methods, provides a high degree of realism, as it preserves authentic textures, colours, and geometric details derived directly from real-world data.

Comparing to manual modelling, this process generates a digital twin characterised by high-fidelity detail, thus it has been set as a standard in the area of web visualisation.

- The level of detail (LOD) is the degree to which real-world objects are abstracted, ranging from raw footprints to sophisticated three-dimensional models. The present case study of the paperwork demonstrates that the 3D model generation, with high levels of detail (LoD), is optimised by the integration of aerial photogrammetry for roofs and site context with terrestrial (ground-based) imagery for facade, vertical, and complex details. This hybrid approach provides a complete coverage, bridging the gap between low-accuracy offered by aerial views and high-resolution offered by ground images, in order to achieve accurate LoD3 models.

In recent practice, 3D modelling together with interactive GIS maps and virtual visualisation tools has been increasingly applied to the presentation of major tourism sites, particularly historic houses. The use of these technologies improves the quality of documentation and at the same time makes the visitor experience more engaging. At the same time, they make it possible to develop digital twin models that support virtual visits, easier navigation within historical spaces, and spatial analyses useful for both heritage conservation and tourism promotion. The following visualisation techniques are to be employed for the purpose of promoting tourism at historic houses: the utilisation of three-dimensional modelling techniques in the preservation and marketing of historic structures enables users to observe these structures from diverse angles and levels of detail, web-based maps facilitate the spatial visualisation of historic houses across the designated territory, thereby enhancing identification and accessibility, and digital platforms have the capacity to curate the narrative surrounding historic houses, integrating visual data with historical, architectural and personal narratives to enhance user engagement (Ugwitz et al., 2021; Kourtit et al., 2025).

In the context of user perception and engagement, survey results have been demonstrated to reveal changes in destination understanding, interest in visiting, and perceived authenticity. These changes can be confirmed through statistical or thematic analysis of feedback (Ugwitz et al., 2021; Kourtit et al., 2025).

A comparison of three-dimensional models and traditional promotional tools, including brochures, photographs and maps, has been undertaken previously. The results of this comparison demonstrate that three-dimensional models significantly outperform traditional promotional tools in modern marketing, by the engender higher customer engagement, faster conversion rates and superior adaptability. Whilst conventional tools boast lower initial expenses and authenticity, three-dimensional visualisations have been demonstrated to enhance conversion rates. A preponderance of users has been observed to demonstrate a predilection for interacting with three-dimensional views as opposed to static images. The utilisation of three-dimensional models enables users to manipulate their environment through rotations and zooms in real-time, thereby sustaining attention for extended periods when compared with two-dimensional

media that is static and passive. Virtual tours represent a significant development in the realm of tourism promotion, offering visitors the opportunity to view the internal and external design of a destination prior to their physical arrival. In the domain of tourism, three-dimensional site models facilitate the provision of interactive, 360-degree views of the surrounding area, terrain, and amenities, thereby offering enhanced contextual information in comparison to two-dimensional maps. Whilst the initial financial outlay required for the creation of a 3D model may be significant, such an investment is frequently justified by the long-term benefits that such a model can deliver. Substantial research has demonstrated that, on average, three-dimensional imaging is six times more cost-effective than traditional photography when used in complex campaigns (Forbes Technology Council, 2021; Ugwitz et al., 2021; Kourtit et al., 2025).

The use of three-dimensional building modelling has been shown to improve spatial awareness and emotional connection by transforming abstract, two-dimensional building plans into tangible, virtual immersive environments that simulate reality. The technology in question is designed to facilitate an intuitive understanding of proportions and flow, in addition to promoting the development of a personal bond through the use of realistic lighting, textures, and interactive, personalised experiences. Three-dimensional modelling has been demonstrated to offer a superior, more intuitive grasp of space than its 2D counterpart, as well as impacting experiences, and thus provides several key benefits (Esri, n.d.; Gómez-Tone et al., 2021):

- It is possible for users to comprehend the true scale, volume, and proportions of a space.
- Interactive walkthroughs and 360° virtual tours have been shown to empower users by allowing them to "walk through" buildings and understand the flow and organisation of the layout.
- The capacity to manipulate, zoom and rotate models has been proven to facilitate superior spatial reasoning, as it enables viewers to observe the structure from different angles, thereby overcoming the limitations imposed by a single static viewpoint.
- Three-dimensional modelling also enables the consideration of environmental aspects, including daylight conditions and nearby contextual features. In this way, a clearer understanding of the relationship between the studied building and its surrounding environment can be obtained.
- The use of virtual 3D models generates a strong sense of presence for the user, who may perceive the simulated space in a manner similar to physical experience. As a consequence, emotional and perceptual reactions tend to be more pronounced.
- Furthermore, three-dimensional animation can be applied in the development of guided tours with narrative support, contributing to a better perception of spatial rhythm and continuity within the analysed space. The integration of these components within the framework of 3D modelling transforms the architectural design process from a technical undertaking to an emotional and experiential journey (Esri, n.d.; Gómez-Tone et al., 2021).

CONCLUSIONS

Three-dimensional building modelling can transform rural tourism promotion by shifting from passive representation to immersive, spatially informed digital experiences. The case study of the "monument" house concluded that the combination of aerial and terrestrial photogrammetry is an effective method for creating an accurate, high-quality 3D model. This model can be utilised for the promotion of the area and the tracking of the construction's progress over time. The application of the present study may also be utilised in the future for the purpose of a past and present comparison, as well as in designing the future appearance of the construction (Coza, 2025).

The present study brings a relevant contribution to both the scientific and applied domains, with a particular focus on digital rural tourism and geospatial visualisation. The paper proposes a practical framework addressed to specialists involved in rural tourism activities and may be considered a useful reference for both academic research and professional practice (Coza, 2025).

The use of modern three-dimensional visualisation technologies in rural tourism promotion is gradually transforming the traditional approach to nature-based tourism by integrating digital, interactive and immersive

components. These tools enable tourists to virtually explore rural landscapes, agricultural areas and cultural heritage objectives from a distance, while also enhancing on-site visits through access to real-time information. In this context, such technologies contribute to the development of rural tourism in a more sustainable, educational and accessible manner. The main advantages of 3D modelling are presented below (Parra-Sanchez & Viviescas-Jaimes, 2024; Coza, 2025; Ilie et al., 2025).

- The utilisation of realistic visualisation techniques facilitates prospective visitors' ability to visualise the appearance of the destination prior to their arrival.
- The utilisation of three-dimensional modelling in the design and architectural professions has been demonstrated to have numerous advantages, including the potential for cost and time reduction in instances where renovation is necessary. This is due to the ability of designers and architects to modify an object without the need for physical reconstruction, thus ensuring a more efficient process.
- The process of monitoring the progression of construction projects over time is undertaken for the purposes of conducting studies or implementing rehabilitation work.
- 3Dmodelling sets out the argument for the importance of digital documentation and preservation for monuments and heritage sites.
- The calculation of volume is imperative for the planning and execution of excavation in case of intervention works.
- The creation of three-dimensional reconstructions of buildings is a key component of cadastral plan development, facilitating the creation of interactive maps.
- The promotion of tourism is achieved through the creation of virtual tours of areas intended for promotion.
- 3D models allow virtual tours of the touristic attractions, such as historic wooden churches or cultural sites, providing a way to virtually visit and appreciate them remotely.
- Modern technologies are used for interactive marketing, generate captivating experiences that increase interest in destinations.
- 3D models help in mapping and preserving architectural heritage, making it accessible for education and research.
- 3D models provide realistic, detailed views, helping tourists better understand the layout of destinations and, consequently, improving their overall experience.
- 3D models, such as 3D mesh models, are being used for interactive, web-based, or VR-driven, 360° virtual, and 3D web-based experiences, that are often more engaging than 2D and can also be used in city-wide planning.

The following key benefits and impact of the project are identified (Parra-Sanchez & Viviescas-Jaimes, 2024; Coza, 2025; Ilie et al., 2025):

- The provision of digital alternatives by modern technologies has been demonstrated to reduce the environmental impact of physical over-tourism in fragile rural areas.
- The removal of barriers for individuals with physical or financial constraints by modern technologies has been shown to provide access to remote or rugged rural locations.
- Digital technologies assist in the preservation of rural cultural identities and the promotion of local products, thereby fostering economic growth and the development of new business models within rural communities.
- The integration of physical and digital experiences, often termed 'hybrid' or 'phygital', has been demonstrated to enhance visitor satisfaction and emotional engagement with rural cultural heritage.

Three-dimensional modelling has also its limitations, which must be considered when undertaking such projects (Coza, 2025):

- The expense of high-quality projects involving large-scale work can be considerable, including the cost of drones, 3D scanners and software licenses for each device.
- The processing time for complex work requiring high precision can be lengthy, necessitating the purchase of high-performance computers capable of supporting and processing data at a high level.
- The use of such equipment and software requires advanced technical skills.
- The outcome is dependent on weather and lighting conditions for photogrammetry.
- The process is susceptible to loss of accuracy if the correct steps are not followed in data processing.
- The limitations imposed by a single case study.

- The existence of dependencies in the technological and infrastructural domains.

The following prospective research directions are hereby put forward (Coza, 2025):

- In order to facilitate the access to equipment such as photogrammetric equipment and high-precision devices, collaboration with local institutions, including universities and heritage NGOs, is imperative.
- The promotion of tourism is achieved through the creation of interactive virtual tours of various tourist attractions within a specific geographical area, such as a city or county.
- The creation of training courses and workshops is a collaborative endeavour undertaken in conjunction with construction, planning, and design companies for the benefit of educational institutions.
- The creation of a database or thematic map for the purpose of promoting tourism is hereby proposed. The objectives of this initiative would include the incorporation of this case study.
- The integration of AR/VR and metaverse tourism platforms is a subject that has been the focus of much recent discussion.
- The long-term ramifications on tourist arrivals and local economies must be given due consideration.
- The scalability of 3D modelling approaches for wider rural regions is a subject that merits further investigation.

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